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Detrital zircon age constraints on the provenance of sandstones on Hatton Bank and Edoras Bank, NE Atlantic

ANDREW C. MORTON1,2\*, KENNETH HITCHEN3, C. MARK FANNING4, GREG YAXLEY4,

HOWARD JOHNSON3 & J. DEREK RITCHIE3

1HM Research Associates, 2 Clive Road, Balsall Common CV7 7DW, UK

2CASP, Department of Earth Sciences, University of Cambridge, 181a Huntingdon Road, Cambridge CB3 0DH, UK

3British Geological Survey, Murchison House, West Mains Road, Edinburgh EH9 3LA, UK

4Research School of Earth Sciences, The Australian National University, Canberra, ACT 0200, Australia

\*Corresponding author (e-mail: a.c.morton@heavyminerals.fsnet.co.uk)

Abstract: U–Pb dating of detrital zircons shows that the provenance of Cretaceous–Palaeogene sandstones on Hatton and Edoras banks (SW Rockall Plateau) comprises magmatic rocks dated at c. 1800 Ma and c. 1750 Ma, respectively. Their depositional setting, first-cycle mineralogy and unimodal detrital zircon populations suggest that these sandstones are of local origin. The zircon age data are therefore considered to provide constraints on these poorly understood areas of the Rockall Plateau. The U–Pb dates are directly comparable with U–Pb zircon crystallization ages from granitoid rocks reported from the Ketilidian Belt of southern Greenland and from the Rhinns Complex of western Britain. Hf isotopic data from the Edoras Bank sample are consistent with derivation from a juvenile Palaeoproterozoic block. In conjunction with previously reported Sm–Nd Tdm model ages from the Ketilidian Belt, Rockall Bank and the Rhinns Complex, these data extend the known distribution of a large juvenile Palaeoproterozoic terrane spanning the southern NE Atlantic. In contrast, Hf isotopic data from the Hatton Bank sample imply a large contribution from Archaean crust. The zircon population from Edoras Bank also contains sparse Mesoproterozoic grains, providing evidence for the presence of volumetrically minor Grenville-age intrusions in the southern part of the Rockall Plateau.

The Rockall Plateau (Fig. 1) is a submerged continental crustal block separated from the northern European continental margin by the highly attenuated crust underlying the Rockall Trough, and from Greenland by oceanic crust (Roberts 1975; Roberts et al. 1988; Joppen & White 1990; Hitchen 2004). The area occupies a critical location in pre-drift North Atlantic reconstructions, but because of the scarcity of samples, the geological history of the basement is poorly understood. The only direct evidence for the nature of the basement forming the Rockall Plateau comes from samples acquired from Rockall Bank. Sm– Nd model (Tdm) ages for five samples (A–E, Fig. 1) recovered during diving expeditions (Roberts et al. 1973) range from 1.89 to 2.14 Ga (Morton & Taylor 1991). A similar Tdm age (1.91 Ga) has been reported more recently from two further sites (56-15/11 and 56-15/12, Fig. 1) in the area (Hitchen 2004). Although no U–Pb zircon age data from these samples have been formally published, Daly et al. (1995) and Scanlon & Daly (2001) indicated that single-grain zircon age dating of samples A, C and D (Fig. 1) yielded results similar to that of the Annagh Gneiss of north Mayo (Ireland), which has a U–Pb zircon crystallization age of c. 1750 Ma. These limited data suggest that the Rockall Bank metamorphic basement comprises a juvenile Palaeoproterozoic terrane (Morton & Taylor 1991; Dickin 1992).

No basement rocks have been recovered from the other bathymetric highs (Hatton, Edoras and George Bligh banks) that make up the Rockall Plateau (Fig. 1). Palaeogene basalts from George Bligh Bank display evidence of contamination by Archaean crust (Hitchen et al. 1997), suggesting that the boundary between the Archaean and Palaeoproterozoic terranes lies between Rockall Bank and George Bligh Bank, as proposed by Dickin (1992) and Dickin & Durant (2002). Pb isotopic

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evidence for Proterozoic contamination of Blackstones Bank basaltic rocks led Dickin & Durant (2002) to place the boundary to the north of this Tertiary igneous complex. Likewise, the boundary between the Archaean and Palaeoproterozoic terranes lies to the north of Stanton Bank, a submerged bathymetric high, on the basis of the occurrence of basement rocks with relatively young Sm–Nd TDM model ages (Scanlon et al. 2003). The location of the proposed boundary coincides with the central strand of the Anton Dohrn lineament as defined from potential field data by Kimbell et al. (2005). Although the location of the boundary west of George Bligh and Rockall banks is not directly constrained from any geological sample data, the central strand of the Anton Dohrn lineament crosses Hatton Bank at a marked inflection point of the axial trace of the North Hatton Bank Anticline (Johnson et al. 2005). To date, there is no evidence, either direct or indirect, regarding the basement underlying Hatton and Edoras banks, which are located in the southwestern part of the Rockall Plateau, separated from Rockall Bank by the intervening Hatton Basin (Fig. 1).

In this paper, we present the results of a combined U–Pb and

Lu–Hf isotopic study of detrital zircons from Cretaceous– Palaeogene sandstones recovered by coring at two sites, one on Hatton Bank (British Geological Survey (BGS) borehole 99/2A) and one close to Edoras Bank (Deep Sea Drilling Project (DSDP) Site 555), and discuss their implications for the age of the basement underlying these two poorly understood areas.

# Analytical methods

Zircon concentrates were obtained using standard density and magnetic separation techniques. Arbitrary, and presumed repre-

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| Fig. 1. Location of the Rockall Plateau west of Britain, showing the main bathymetric features and location of sites discussed in the text. Bathymetry in |

metres.

sentative, fractions were poured onto double-sided adhesive tape, cast into an epoxy resin disc, sectioned and polished. Transmitted and reflected light photomicrographs, together with cathodoluminescence (CL) images, were prepared for all grains. Representative transmitted light photomicrographs for the two samples are shown in Figure 2.

The U–Pb analyses were undertaken using the sensitive highresolution ion microprobe (SHRIMP) RG at The Australian National University in Canberra. The procedures employed for zircon U–Pb dating followed Williams (1998) and references therein. The number of scans through the mass stations was limited to four, thereby achieving rapid data acquisition at the expense of some counting precision per analysis. An arbitrary group of 60 zircons was analysed from each sample. Subjectivity in zircon dating was avoided by analysing all zircons encountered during the traverse of the mount, unless the grain showed evidence of being metamict or otherwise structurally compromised, as determined by examination of the reflected and transmitted light photomicrographs and CL images. Normalization of Pb/U isotopic ratios was achieved by reference to analyses of the FC1 reference zircon (1099 Ma: 206Pb/ 238U ¼ 0.1589: Paces & Miller 1993). The raw SHRIMP data were processed using SQUID (Ludwig 2000), with plots generated using Isoplot/Ex (Ludwig 1999). The measured 206Pb/204Pb ratios have been used to correct for common Pb and the radiogenic 207Pb/206Pb ratio has been used to calculate the preferred age, despite the fact that a number of the areas analysed are interpreted to have lost radiogenic Pb. The zircon age data are presented in Tables 1 and 2.

Hf isotopic analyses were performed by laser ablation on the same locations as previously analysed by SHRIMP, using the reflected light micrographs to reveal the locations of the ion probe sputter pits (typically about 30 m across). For most analyses of unknowns or secondary standards, the laser spot size on the sample was either 47 or 37 m in diameter, depending on the size of the grain and the nature of internal structure as revealed by CL imaging.

The Hf isotope measurements were conducted by laser ablation multicollector inductively coupled plasma mass spectroscopy (MC-ICPMS) using the Research School of Earth Sciences Neptune system coupled to a 193 nm ArF Excimer laser. The mass spectrometer was first tuned to optimal sensitivity using a large grain of zircon from the Monastery kimberlite. All isotopes were measured simultaneously in static-collection mode. A gas blank was acquired at regular intervals throughout the analytical session (every 10 or so analyses). The laser was fired with typically 5–8 Hz repetition rate and 60 mJ energy. Data were acquired for 100 s, but in many cases only a selected interval from the total acquisition was used in data reduction. In each batch of samples between gas blank measurements, several secondary standard zircons (91500, FC-1, Temora-2, Monastery and Mud Tank) were measured as a check on data quality, along with several unknowns. Signal intensity was typically c. 5-6 V for total Hf at the beginning of ablation, and decreased over the acquisition time to 2 V or less. The Hf isotopic data are presented in Table 3.

# Borehole 99/2A

BGS borehole 99/2A was drilled into the Mesozoic succession on Hatton Bank (Hitchen 2004), and recovered 28.5 m of sandstone and siltstone dated as Albian on the basis of terrestrial palynomorphs. The sample selected for zircon isotopic analysis was taken from the range 45.65–45.72 m within the Albian clastic succession. The absence of marine microplankton and low overall species diversity indicates a paralic depositional environment. The sandstone is dominated by fresh angular quartz and feldspar, and contains a heavy mineral assemblage dominated by unstable phases such as calcic amphibole and epidote (Hitchen 2004). These characteristics suggest first-cycle derivation from basement of intermediate–acidic nature. The zircon morphologies (Fig. 2) provide further support for first-cycle derivation, with all grains having euhedral or angular habits. In transmitted light, the zircons show structural imperfections, with large cracks evident in many grains. The CL images of the zircons (Fig. 2) show that they have typical magmatic zoning patterns (Corfu et al. 2003). Grains with apparent cores form a small proportion of the zircon population, but where they do occur (e.g. grain 13)

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| Fig. 2. Transmitted light and CL photomicrographs of detrital zircons in (a) BGS borehole 99/2A, 45.65–45.72 m and (b) DSDP Site 555-88-5, 18–  25 cm. It should be noted that the zircons from 99/2A show greater visible structural incoherence, including fractures and zoning, compared with those |

from Site 555.

they have similar ages to rims on other grains with cores (e.g. grains 4 and 6). Hence, although some zircons are structured (in that they have cores and rims), there is little to no apparent age difference. This is not uncommon in zoned igneous zircons. Although there are discontinuities in zoning between apparent centres and rims, the lack of a significant age difference, at least at the uncertainties of our measurements, implies either that the chemistry of the magma changed during crystallization, or that there were two or more magmatic pulses within a short period of time.

The U–Pb isotopic data and ages of single grains are given in Table 1. All the zircons in the sample have relatively high Th/U, indicating they have an igneous parentage, probably of felsic– intermediate composition (Hartmann & Santos 2004; Link et al. 2005). Many of the grains are significantly discordant, with the U–Pb isotopic data defining a simple discordia line with a lower intercept within uncertainty of the present day. This suggests that the isotopic system has been disturbed by a present-day event. However, fission-track analysis and (U–Th)/He dating of apatites identified a thermal event with a maximum palaeo-temperature of 50 8C and subsequent cooling beginning around 80–50 Ma (Hitchen 2004). This was interpreted as the result of the Late Palaeocene–Early Eocene magmatic event associated with the opening of this sector of the NE Atlantic. In view of this, a linear regression with a lower intercept at 55 Ma was forced through the data (Fig. 3). Although this alternative regression line is not as well fitted (MSWD of 1.4, compared with 1.2), it appears more geologically plausible.

Despite the discordance shown by many grains, the combined histogram–relative probability plot indicates that the zircons form a single coherent population of 207Pb/206Pb ages (Fig. 4). The only zircons that deviate from this population are highly discordant, and their ages are therefore unreliable. The single peak has a mean 207Pb/206Pb age of 1798.5 4.5 Ma (MSWD 0.69). This calculation used the entire zircon population, with only three zircons (grains 4.1, 24.1 and 31.1) falling outside error, all of which are highly discordant (35%, 79% and 43%, respectively).

Hf(t) values for the zircons from borehole 99/2A range from +2.97 to 3.30 (Table 3, Fig. 5), with TDM ages ranging from 2216 to 2643 Ma. These Hf(t) values differ significantly from that estimated for the depleted mantle at c. 1800 Ma (Vervoort & Blichert-Toft 1999). The Hf isotopic data therefore indicate that the depleted mantle was not entirely responsible for generating

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| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Table 1. Summary of SHRIMP U–Pb zircon results for BGS borehole 99/2A, 45.65–45.72 m (Hatton Bank)   |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | | Grain. spot | U  (ppm) | Th (ppm) | Th/U | Pb\* (ppm) | 204Pb/206Pb f | 206 % | 238U/  206Pb | Total ratios | 207Pb/ 206Pb |  | 206Pb/ 238U |  | Radiogenic ratios  207Pb/  235U |  | 207Pb/ 206Pb |  | r |  | Age (Ma) | |  |  | | 206Pb/ 238U |  | 207Pb/ 206Pb |  | %  Disc. | | 1.1 | 289 | 180 | 0.62 | 68.7 | 0.000128 | 0.20 | 3.615 | 0.046 | 0.1122 | 0.0008 | 0.2761 | 0.0035 | 4.205 | 0.066 | 0.1105 | 0.0010 | 0.818 | 1572 | 18 | 1807 | 16 | 13 | | 2.1 | 191 | 90 | 0.47 | 51.5 | 0.000052 | 0.08 | 3.189 | 0.044 | 0.1108 | 0.0010 | 0.3133 | 0.0043 | 4.756 | 0.079 | 0.1101 | 0.0010 | 0.828 | 1757 | 21 | 1801 | 17 | 2 | | 3.1 | 348 | 246 | 0.71 | 60.1 | 0.000471 | 0.73 | 4.966 | 0.062 | 0.1164 | 0.0011 | 0.1999 | 0.0025 | 3.031 | 0.062 | 0.1100 | 0.0018 | 0.605 | 1175 | 13 | 1799 | 30 | 35 | | 4.1 | 880 | 461 | 0.52 | 133.4 | 0.000453 | 0.71 | 5.669 | 0.063 | 0.1114 | 0.0009 | 0.1751 | 0.0019 | 2.542 | 0.045 | 0.1053 | 0.0015 | 0.620 | 1040 | 11 | 1719 | 26 | 39 | | 5.1 | 272 | 143 | 0.53 | 48.6 | 0.000167 | 0.26 | 4.813 | 0.061 | 0.1114 | 0.0009 | 0.2072 | 0.0026 | 3.119 | 0.056 | 0.1092 | 0.0014 | 0.712 | 1214 | 14 | 1785 | 23 | 32 | | 6.1 | 228 | 94 | 0.41 | 56.5 | 0.000051 | 0.08 | 3.471 | 0.050 | 0.1107 | 0.0011 | 0.2879 | 0.0042 | 4.366 | 0.077 | 0.1100 | 0.0011 | 0.823 | 1631 | 21 | 1799 | 18 | 9 | | 7.1 | 80 | 52 | 0.65 | 21.7 | 0.000086 | 0.13 | 3.159 | 0.056 | 0.1097 | 0.0014 | 0.3162 | 0.0056 | 4.732 | 0.104 | 0.1086 | 0.0014 | 0.798 | 1771 | 27 | 1775 | 24 | 0 | | 8.1 | 289 | 113 | 0.39 | 80.6 | 0.000041 | 0.06 | 3.084 | 0.039 | 0.1118 | 0.0008 | 0.3241 | 0.0042 | 4.969 | 0.075 | 0.1112 | 0.0009 | 0.846 | 1810 | 20 | 1819 | 15 | 1 | | 9.1 | 159 | 78 | 0.49 | 41.7 | 0.000239 | 0.37 | 3.266 | 0.048 | 0.1127 | 0.0011 | 0.3050 | 0.0045 | 4.603 | 0.094 | 0.1094 | 0.0015 | 0.722 | 1716 | 22 | 1790 | 26 | 4 | | 10.1 | 239 | 106 | 0.44 | 63.1 | 0.000294 | 0.46 | 3.256 | 0.045 | 0.1114 | 0.0010 | 0.3057 | 0.0042 | 4.528 | 0.089 | 0.1074 | 0.0015 | 0.705 | 1719 | 21 | 1756 | 26 | 2 | | 11.1 | 169 | 66 | 0.39 | 46.2 | 0.000089 | 0.14 | 3.146 | 0.046 | 0.1125 | 0.0011 | 0.3174 | 0.0046 | 4.872 | 0.091 | 0.1113 | 0.0013 | 0.781 | 1777 | 23 | 1821 | 21 | 2 | | 12.1 | 349 | 198 | 0.57 | 61.3 | 0.000384 | 0.60 | 4.894 | 0.062 | 0.1140 | 0.0009 | 0.2031 | 0.0026 | 3.047 | 0.061 | 0.1088 | 0.0017 | 0.638 | 1192 | 14 | 1779 | 28 | 33 | | 13.1 | 537 | 249 | 0.46 | 123.6 | 0.000243 | 0.38 | 3.735 | 0.044 | 0.1123 | 0.0007 | 0.2667 | 0.0031 | 4.007 | 0.061 | 0.1090 | 0.0011 | 0.771 | 1524 | 16 | 1782 | 18 | 14 | | 14.1 | 187 | 112 | 0.60 | 52.4 | 0.000137 | 0.21 | 3.072 | 0.043 | 0.1131 | 0.0010 | 0.3249 | 0.0046 | 4.983 | 0.088 | 0.1112 | 0.0012 | 0.796 | 1813 | 22 | 1820 | 19 | 0 | | 15.1 | 296 | 131 | 0.44 | 51.0 | 0.000192 | 0.30 | 4.984 | 0.063 | 0.1124 | 0.0009 | 0.2000 | 0.0026 | 3.030 | 0.053 | 0.1098 | 0.0013 | 0.725 | 1176 | 14 | 1797 | 22 | 35 | | 16.1 | 142 | 69 | 0.49 | 38.5 | 0.000188 | 0.29 | 3.168 | 0.048 | 0.1112 | 0.0011 | 0.3148 | 0.0048 | 4.715 | 0.100 | 0.1086 | 0.0016 | 0.713 | 1764 | 23 | 1777 | 27 | 1 | | 17.1 | 450 | 260 | 0.58 | 94.0 | 0.000139 | 0.22 | 4.111 | 0.049 | 0.1111 | 0.0007 | 0.2427 | 0.0029 | 3.656 | 0.054 | 0.1092 | 0.0010 | 0.803 | 1401 | 15 | 1787 | 16 | 22 | | 18.1 | 192 | 126 | 0.66 | 53.1 | 0.000069 | 0.11 | 3.102 | 0.043 | 0.1103 | 0.0009 | 0.3220 | 0.0044 | 4.855 | 0.083 | 0.1094 | 0.0011 | 0.808 | 1799 | 22 | 1789 | 18 | 1 | | 19.1 | 157 | 71 | 0.45 | 43.0 | 0.000104 | 0.16 | 3.132 | 0.045 | 0.1106 | 0.0016 | 0.3188 | 0.0046 | 4.800 | 0.104 | 0.1092 | 0.0018 | 0.668 | 1784 | 23 | 1786 | 29 | 0 | | 20.1 | 147 | 98 | 0.67 | 40.6 | 0.000119 | 0.19 | 3.108 | 0.046 | 0.1129 | 0.0011 | 0.3211 | 0.0047 | 4.929 | 0.091 | 0.1113 | 0.0012 | 0.803 | 1795 | 23 | 1821 | 20 | 1 | | 21.1 | 290 | 211 | 0.73 | 80.4 | 0.000000 | 0.00 | 3.096 | 0.040 | 0.1101 | 0.0008 | 0.3230 | 0.0042 | 4.905 | 0.073 | 0.1101 | 0.0008 | 0.869 | 1805 | 20 | 1801 | 13 | 0 | | 22.1 | 128 | 60 | 0.47 | 35.1 | 0.000086 | 0.13 | 3.142 | 0.048 | 0.1110 | 0.0012 | 0.3178 | 0.0049 | 4.812 | 0.096 | 0.1098 | 0.0014 | 0.770 | 1779 | 24 | 1796 | 23 | 1 | | 23.1 | 342 | 184 | 0.54 | 92.6 | 0.000022 | 0.03 | 3.168 | 0.039 | 0.1101 | 0.0007 | 0.3155 | 0.0039 | 4.779 | 0.067 | 0.1098 | 0.0007 | 0.882 | 1768 | 19 | 1797 | 12 | 2 | | 24.1 | 3282 | 2985 | 0.91 | 160.3 | 0.000638 | 1.01 | 17.592 | 0.186 | 0.1111 | 0.0006 | 0.0563 | 0.0006 | 0.794 | 0.015 | 0.1024 | 0.0016 | 0.571 | 353 | 4 | 1668 | 28 | 79 | | 25.1 | 126 | 71 | 0.57 | 33.8 | 0.000209 | 0.33 | 3.191 | 0.049 | 0.1117 | 0.0014 | 0.3123 | 0.0048 | 4.687 | 0.105 | 0.1088 | 0.0018 | 0.683 | 1752 | 24 | 1780 | 30 | 2 | | 26.1 | 134 | 70 | 0.52 | 37.1 | 0.000150 | 0.23 | 3.106 | 0.054 | 0.1119 | 0.0012 | 0.3212 | 0.0055 | 4.866 | 0.107 | 0.1099 | 0.0015 | 0.785 | 1795 | 27 | 1798 | 25 | 0 | | 27.1 | 142 | 60 | 0.42 | 39.6 | 0.000000 | 0.00 | 3.072 | 0.046 | 0.1090 | 0.0011 | 0.3255 | 0.0049 | 4.892 | 0.089 | 0.1090 | 0.0011 | 0.829 | 1817 | 24 | 1783 | 19 | 2 | | 28.1 | 235 | 101 | 0.43 | 65.2 | 0.000016 | 0.03 | 3.097 | 0.041 | 0.1109 | 0.0009 | 0.3229 | 0.0043 | 4.928 | 0.077 | 0.1107 | 0.0009 | 0.854 | 1804 | 21 | 1811 | 15 | 0 | | 29.1 | 248 | 151 | 0.61 | 68.7 | 0.000011 | 0.02 | 3.105 | 0.045 | 0.1092 | 0.0009 | 0.3220 | 0.0047 | 4.842 | 0.080 | 0.1091 | 0.0009 | 0.877 | 1800 | 23 | 1784 | 15 | 1 | | 30.1 | 244 | 129 | 0.53 | 65.6 | 0.000057 | 0.09 | 3.193 | 0.046 | 0.1111 | 0.0009 | 0.3129 | 0.0045 | 4.760 | 0.079 | 0.1103 | 0.0009 | 0.864 | 1755 | 22 | 1805 | 15 | 3 | | 31.1 | 394 | 227 | 0.58 | 60.0 | 0.000212 | 0.33 | 5.651 | 0.069 | 0.1151 | 0.0009 | 0.1764 | 0.0022 | 2.730 | 0.046 | 0.1123 | 0.0013 | 0.728 | 1047 | 12 | 1836 | 21 | 43 | | 32.1 | 226 | 162 | 0.72 | 60.1 | 0.000084 | 0.13 | 3.231 | 0.043 | 0.1118 | 0.0009 | 0.3091 | 0.0041 | 4.715 | 0.078 | 0.1106 | 0.0011 | 0.809 | 1736 | 20 | 1810 | 18 | 4 | | 33.1 | 305 | 146 | 0.48 | 80.2 | 0.000154 | 0.24 | 3.271 | 0.041 | 0.1126 | 0.0008 | 0.3050 | 0.0039 | 4.646 | 0.072 | 0.1105 | 0.0010 | 0.814 | 1716 | 19 | 1808 | 16 | 5 | | 34.1 | 694 | 295 | 0.43 | 89.8 | 0.000251 | 0.39 | 6.639 | 0.076 | 0.1136 | 0.0007 | 0.1500 | 0.0017 | 2.279 | 0.035 | 0.1102 | 0.0011 | 0.744 | 901 | 10 | 1802 | 19 | 50 | | 35.1 | 184 | 81 | 0.44 | 49.0 | 0.000191 | 0.30 | 3.229 | 0.051 | 0.1111 | 0.0010 | 0.3088 | 0.0049 | 4.622 | 0.094 | 0.1086 | 0.0014 | 0.770 | 1735 | 24 | 1775 | 24 | 2 | | 36.1 | 740 | 469 | 0.63 | 77.7 | 0.000281 | 0.44 | 8.182 | 0.095 | 0.1168 | 0.0008 | 0.1217 | 0.0014 | 1.895 | 0.030 | 0.1130 | 0.0013 | 0.721 | 740 | 8 | 1847 | 20 | 60 | | 37.1 | 376 | 123 | 0.33 | 98.4 | 0.000034 | 0.05 | 3.285 | 0.043 | 0.1105 | 0.0007 | 0.3043 | 0.0040 | 4.615 | 0.068 | 0.1100 | 0.0007 | 0.893 | 1712 | 20 | 1800 | 12 | 5 | | 38.1 | 261 | 94 | 0.36 | 76.0 | 0.000042 | 0.07 | 2.947 | 0.041 | 0.1102 | 0.0008 | 0.3391 | 0.0048 | 5.127 | 0.085 | 0.1096 | 0.0009 | 0.854 | 1882 | 23 | 1794 | 16 | 5 | | 39.1 | 432 | 158 | 0.37 | 112.6 | 0.000057 | 0.09 | 3.291 | 0.039 | 0.1099 | 0.0007 | 0.3036 | 0.0036 | 4.568 | 0.062 | 0.1091 | 0.0007 | 0.874 | 1709 | 18 | 1785 | 12 | 4 | | 40.1 | 192 | 135 | 0.71 | 35.2 | 0.000129 | 0.20 | 4.675 | 0.064 | 0.1124 | 0.0014 | 0.2135 | 0.0029 | 3.257 | 0.068 | 0.1107 | 0.0017 | 0.658 | 1247 | 16 | 1810 | 29 | 31 | | 41.1 | 165 | 79 | 0.48 | 45.7 | 0.000212 | 0.33 | 3.098 | 0.043 | 0.1109 | 0.0010 | 0.3222 | 0.0045 | 4.855 | 0.081 | 0.1093 | 0.0010 | 0.836 | 1800 | 24 | 1788 | 17 | 1 | | 42.1 | 319 | 175 | 0.55 | 69.2 | 0.000093 | 0.15 | 3.958 | 0.049 | 0.1116 | 0.0008 | 0.2523 | 0.0031 | 3.838 | 0.059 | 0.1103 | 0.0010 | 0.802 | 1450 | 16 | 1805 | 17 | 20 | | 43.1 | 140 | 76 | 0.54 | 39.2 | 0.000445 | 0.69 | 3.055 | 0.044 | 0.1149 | 0.0011 | 0.3251 | 0.0047 | 4.881 | 0.117 | 0.1089 | 0.0021 | 0.609 | 1815 | 23 | 1781 | 35 | 2 | | 44.1 | 825 | 378 | 0.46 | 105.8 | 0.000205 | 0.32 | 6.700 | 0.078 | 0.1131 | 0.0006 | 0.1488 | 0.0017 | 2.262 | 0.033 | 0.1103 | 0.0009 | 0.806 | 894 | 10 | 1804 | 16 | 50 | | 45.1 | 221 | 103 | 0.47 | 61.8 | 0.000059 | 0.09 | 3.069 | 0.040 | 0.1091 | 0.0008 | 0.3255 | 0.0042 | 4.861 | 0.076 | 0.1083 | 0.0009 | 0.835 | 1817 | 21 | 1771 | 16 | 3 | | 46.1 | 192 | 86 | 0.45 | 46.7 | 0.000079 | 0.12 | 3.525 | 0.048 | 0.1115 | 0.0012 | 0.2833 | 0.0039 | 4.314 | 0.077 | 0.1104 | 0.0013 | 0.764 | 1608 | 19 | 1807 | 21 | 11 | | 47.1 | 440 | 250 | 0.57 | 91.1 | 0.000137 | 0.21 | 4.144 | 0.048 | 0.1122 | 0.0006 | 0.2408 | 0.0028 | 3.663 | 0.051 | 0.1103 | 0.0008 | 0.833 | 1391 | 14 | 1805 | 14 | 23 | | 48.1 | 290 | 162 | 0.56 | 70.1 | 0.000086 | 0.13 | 3.562 | 0.043 | 0.1103 | 0.0007 | 0.2804 | 0.0034 | 4.217 | 0.064 | 0.1091 | 0.0010 | 0.806 | 1593 | 17 | 1784 | 16 | 11 | | 49.1 | 284 | 199 | 0.70 | 78.9 | 0.000029 | 0.05 | 3.090 | 0.037 | 0.1103 | 0.0007 | 0.3235 | 0.0039 | 4.903 | 0.067 | 0.1099 | 0.0007 | 0.885 | 1807 | 19 | 1798 | 12 | 0 | | 50.1 | 281 | 97 | 0.34 | 79.1 | 0.000020 | 0.03 | 3.055 | 0.037 | 0.1104 | 0.0007 | 0.3273 | 0.0040 | 4.969 | 0.068 | 0.1101 | 0.0007 | 0.883 | 1825 | 19 | 1801 | 12 | 1 | | 51.1 | 258 | 133 | 0.51 | 70.0 | 0.000063 | 0.10 | 3.172 | 0.039 | 0.1091 | 0.0007 | 0.3150 | 0.0039 | 4.702 | 0.068 | 0.1083 | 0.0008 | 0.851 | 1765 | 19 | 1771 | 14 | 0 | | 52.1 | 173 | 68 | 0.39 | 33.8 | 0.000130 | 0.20 | 4.401 | 0.058 | 0.1115 | 0.0010 | 0.2268 | 0.0030 | 3.432 | 0.063 | 0.1098 | 0.0014 | 0.726 | 1318 | 16 | 1795 | 23 | 27 | | 53.1 | 266 | 137 | 0.52 | 70.3 | 0.000057 | 0.09 | 3.252 | 0.039 | 0.1105 | 0.0012 | 0.3072 | 0.0037 | 4.647 | 0.075 | 0.1097 | 0.0012 | 0.740 | 1727 | 18 | 1795 | 20 | 4 | | 54.1 | 537 | 346 | 0.64 | 95.3 | 0.000183 | 0.28 | 4.843 | 0.055 | 0.1133 | 0.0006 | 0.2059 | 0.0023 | 3.147 | 0.044 | 0.1108 | 0.0009 | 0.810 | 1207 | 12 | 1813 | 15 | 33 | | 55.1 | 131 | 74 | 0.56 | 36.6 | 0.000043 | 0.07 | 3.080 | 0.044 | 0.1123 | 0.0010 | 0.3245 | 0.0046 | 4.998 | 0.086 | 0.1117 | 0.0011 | 0.824 | 1812 | 22 | 1828 | 18 | 1 | | 56.1 | 502 | 183 | 0.36 | 79.7 | 0.000158 | 0.25 | 5.408 | 0.062 | 0.1119 | 0.0007 | 0.1845 | 0.0021 | 2.791 | 0.039 | 0.1097 | 0.0009 | 0.823 | 1091 | 11 | 1795 | 14 | 39 | | 57.1 | 131 | 57 | 0.43 | 36.0 | 0.000046 | 0.07 | 3.133 | 0.045 | 0.1113 | 0.0010 | 0.3189 | 0.0045 | 4.866 | 0.087 | 0.1107 | 0.0012 | 0.801 | 1784 | 22 | 1810 | 19 | 1 | | 58.1 | 195 | 84 | 0.43 | 53.7 | 0.000038 | 0.06 | 3.118 | 0.040 | 0.1103 | 0.0008 | 0.3205 | 0.0041 | 4.852 | 0.073 | 0.1098 | 0.0009 | 0.854 | 1792 | 20 | 1796 | 14 | 0 | | 59.1 | 531 | 225 | 0.42 | 96.0 | 0.000264 | 0.41 | 4.751 | 0.057 | 0.1146 | 0.0006 | 0.2096 | 0.0025 | 3.209 | 0.048 | 0.1110 | 0.0010 | 0.794 | 1227 | 13 | 1816 | 17 | 32 | | 60.1 | 186 | 93 | 0.50 | 51.3 | 0.000066 | 0.10 | 3.114 | 0.045 | 0.1122 | 0.0009 | 0.3028 | 0.0046 | 4.922 | 0.084 | 0.1113 | 0.0010 | 0.846 | 1794 | 23 | 1820 | 17 | 1 |   Uncertainties given at the 1 level. Error in FC1 reference zircon calibration was 0.37% for the analytical session (not included in above errors but required when comparing 206Pb/238U data from different mounts). f206 % denotes the percentage of 206Pb that is common Pb. Correction for common Pb made using the measured 204Pb/206Pb ratio. For |

% Disc., 0% denotes a concordant analysis.

the magmas from which the zircons crystallized, and that a large proportion of pre-existing crust of Archaean age must have been involved.

# Site 555

DSDP Site 555 is located on a col between Edoras Bank and Hatton Bank, to the SW of BGS borehole 99/2A (Fig. 1). Beneath a Miocene deep-water biogenic pelagic succession, the borehole encountered a Palaeocene–Eocene succession dominated by basalt flows and volcaniclastic sediment, with occasional units containing terrigenous clastic sediments (Shipboard Scientific Party 1984). This volcanic-dominated succession was generated during the early stages of sea-floor spreading between Rockall Plateau and Greenland, and is coeval with the seawarddipping reflector sequence found to the SW of Edoras Bank (Roberts et al. 1984).

The sample analysed by SHRIMP (555-88-5, 18–25 cm) is a feldspathic and micaceous sandstone from subunit IVb, dated as Late Palaeocene on the basis of nannofossils and dinoflagellates (Shipboard Scientific Party 1984). Sedimentary structures in this subunit include scours, cross-lamination and soft sediment deformation, suggesting a high-energy depositional environment. This, taken in conjunction with the microfossil evidence, argues for deposition in a nearshore marine environment. There are strong volcanic influences throughout the subunit, including interbedded thin basalt flows and abundant tuffs and lapilli tuffs. Heavy mineral assemblages are rich in apatite and garnet, with

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
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| Table 2. Summary of SHRIMP U–Pb zircon results for DSDP sample 555-88-5, 18–25 cm (Edoras Bank)   |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | | Grain. spot | U  (ppm) ( | Th ppm) | Th/U | Pb\* (ppm) | 204Pb/206Pb | f206 % | 238U/  206Pb |  | Total ratios 207Pb/206Pb |  | 206Pb/ 238U |  | Radiogenic ratios  207Pb/  235U |  | 207Pb/  206Pb | r |  |  | Age (Ma) |  |  | | 206Pb/ 238U |  | 207Pb/ 206Pb |  | % Disc. | | 1.1 | 615 | 142 | 0.23 | 158.6 | 0.000059 | 0.09 | 3.329 | 0.042 | 0.1081 | 0.0011 | 0.3001 | 0.0038 | 4.440 | 0.073 | 0.1073 0.0011 | 0.773 | 1692 | 19 | 1754 | 19 | 4 | | 2.1 | 172 | 74 | 0.43 | 44.3 | 0.000458 | 0.72 | 3.343 | 0.071 | 0.1125 | 0.0015 | 0.2969 | 0.0064 | 4.352 | 0.155 | 0.1063 0.0030 | 0.601 | 1676 | 32 | 1737 | 52 | 3 | | 3.1 | 273 | 67 | 0.24 | 69.4 | 0.000382 | 0.60 | 3.374 | 0.054 | 0.1125 | 0.0012 | 0.2946 | 0.0047 | 4.360 | 0.108 | 0.1073 0.0020 | 0.648 | 1665 | 23 | 1754 | 34 | 5 | | 4.1 | 375 | 73 | 0.19 | 95.9 | 0.000289 | 0.46 | 3.362 | 0.051 | 0.1088 | 0.0011 | 0.2961 | 0.0045 | 4.279 | 0.095 | 0.1048 0.0017 | 0.680 | 1672 | 22 | 1711 | 30 | 2 | | 5.1 | 685 | 125 | 0.18 | 159.5 | 0.000145 | 0.22 | 3.689 | 0.049 | 0.1229 | 0.0060 | 0.2705 | 0.0036 | 4.511 | 0.232 | 0.1210 0.0060 | 0.259 | 1543 | 18 | 1971 | 89 | 22 | | 6.1 | 715 | 160 | 0.22 | 183.7 | 0.000047 | 0.07 | 3.345 | 0.040 | 0.1087 | 0.0006 | 0.2987 | 0.0036 | 4.452 | 0.060 | 0.1081 0.0007 | 0.888 | 1685 | 18 | 1768 | 11 | 5 | | 7.1 | 423 | 128 | 0.30 | 108.0 | 0.000058 | 0.09 | 3.360 | 0.048 | 0.1090 | 0.0008 | 0.2973 | 0.0042 | 4.437 | 0.073 | 0.1082 0.0009 | 0.862 | 1678 | 21 | 1770 | 15 | 5 | | 8.1 | 667 | 132 | 0.20 | 174.9 | 0.000084 | 0.13 | 3.277 | 0.039 | 0.1073 | 0.0011 | 0.3048 | 0.0036 | 4.460 | 0.071 | 0.1061 0.0011 | 0.749 | 1715 | 18 | 1734 | 19 | 1 | | 9.1 | 350 | 109 | 0.31 | 89.7 | 0.000141 | 0.22 | 3.350 | 0.045 | 0.1088 | 0.0009 | 0.2979 | 0.0040 | 4.388 | 0.073 | 0.1068 0.0011 | 0.800 | 1681 | 20 | 1746 | 18 | 4 | | 10.1 | 341 | 117 | 0.34 | 89.7 | 0.000100 | 0.16 | 3.270 | 0.044 | 0.1124 | 0.0009 | 0.3053 | 0.0041 | 4.674 | 0.077 | 0.1110 0.0011 | 0.814 | 1718 | 20 | 1817 | 17 | 5 | | 11.1 | 431 | 125 | 0.29 | 110.3 | 0.000157 | 0.25 | 3.360 | 0.047 | 0.1103 | 0.0009 | 0.2969 | 0.0042 | 4.426 | 0.081 | 0.1081 0.0013 | 0.764 | 1676 | 21 | 1768 | 22 | 5 | | 12.1 | 653 | 64 | 0.10 | 256.4 | 0.000023 | 0.03 | 2.187 | 0.028 | 0.1623 | 0.0066 | 0.4570 | 0.0058 10.208 | | 0.433 | 0.1620 0.0066 | 0.298 | 2427 | 26 | 2477 | 68 | 2 | | 13.1 | 640 | 122 | 0.19 | 167.6 | 0.000119 | 0.19 | 3.278 | 0.043 | 0.1090 | 0.0010 | 0.3045 | 0.0040 | 4.507 | 0.075 | 0.1073 0.0011 | 0.781 | 1714 | 20 | 1755 | 19 | 2 | | 14.1 | 766 | 72 | 0.09 | 208.8 | 0.000089 | 0.14 | 3.151 | 0.037 | 0.1087 | 0.0006 | 0.3174 | 0.0037 | 4.761 | 0.062 | 0.1088 0.0006 | 0.908 | 1777 | 19 | 1779 | 10 | 0 | | 15.1 | 412 | 85 | 0.21 | 110.7 | 0.000075 | 0.12 | 3.200 | 0.042 | 0.1095 | 0.0014 | 0.3121 | 0.0041 | 4.668 | 0.090 | 0.1085 0.0015 | 0.682 | 1751 | 20 | 1774 | 26 | 1 | | 16.1 | 328 | 86 | 0.26 | 86.6 | 0.000093 | 0.15 | 3.255 | 0.046 | 0.1076 | 0.0010 | 0.3068 | 0.0043 | 4.498 | 0.082 | 0.1063 0.0012 | 0.778 | 1725 | 21 | 1737 | 21 | 1 | | 17.1 | 571 | 117 | 0.20 | 150.7 | 0.000057 | 0.09 | 3.251 | 0.044 | 0.1069 | 0.0007 | 0.3073 | 0.0041 | 4.498 | 0.070 | 0.1062 0.0008 | 0.870 | 1727 | 20 | 1734 | 14 | 0 | | 18.1 | 225 | 93 | 0.41 | 58.4 | 0.000139 | 0.22 | 3.318 | 0.051 | 0.1077 | 0.0011 | 0.3008 | 0.0047 | 4.389 | 0.083 | 0.1058 0.0012 | 0.814 | 1695 | 23 | 1729 | 20 | 2 | | 19.1 | 177 | 89 | 0.50 | 46.1 | 0.000133 | 0.21 | 3.308 | 0.055 | 0.1112 | 0.0013 | 0.3016 | 0.0050 | 4.549 | 0.111 | 0.1094 0.0019 | 0.687 | 1699 | 25 | 1789 | 32 | 5 | | 20.1 | 1272 | 340 | 0.27 | 335.9 | 0.000029 | 0.05 | 3.252 | 0.036 | 0.1080 | 0.0004 | 0.3073 | 0.0034 | 4.562 | 0.054 | 0.1077 0.0004 | 0.944 | 1728 | 17 | 1760 | 7 | 2 | | 21.1 | 545 | 116 | 0.21 | 141.8 | 0.000010 | 0.01 | 3.304 | 0.039 | 0.1071 | 0.0006 | 0.3026 | 0.0036 | 4.464 | 0.058 | 0.1070 0.0006 | 0.898 | 1704 | 18 | 1749 | 11 | 3 | | 22.1 | 967 | 222 | 0.23 | 255.6 | 0.000007 | 0.01 | 3.251 | 0.036 | 0.1065 | 0.0004 | 0.3075 | 0.0034 | 4.510 | 0.053 | 0.1064 0.0004 | 0.933 | 1729 | 17 | 1738 | 8 | 1 | | 23.1 | 540 | 128 | 0.24 | 135.9 | 0.000021 | 0.03 | 3.415 | 0.043 | 0.1089 | 0.0006 | 0.2927 | 0.0037 | 4.384 | 0.061 | 0.1086 0.0006 | 0.908 | 1655 | 18 | 1777 | 11 | 7 | | 24.1 | 576 | 111 | 0.19 | 152.5 | 0.000007 | 0.01 | 3.244 | 0.041 | 0.1096 | 0.0006 | 0.3083 | 0.0039 | 4.654 | 0.064 | 0.1095 0.0006 | 0.912 | 1732 | 19 | 1791 | 10 | 3 | | 25.1 | 455 | 181 | 0.40 | 117.8 | – | ,0.01 | 3.316 | 0.036 | 0.1065 | 0.0005 | 0.3016 | 0.0033 | 4.429 | 0.052 | 0.1065 0.0005 | 0.931 | 1699 | 16 | 1741 | 8 | 2 | | 26.1 | 458 | 121 | 0.26 | 119.4 | 0.000005 | 0.01 | 3.299 | 0.036 | 0.1075 | 0.0005 | 0.3031 | 0.0033 | 4.487 | 0.053 | 0.1074 0.0005 | 0.932 | 1707 | 16 | 1755 | 8 | 3 | | 27.1 | 818 | 242 | 0.30 | 214.2 | – | ,0.01 | 3.280 | 0.035 | 0.1071 | 0.0003 | 0.3049 | 0.0032 | 4.508 | 0.050 | 0.1072 0.0003 | 0.957 | 1716 | 16 | 1753 | 6 | 2 | | 28.1 | 887 | 194 | 0.22 | 229.5 | 0.000001 | 0.00 | 3.322 | 0.035 | 0.1073 | 0.0003 | 0.3010 | 0.0032 | 4.451 | 0.049 | 0.1072 0.0003 | 0.960 | 1696 | 16 | 1753 | 6 | 3 | | 29.1 | 59 | 57 | 0.96 | 8.8 | 0.000113 | 0.19 | 5.811 | 0.097 | 0.0742 | 0.0014 | 0.1718 | 0.0029 | 1.719 | 0.056 | 0.0726 0.0020 | 0.520 | 1022 | 16 | 1003 | 56 | 2 | | 30.1 | 306 | 74 | 0.24 | 80.4 | 0.000001 | 0.00 | 3.270 | 0.037 | 0.1075 | 0.0006 | 0.3058 | 0.0035 | 4.532 | 0.057 | 0.1075 0.0006 | 0.909 | 1720 | 17 | 1757 | 10 | 2 | | 31.1 | 413 | 82 | 0.20 | 111.0 | 0.000004 | 0.01 | 3.197 | 0.035 | 0.1071 | 0.0005 | 0.3128 | 0.0035 | 4.619 | 0.055 | 0.1071 0.0005 | 0.929 | 1755 | 17 | 1750 | 8 | 0 | | 32.1 | 641 | 161 | 0.25 | 172.5 | 0.000019 | 0.03 | 3.195 | 0.034 | 0.1076 | 0.0004 | 0.3129 | 0.0033 | 4.632 | 0.053 | 0.1074 0.0004 | 0.943 | 1755 | 16 | 1755 | 7 | 0 | | 33.1 | 363 | 227 | 0.62 | 97.4 | 0.000006 | 0.01 | 3.201 | 0.036 | 0.1076 | 0.0005 | 0.3123 | 0.0035 | 4.631 | 0.056 | 0.1075 0.0005 | 0.919 | 1752 | 17 | 1758 | 9 | 0 | | 34.1 | 165 | 73 | 0.44 | 42.2 | 0.000000 | 0.00 | 3.359 | 0.042 | 0.1071 | 0.0008 | 0.2977 | 0.0037 | 4.398 | 0.064 | 0.1071 0.0008 | 0.860 | 1680 | 19 | 1751 | 14 | 4 | | 35.1 | 673 | 158 | 0.23 | 165.8 | 0.000003 | 0.01 | 3.488 | 0.037 | 0.1066 | 0.0004 | 0.2866 | 0.0031 | 4.210 | 0.048 | 0.1065 0.0004 | 0.945 | 1625 | 15 | 1741 | 7 | 7 | | 36.1 | 303 | 80 | 0.26 | 79.5 | 0.000027 | 0.04 | 3.273 | 0.037 | 0.1073 | 0.0006 | 0.3054 | 0.0035 | 4.502 | 0.057 | 0.1069 0.0006 | 0.898 | 1718 | 17 | 1747 | 10 | 2 | | 37.1 | 398 | 227 | 0.57 | 104.4 | – | ,0.01 | 3.273 | 0.036 | 0.1070 | 0.0005 | 0.3055 | 0.0034 | 4.517 | 0.054 | 0.1072 0.0005 | 0.921 | 1719 | 17 | 1753 | 9 | 2 | | 38.1 | 690 | 138 | 0.20 | 185.1 | 0.000006 | 0.01 | 3.202 | 0.034 | 0.1071 | 0.0004 | 0.3123 | 0.0033 | 4.610 | 0.052 | 0.1071 0.0004 | 0.946 | 1752 | 16 | 1750 | 7 | 0 | | 39.1 | 237 | 66 | 0.28 | 37.2 | – | ,0.01 | 5.478 | 0.066 | 0.0760 | 0.0007 | 0.1827 | 0.0022 | 1.931 | 0.029 | 0.0766 0.0007 | 0.810 | 1082 | 12 | 1112 | 17 | 3 | | 40.1 | 278 | 115 | 0.41 | 69.3 | – | ,0.01 | 3.442 | 0.040 | 0.1008 | 0.0006 | 0.2906 | 0.0034 | 4.041 | 0.052 | 0.1009 0.0006 | 0.895 | 1644 | 17 | 1640 | 11 | 0 | | 41.1 | 292 | 83 | 0.29 | 79.7 | 0.000018 | 0.03 | 3.151 | 0.036 | 0.1070 | 0.0006 | 0.3172 | 0.0036 | 4.672 | 0.059 | 0.1068 0.0006 | 0.908 | 1776 | 18 | 1745 | 10 | 2 | | 42.1 | 407 | 92 | 0.23 | 108.2 | 0.000008 | 0.01 | 3.227 | 0.036 | 0.1065 | 0.0005 | 0.3098 | 0.0034 | 4.545 | 0.055 | 0.1064 0.0005 | 0.923 | 1740 | 17 | 1739 | 9 | 0 | | 43.1 | 281 | 88 | 0.31 | 73.3 | 0.000030 | 0.05 | 3.292 | 0.038 | 0.1070 | 0.0006 | 0.3036 | 0.0035 | 4.461 | 0.058 | 0.1066 0.0006 | 0.899 | 1709 | 17 | 1742 | 10 | 2 | | 44.1 | 469 | 179 | 0.38 | 124.4 | 0.000018 | 0.03 | 3.242 | 0.036 | 0.1073 | 0.0005 | 0.3083 | 0.0034 | 4.552 | 0.054 | 0.1071 0.0005 | 0.931 | 1733 | 17 | 1750 | 8 | 1 | | 45.1 | 704 | 186 | 0.26 | 186.2 | 0.000007 | 0.01 | 3.250 | 0.036 | 0.1074 | 0.0004 | 0.3077 | 0.0034 | 4.552 | 0.053 | 0.1073 0.0004 | 0.950 | 1729 | 17 | 1754 | 7 | 1 | | 46.1 | 782 | 166 | 0.21 | 193.0 | 0.000004 | 0.01 | 3.483 | 0.037 | 0.1064 | 0.0004 | 0.2871 | 0.0031 | 4.211 | 0.047 | 0.1064 0.0004 | 0.950 | 1627 | 15 | 1738 | 6 | 6 | | 47.1 | 17 | 3 | 0.21 | 4.1 | 0.000671 | 1.09 | 3.450 | 0.096 | 0.1020 | 0.0027 | 0.2888 | 0.0080 | 3.941 | 0.153 | 0.0990 0.0027 | 0.713 | 1636 | 41 | 1605 | 51 | 2 | | 48.1 | 541 | 166 | 0.31 | 140.9 | 0.000135 | 0.21 | 3.302 | 0.036 | 0.1079 | 0.0005 | 0.3022 | 0.0033 | 4.422 | 0.072 | 0.1061 0.0013 | 0.681 | 1702 | 17 | 1734 | 22 | 2 | | 49.1 | 547 | 107 | 0.19 | 143.5 | – | ,0.01 | 3.274 | 0.036 | 0.1066 | 0.0005 | 0.3054 | 0.0034 | 4.491 | 0.053 | 0.1066 0.0005 | 0.932 | 1718 | 17 | 1743 | 8 | 1 | | 50.1 | 1032 | 252 | 0.24 | 276.4 | 0.000001 | ,0.01 | 3.208 | 0.034 | 0.1065 | 0.0004 | 0.3119 | 0.0033 | 4.600 | 0.052 | 0.1070 0.0005 | 0.928 | 1750 | 17 | 1748 | 8 | 0 | | 51.1 | 492 | 165 | 0.33 | 126.2 | 0.000022 | 0.03 | 3.350 | 0.040 | 0.1070 | 0.0005 | 0.2984 | 0.0035 | 4.391 | 0.057 | 0.1067 0.0005 | 0.918 | 1683 | 18 | 1744 | 9 | 3 | | 52.1 | 502 | 167 | 0.33 | 126.3 | 0.000014 | 0.02 | 3.414 | 0.038 | 0.1071 | 0.0005 | 0.2928 | 0.0033 | 4.315 | 0.053 | 0.1069 0.0005 | 0.913 | 1656 | 16 | 1747 | 9 | 5 | | 53.1 | 59 | 29 | 0.48 | 13.0 | 0.000091 | 0.14 | 3.907 | 0.070 | 0.1039 | 0.0016 | 0.2556 | 0.0046 | 3.616 | 0.092 | 0.1026 0.0018 | 0.711 | 1467 | 24 | 1672 | 33 | 12 | | 54.1 | 162 | 56 | 0.35 | 39.7 | 0.000055 | 0.09 | 3.504 | 0.047 | 0.1063 | 0.0009 | 0.2852 | 0.0038 | 4.151 | 0.069 | 0.1056 0.0010 | 0.808 | 1617 | 19 | 1724 | 18 | 6 | | 55.1 | 300 | 71 | 0.24 | 79.2 | 0.000004 | 0.01 | 3.251 | 0.039 | 0.1084 | 0.0009 | 0.3075 | 0.0037 | 4.596 | 0.068 | 0.1084 0.0009 | 0.825 | 1729 | 18 | 1773 | 15 | 2 | | 56.1 | 376 | 50 | 0.13 | 99.4 | – | ,0.01 | 3.252 | 0.039 | 0.1080 | 0.0006 | 0.3075 | 0.0037 | 4.579 | 0.061 | 0.1080 0.0006 | 0.893 | 1729 | 18 | 1766 | 11 | 2 | | 57.1 | 380 | 68 | 0.18 | 100.0 | – | ,0.01 | 3.264 | 0.042 | 0.1075 | 0.0007 | 0.3064 | 0.0039 | 4.542 | 0.064 | 0.1075 0.0007 | 0.904 | 1723 | 19 | 1758 | 11 | 2 | | 58.1 | 698 | 133 | 0.19 | 182.2 | – | ,0.01 | 3.289 | 0.039 | 0.1069 | 0.0005 | 0.3040 | 0.0036 | 4.479 | 0.057 | 0.1069 0.0005 | 0.928 | 1711 | 18 | 1746 | 9 | 2 | | 59.1 | 439 | 104 | 0.24 | 112.1 | 0.000005 | 0.01 | 3.362 | 0.040 | 0.1075 | 0.0007 | 0.2975 | 0.0036 | 4.407 | 0.059 | 0.1075 0.0007 | 0.889 | 1679 | 18 | 1757 | 11 | 4 | | 60.1 | 544 | 112 | 0.21 | 135.9 | 0.000008 | 0.01 | 3.438 | 0.040 | 0.1067 | 0.0006 | 0.2908 | 0.0034 | 4.276 | 0.056 | 0.1066 0.0006 | 0.895 | 1646 | 17 | 1742 | 11 | 6 |   Uncertainties given at the 1 level. Error in FC1 reference zircon calibration was 0.37% for the analytical session (not included in above errors but required when comparing 206Pb/238U data from different mounts). f206 % denotes the percentage of 206Pb that is common Pb. Correction for common Pb made using the measured 204Pb/206Pb ratio. For |

% Disc., 0% denotes a concordant analysis.

subordinate zircon, epidote and amphibole (Morton 1984), indicating derivation from basement of predominantly intermediate– acidic nature. The zircon habits (Fig. 2) are strongly suggestive of a first-cycle origin, with grains lacking significant degrees of rounding. The transmitted light photomicrographs show that the grains from DSDP Site 555 are much simpler and less structured, with more large clear areas that could be analysed, compared with grains from borehole 99/2A, which show more zoning and cracking (Fig. 2). The CL images of the zircons (Fig. 2) show that they have typical magmatic zoning patterns (Corfu et al. 2003). Grains with apparent cores are present in small numbers.

The analysed zircons in the sample from Site 555 are concordant or near-concordant, with only one zircon being more than 20% discordant (Fig. 3). The zircon age spectrum is slightly more diverse than in borehole 99/2A, although the vast majority of the zircons (c. 80%) form a single 207Pb/206Pb peak (Fig. 4) with a weighted mean age of 1749.5 2.7 Ma (MSWD 0.79 for 47 analyses). The significance of the other 207Pb/206Pb ages is uncertain, as they do not form a coherent group. There is a single very early Palaeoproterozoic grain with a large error bar (2477 68 Ma), a discordant grain dated at 1971 89 Ma, a small number of grains slightly younger than the main peak (ranging to 1605 Ma), and two late Mesoproterozoic grains (1003 Ma, 1112 Ma). As with the sample from borehole 99/2A, all the zircons in the sample have relatively high Th/U, implying an igneous parentage of felsic–intermediate composition.

The Hf isotopic data contrast markedly with those from borehole 99/2A (Table 3, Fig. 5), with Hf(t) values ranging from

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| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Table 3. Hf isotopic compositions of detrital zircons from BGS borehole 99/2A and DSDP Site 555   |  |  |  |  |  |  |  |  |  |  | | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | | Grain 176Hf/177Hf | | 2SE | 176Lu/177Hf | 2SE | U–Pb age (t1) | Hf(0) | 176Hf/177Hf(t1) | Hf(t1) | TDM | | Sample 99/2A, 45.65–45.72 m  2 0.281659 | | 0.000050 | 0.000643 | 0.000036 | 1801 | 39.35 | 0.281637 | 0.02 | 2417 | | 8 | 0.281700 | 0.000064 | 0.001276 | 0.000117 | 1819 | 37.92 | 0.281656 | 1.09 | 2363 | | 11 | 0.281614 | 0.000050 | 0.000383 | 0.000008 | 1821 | 40.95 | 0.281601 | 0.82 | 2486 | | 14 | 0.281556 | 0.000038 | 0.000699 | 0.000013 | 1820 | 43.01 | 0.281532 | 3.30 | 2643 | | 18 | 0.281606 | 0.000042 | 0.001096 | 0.000024 | 1789 | 41.24 | 0.281569 | 2.69 | 2581 | | 19 | 0.281641 | 0.000049 | 0.000427 | 0.000006 | 1786 | 39.99 | 0.281627 | 0.70 | 2451 | | 21 | 0.281651 | 0.000049 | 0.000901 | 0.000006 | 1801 | 39.64 | 0.281620 | 0.58 | 2456 | | 22 | 0.281659 | 0.000039 | 0.000441 | 0.000005 | 1796 | 39.34 | 0.281644 | 0.16 | 2404 | | 23 | 0.281689 | 0.000046 | 0.000860 | 0.000019 | 1797 | 38.29 | 0.281660 | 0.73 | 2369 | | 25 | 0.281644 | 0.000042 | 0.001045 | 0.000008 | 1780 | 39.90 | 0.281608 | 1.48 | 2497 | | 26 | 0.281709 | 0.000046 | 0.000911 | 0.000015 | 1798 | 37.58 | 0.281678 | 1.40 | 2327 | | 27 | 0.281618 | 0.000038 | 0.000421 | 0.000011 | 1783 | 40.79 | 0.281604 | 1.56 | 2504 | | 28 | 0.281669 | 0.000034 | 0.000533 | 0.000003 | 1811 | 39.02 | 0.281650 | 0.71 | 2381 | | 29 | 0.281757 | 0.000040 | 0.000765 | 0.000016 | 1784 | 35.89 | 0.281731 | 2.97 | 2216 | | 30 | 0.281646 | 0.000041 | 0.001107 | 0.000046 | 1805 | 39.83 | 0.281608 | 0.94 | 2481 | | 32 | 0.281636 | 0.000033 | 0.000610 | 0.000037 | 1810 | 40.17 | 0.281615 | 0.56 | 2461 | | 41 | 0.281668 | 0.000038 | 0.000560 | 0.000004 | 1788 | 39.03 | 0.281649 | 0.15 | 2399 | | 43 | 0.281630 | 0.000037 | 0.000552 | 0.000006 | 1781 | 40.38 | 0.281611 | 1.35 | 2489 | | 49 | 0.281646 | 0.000046 | 0.000863 | 0.000070 | 1798 | 39.83 | 0.281616 | 0.79 | 2467 | | 50 | 0.281685 | 0.000033 | 0.000834 | 0.000030 | 1801 | 38.44 | 0.281657 | 0.71 | 2374 | | 57 | 0.281647 | 0.000032 | 0.000531 | 0.000019 | 1810 | 39.79 | 0.281629 | 0.08 | 2431 | | 58 | 0.281749 | 0.000054 | 0.000889 | 0.000016 | 1796 | 36.19 | 0.281718 | 2.79 | 2237 | | 60 | 0.281678 | 0.000042 | 0.000590 | 0.000021 | 1820 | 38.67 | 0.281658 | 1.19 | 2357 | | Sample 555-88-5, 18–25 cm  13 0.281834 | | 0.000043 | 0.000609 | 0.000014 | 1755 | 33.17 | 0.281814 | 5.24 | 2048 | | 20 | 0.281839 | 0.000047 | 0.001070 | 0.000017 | 1760 | 32.99 | 0.281803 | 4.99 | 2068 | | 21 | 0.281874 | 0.000079 | 0.000654 | 0.000013 | 1749 | 31.74 | 0.281853 | 6.49 | 1964 | | 25 | 0.281646 | 0.000073 | 0.000692 | 0.000064 | 1741 | 39.83 | 0.281623 | 1.86 | 2491 | | 26 | 0.281877 | 0.000064 | 0.000887 | 0.000048 | 1755 | 31.65 | 0.281848 | 6.44 | 1971 | | 27 | 0.281765 | 0.000032 | 0.001307 | 0.000002 | 1753 | 35.61 | 0.281721 | 1.92 | 2259 | | 28 | 0.281831 | 0.000065 | 0.000859 | 0.000002 | 1753 | 33.29 | 0.281802 | 4.78 | 2076 | | 30 | 0.281752 | 0.000031 | 0.001036 | 0.000026 | 1757 | 36.08 | 0.281717 | 1.86 | 2266 | | 31 | 0.281790 | 0.000043 | 0.000400 | 0.000007 | 1750 | 34.74 | 0.281776 | 3.80 | 2137 | | 32 | 0.281826 | 0.000038 | 0.000514 | 0.000004 | 1755 | 33.45 | 0.281809 | 5.07 | 2059 | | 33 | 0.281821 | 0.000074 | 0.001153 | 0.000037 | 1758 | 33.65 | 0.281782 | 4.19 | 2118 | | 36 | 0.281857 | 0.000042 | 0.000719 | 0.000009 | 1747 | 32.35 | 0.281833 | 5.76 | 2009 | | 37 | 0.281828 | 0.000041 | 0.000418 | 0.000012 | 1753 | 33.37 | 0.281815 | 5.22 | 2048 | | 38 | 0.281787 | 0.000041 | 0.000799 | 0.000014 | 1750 | 34.82 | 0.281761 | 3.25 | 2172 | | 41 | 0.281841 | 0.000053 | 0.000636 | 0.000030 | 1745 | 32.94 | 0.281819 | 5.22 | 2042 | | 42 | 0.281796 | 0.000036 | 0.000310 | 0.000007 | 1739 | 34.52 | 0.281786 | 3.88 | 2123 | | 43 | 0.281780 | 0.000041 | 0.000345 | 0.000004 | 1742 | 35.08 | 0.281769 | 3.34 | 2160 | | 44 | 0.281870 | 0.000058 | 0.001085 | 0.000029 | 1750 | 31.89 | 0.281834 | 5.86 | 2005 | | 45 | 0.281870 | 0.000038 | 0.000767 | 0.000005 | 1754 | 31.89 | 0.281845 | 6.32 | 1978 | | 49 | 0.281824 | 0.000041 | 0.001195 | 0.000039 | 1743 | 33.53 | 0.281784 | 3.92 | 2124 | | 50 | 0.281825 | 0.000053 | 0.000808 | 0.000029 | 1748 | 33.48 | 0.281799 | 4.54 | 2088 | | 51 | 0.281829 | 0.000043 | 0.000589 | 0.000008 | 1744 | 33.34 | 0.281810 | 4.84 | 2065 | | 57 | 0.281848 | 0.000048 | 0.000530 | 0.000008 | 1758 | 32.69 | 0.281830 | 5.88 | 2009 | | 58 | 0.281828 | 0.000045 | 0.000713 | 0.000019 | 1746 | 33.37 | 0.281805 | 4.71 | 2075 |   176Lu decay constant from So¨derlund et al. (2004). Chondritic values from Blichert-Toft & Albare`de (1997). Present-day depleted mantle values from Vervoort & Blichert-Toft |

(1999). ‘Bulk Earth’ from Goodge & Vervoort (2006).

+1.86 to +6.49 (excluding one zircon with an Hf(t) value of 1.86). These values correspond to TDM ages of 1964–2266 Ma, with one outlier at 2491 Ma. The depleted mantle was therefore a major contributor to the magmas from which these zircons crystallized, although there is some evidence for the involvement of pre-existing crust.

# Discussion

The zircon age distributions in the Edoras and Hatton Bank samples indicate that the sediment was derived almost exclusively from basement rocks dated at c. 1750 Ma and c. 1800 Ma, respectively. There are several lines of evidence indicating that the sediment was locally derived. The succession cored in borehole 99/2A was deposited in a non-marine environment and is characterized by first-cycle sediment, suggesting local derivation from adjacent basement on Hatton Bank. Subunit IVb at Site 555 was deposited in a high-energy nearshore environment, again suggesting proximity to the hinterland, and contains heavy mineral assemblages of first-cycle character. Regional variations in heavy mineral assemblages on the SW Rockall Plateau margin indicate that the sandstones in this part of the Site 555 succession were derived from the Rockall Plateau, rather than from the conjugate SE Greenland margin (Morton 1984).

Link et al. (2005) recently conducted a study of detrital zircon age distributions in first- and second-order drainage systems as defined by Ingersoll (1990) and Ingersoll et al. (1993). They showed that first-order systems, which range from talus slopes to small fluvial drainages, contain ‘defining grain populations’ that form over 50% of the entire zircon distribution. These defining populations are also seen in second-order systems, but in lower abundances because of dilution by sediment introduced by other tributaries. The two zircon assemblages described in this paper are both dominated by single ‘defining grain populations’, their age distributions being characterized by single peaks comprising 100% of the zircons in borehole 99/2A and 80% of the zircons at Site 555. The zircon age data therefore suggest that the sandstones at the two locations are of local origin, as they represent the products of small-scale first-order drainage systems.

The only plausible alternative provenance for the zircons in the samples from borehole 99/2A and Site 555 would be the Ketilidian Belt of southern Greenland, which was adjacent to Hatton and Edoras banks prior to opening of the NE Atlantic (Fig. 6). Derivation from the east (Rockall Bank) can be ruled

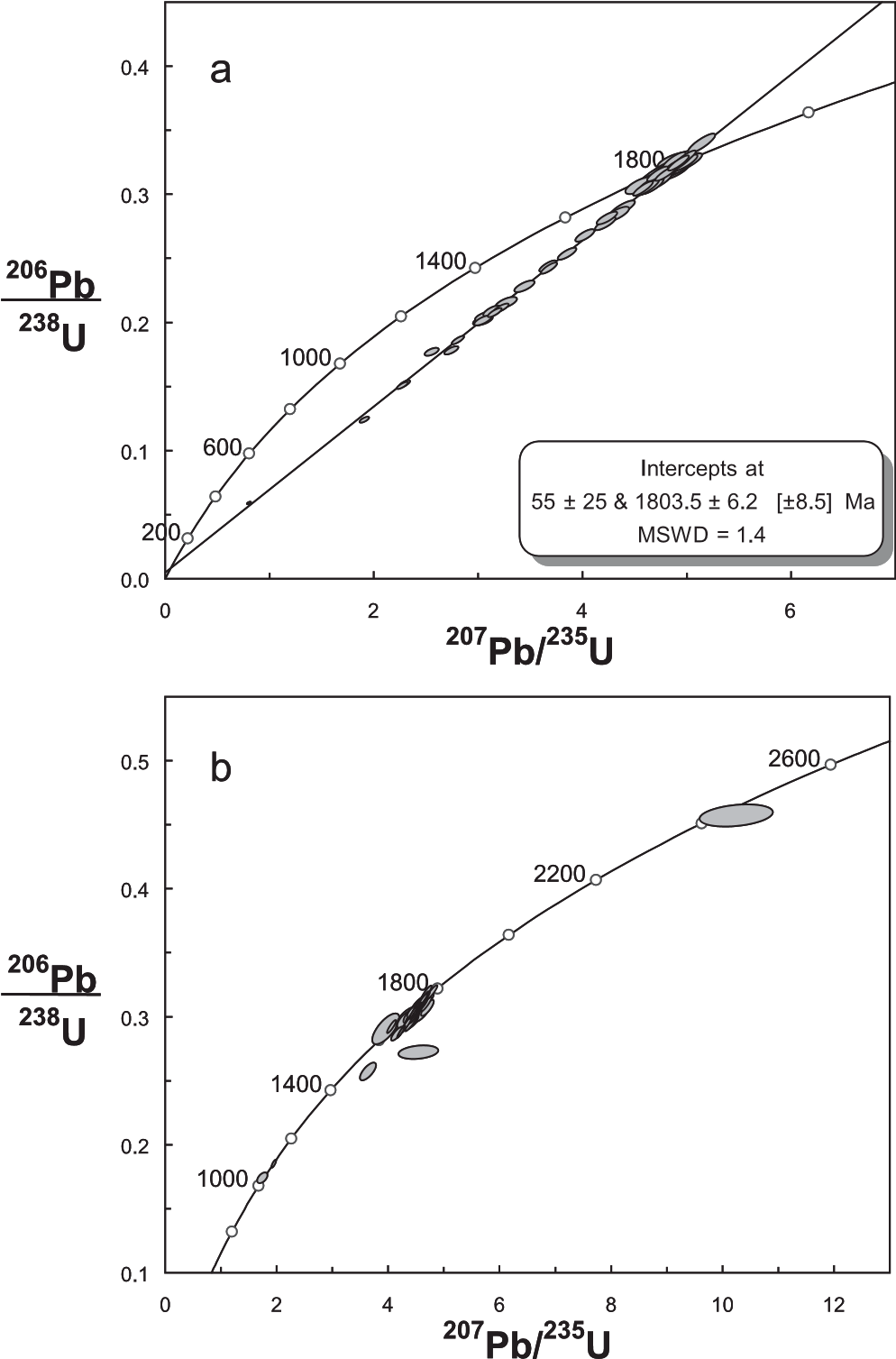


Fig. 3. Detrital zircons from (a) BGS borehole 99/2A, 45.65–45.72 m, and (b) DSDP Site 555-88-5, 18–25 cm, plotted on 206Pb/238U–207Pb/ 235U diagrams. Error ellipses are 1. Many of the grains in BGS borehole 99/2A are discordant, with the U–Pb isotopic data defining a simple discordia line. A linear regression of the zircon age data forced through a lower intercept at 55 Ma is shown in (a). In contrast, the zircons from DSDP Site 555 are mostly concordant.

out as the intervening Hatton Basin was a depocentre during the Mesozoic and Cenozoic (Hitchen 2004). The ages found in borehole 99/2A and Site 555 (c. 1800 Ma and c. 1750 Ma, respectively) fall within the range shown by granitoids of the Ketilidian Belt (c. 1850 Ma to c. 1730 Ma; Garde et al. 2002). However, if the sediment had been derived from the Ketilidian Belt, single samples would be expected to show a wider range of zircon ages than is actually observed, given the c. 120 Ma age range present in the Ketilidian catchment. Therefore, on the basis of depositional environment and zircon age distributions, the zircons in borehole 99/2A and Site 555 are considered to be locally derived, rather than transported from the conjugate margin in southern Greenland. Consequently, they are believed to be representative of local basement on Edoras and Hatton banks.

This provenance study therefore provides evidence for the existence of basement rocks dated at c. 1750 Ma on Edoras Bank and c. 1800 Ma on Hatton Bank. The Hatton and Edoras basement appears to be closely comparable with that of Rockall Bank, as single-grain zircon age dating on samples A, C and D

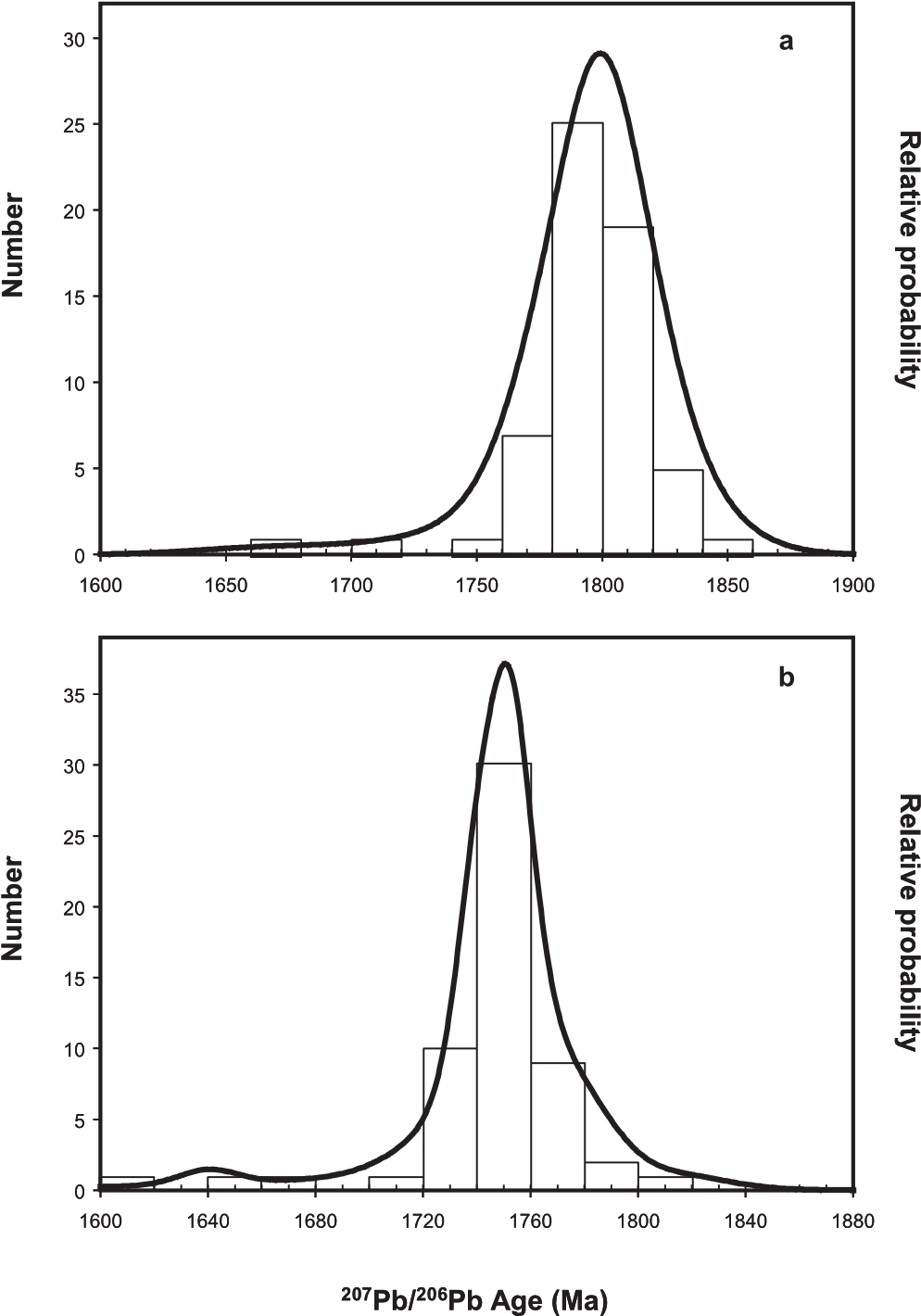


Fig. 4. Combined histogram–relative probability plots of detrital zircon ages from (a) BGS borehole 99/2A, 45.65–45.72 m and (b) DSDP Site 555-88-5, 18–25 cm. Analyses more than 20% discordant have been excluded from the plots. It should be noted that the plot for Site 555 does not show two younger zircons dated at c. 1005 Ma and c. 1110 Ma.

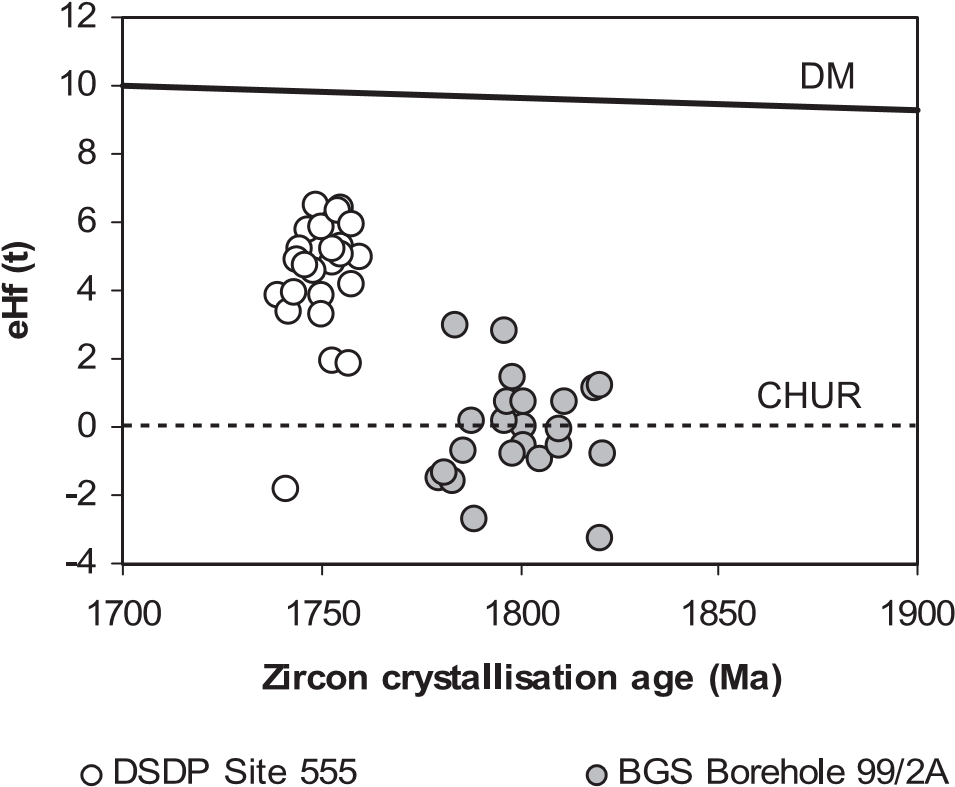
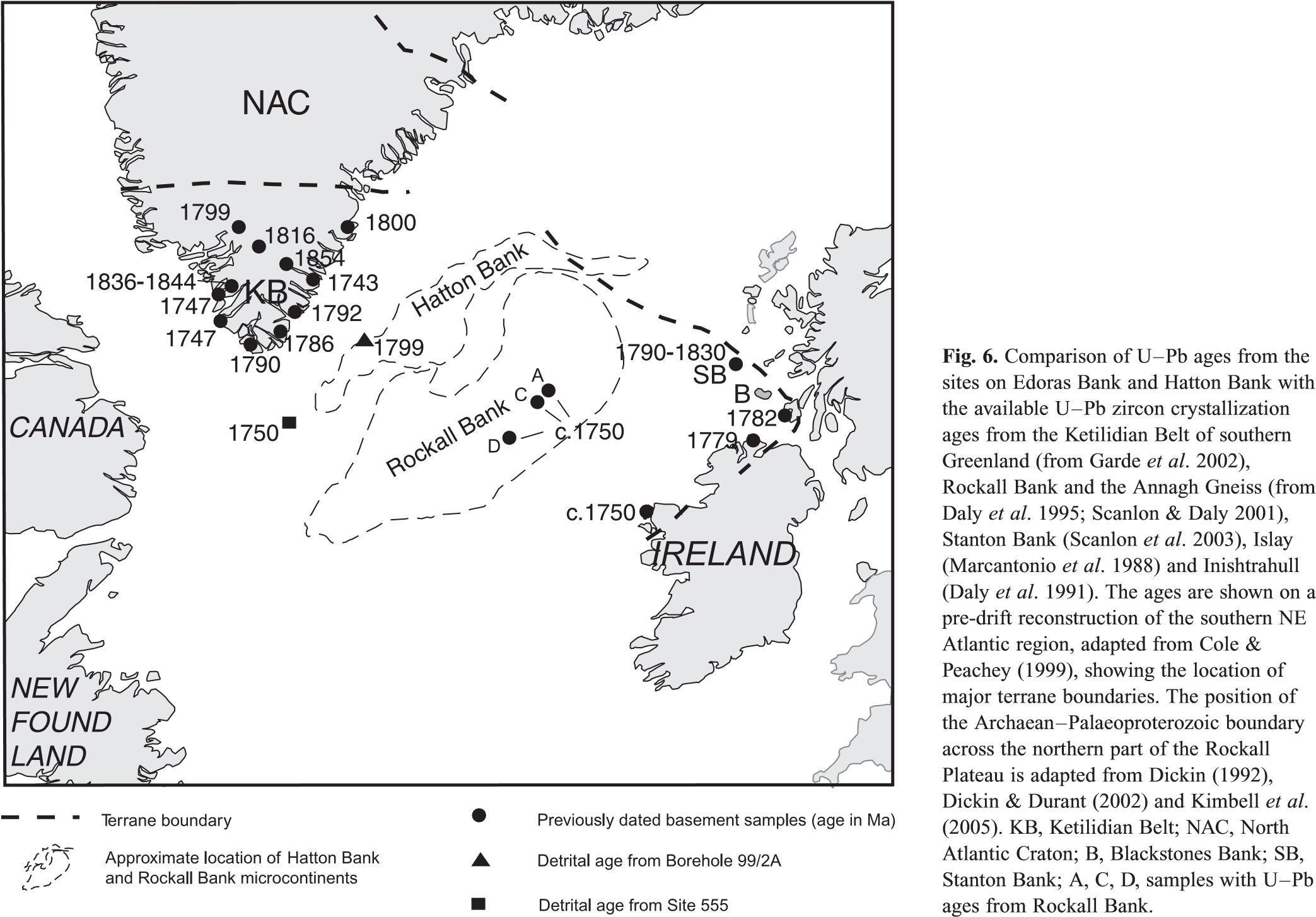


Fig. 5. U–Pb crystallization ages v. initial Hf for BGS borehole 99/2A, 45.65–45.72 m and DSDP Site 555-88-5, 18–25 cm. CHUR, Chondritic Uniform Reservoir; DM, Depleted Mantle.

(Fig. 6) yielded results similar to that of the Annagh Gneiss of north Mayo (Ireland), which has a U–Pb zircon crystallization age of c. 1750 Ma (Daly et al. 1995; Scanlon & Daly 2001).

Dickin (1992) showed a reconstruction of the southern NE Atlantic, drawing attention to the similarity in Sm–Nd TDM ages between the Rockall Bank (TDM ¼ 1.89–2.14), the Ketilidian Belt of southern Greenland (TDM ¼ 1.98–2.18 Ga) and the

Rhinns Complex of Ireland and western Scotland (TDM ¼ 1.91– 1.98 Ga). On the basis of the Sm–Nd isotopic data, he suggested that these areas originally formed a single juvenile Palaeoproterozoic crustal province.

The Ketilidian Belt of southern Greenland, which, on a continental reconstruction, abuts the western margin of the Rockall Plateau (Fig. 6), is characterized by two main phases of granitoid emplacement (Garde et al. 2002). The first phase involved intrusion of the calc-alkaline Julieneha˚b batholith at 1854–1795 Ma, closely followed by high-temperature–lowpressure metamorphism and intrusion of I-type granites at 1795– 1785 Ma. A second phase involving emplacement of rapakivi granite sheets occurred at 1755–1732 Ma. The U–Pb dates acquired from the two samples from Hatton and Edoras banks can be directly matched with the two phases of granite emplacement in the Ketilidian Belt. The c. 1750 Ma date from Edoras Bank matches the age of the rapakivi granites, and the c. 1800 Ma date from Hatton Bank matches the earlier phase.

The Rhinns Complex, which lies to the east of the Rockall Plateau (Fig. 6), comprises basement rocks that crop out on Islay and Colonsay in SW Scotland, and on Inishtrahull and Tor Rocks in NW Ireland (Muir et al. 1994). Gneisses from Islay have TDM ages of 1.93–1.98 Ga and a U–Pb zircon crystallization age of c. 1780 Ma (Marcantonio et al. 1988), closely comparable with gneisses from Inishtrahull, which have TDM ages of 1.91–1.98 Ga and a U–Pb zircon crystallization age of c. 1780 Ma (Daly et al. 1991). The Rhinns Complex therefore represents juvenile Palaeoproterozoic crust with similar characteristics to Rockall Bank and the Ketilidian Belt.

The new U–Pb age data from Edoras and Hatton banks therefore provide a link between the Ketilidian Belt to the SW, Rockall Bank to the east, and the Rhinns Complex to the NE, and support the concept of a juvenile Palaeoproterozoic block across the southern part of the NE Atlantic. However, the Hf isotopic data introduce a degree of complexity to this apparently simple picture. The results from Edoras Bank (Hf(t) values ranging from +1.86 to +6.49, TDM ages ranging from 1964 to 2266 Ma) are consistent with the derivation from a juvenile Palaeoproterozoic block. The Hf(t) values from the Edoras Bank sample are consistent with Nd(t) values reported from the Ketilidian Belt, where metatholeiites have Nd(t) between 5 and +5, granitoids have Nd(t) between 0.6 and +1.6, and norites have Nd(t) between +0.4 and +2.8 (Patchett & Bridgwater 1984; Brown et al. 2003). Following Vervoort & BlichertToft (1999), these Nd(t) values are approximately equivalent to Hf(t) values of between +7.7 and +9.1 for the metatholeiites, between +1.3 and +4.3 for the granitoids, and between +2.1 and +3.5 for the norites. The Nd isotopic data from the Ketilidian Belt have been interpreted as showing that the metatholeiites represent a juvenile mantle contribution, and that the granitoids represent juvenile mantle with a c. 10% contribution from Archaean crust, the latter comprising clastic material that had been transported to the orogenic zone and deposited on oceanic crust (Patchett & Bridgwater 1984).

In contrast, the results from borehole 99/2A indicate that the magmatic source that supplied the zircons to the Hatton Bank site had a large Archaean component (Hf(t) values ranging from +2.97 to 3.30, TDM ages ranging from 2216 to

2643 Ma). According to the geophysical evidence, borehole 99/ 2A lies a considerable distance (c. 230 km) from the proposed Archaean–Palaeoproterozoic boundary, and on pre-drift reconstructions (Fig. 6), Hatton Bank abuts the Ketilidian Belt of southern Greenland. The presence of a large Archaean component is therefore surprising. In the Border Zone of the Ketilidian Belt (the c. 50 km wide zone that lies between the Julienha˚b batholith and the North Atlantic Craton), there is isotopic evidence for extensive Archaean contamination of Ketilidian-age granitoids (Kalsbeek & Taylor 1985), but this disappears rapidly southwards. The combination of a c. 1800 Ma zircon U–Pb crystallization age and a large Archaean Hf component is consistent with derivation from a granitoid with similar characteristics to those of the Border Zone in the Ketilidian Belt, but given the distance from the proposed boundary and the relatively narrow width of the Border Zone, this would require relatively long-distance transport, a possibility that seems unlikely given the depositional setting and the unimodal nature of the detrital zircon population. There are a number of other possible explanations for the anomaly: for example, the interpreted location of the Palaeoproterozoic– Archaean boundary at the northern end of Hatton Bank may be incorrect, or the melt that generated the Hatton Bank igneous body included a large proportion of Archaean-derived sediment. Perhaps more likely is that the distribution of Archaean and Palaeoproterozoic crust is more complex than currently envisaged, especially in view of the recently published evidence for the presence of suspect terranes comprising Palaeoproterozoic juvenile crust within the Lewisian (Kinny et al. 2005). Finally, Dahl-Jensen et al. (1998) interpreted seismic profiles from southern Greenland as showing the presence of an Archaean wedge in the lower crust beneath the Julienha˚b batholith, a model that would suggest that the batholith was emplaced through Archaean crust (Garde et al. 2002). By analogy, it is possible that there is a relatively thick wedge of Archaean crust at depth below Hatton Bank. In the absence of direct basement samples from the area, none of these possibilities can be definitively ruled in or out.

The zircon age data from Hatton and Edoras banks suggest that, following the creation of the Palaeoproterozoic crustal block, the area remained comparatively undisturbed by tectonothermal events until rifting took place during the Mesozoic and Palaeocene, leading to continental break-up and subsequent sea-floor spreading in the Early Eocene. However, the data may have some significance regarding the location of the Grenville Front. Miller et al. (1973) reported a whole-rock Ar–Ar age of c. 1.0 Ga for sample B (Fig. 1) from Rockall Bank, suggesting that the Grenville Front may have passed across the southern part of the Rockall Plateau. The Ketilidian Belt includes minor younger intrusions, such as the Paatusoq syenite, dated at c. 1140 Ma (Grocott et al. 1999). The presence of two Mesoproterozoic zircon grains (c. 1005 Ma and c. 1110 Ma) in the sample from Site 555 suggests that similar, but volumetrically minor, broadly Grenville-age intrusions may be present in the southern part of the Rockall Plateau.

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# References

Blichert-Toft, J. & Albare`de, F. 1997. The Lu–Hf isotope geochemistry of chondrites and the evolution of the mantle–crust system. Earth and Planetary Science Letters, 148, 243–258.

Brown, P.E., Dempster, T.J., Hutton, D.H.W. & Becker, S.M. 2003. Extensional tectonics and mafic plutons in the Ketilidian rapakivi granite suite of South Greenland. Lithos, 67, 1–13.

Cole, J.E. & Peachey, J. 1999. Evidence for pre-Cretaceous rifting in the Rockall Trough: analysis using quantitative plate tectonic modelling. In: Fleet, A.J. & Boldy, S.A.R. (eds) Petroleum Geology of Northwest Europe: Proceedings of the 5th Conference. Geological Society, London, 359–370.

Corfu, F., Hanchar, J.M., Hoskin, P.W.O. & Kinny, P. 2003. Atlas of zircon textures. In: Hanchar, J.M. & Hoskin, P.W.O. (eds) Zircon. Mineralogical Society of America, Reviews in Mineralogy and Geochemistry, 55, 469–500.

Dahl-Jensen, T., Thybo, H., Hopper, J. & Rosing, M. 1998. Crustal structure at the SE Greenland margin from wide-angle and normal incidence seismic data. Tectonophysics, 288, 191–198.

Daly, J.S., Muir, R.J. & Cliff, R.A. 1991. A precise U–Pb age of the Inishtrahull syenitic gneiss, County Donegal, Ireland. Journal of the Geological Society, London, 148, 639–642.

Daly, J.S., Heaman, L.M., Fitzgerald, R.C., Menuge, J.F., Brewer, T.S. & Morton, A.C. 1995. Age and crustal evolution of crystalline basement in western Ireland and Rockall. In: Croker, P.F. & Shannon, P.M. (eds) The Petroleum Geology of Ireland’s Offshore Basins. Geological Society, London, Special Publications, 93, 433–434.

Dickin, A.P. 1992. Evidence for an Early Proterozoic crustal province in the North Atlantic region. Journal of the Geological Society, London, 149, 483–486.

Dickin, A.P. & Durant, G.P. 2002. The Blackstones Bank igneous complex: geochemistry and crustal context of a submerged Tertiary igneous centre in the Scottish Hebrides. Geological Magazine, 139, 199–207.

Garde, A.A., Hamilton, M.A., Chadwick, B., Grocott, J. & McCaffrey, K.J.W. 2002. The Ketilidian orogen of South Greenland: geochronology, tectonics, magmatism, and fore-arc accretion during Palaeoproterozoic oblique convergence. Canadian Journal of Earth Sciences, 39, 765–793.

Goodge, J.W. & Vervoort, J.D. 2006. Origin of Mesoproterozoic A-type granites in Laurentia: Hf isotope evidence. Earth and Planetary Science Letters, 243, 711–731.

Grocott, J., Garde, A.A., Chadwick, B., Cruden, A.R. & Swager, C. 1999. Emplacement of rapakivi granite and syenite by floor depression and roof uplift in the Palaeoproterozoic Ketilidian orogen, South Greenland. Journal of the Geological Society, London, 156, 15–24.

Hartmann, L.A. & Santos, J.O.S. 2004. Predominance of high Th/U, magmatic zircon in Brazilian Shield sandstones. Geology, 32, 73–76.

Hitchen, K. 2004. The geology of the UK Hatton–Rockall margin. Marine and Petroleum Geology, 21, 993–1012.

Hitchen, K., Morton, A.C., Mearns, E.W., Whitehouse, M. & Stoker, M.S. 1997. Geological implications from geochemical and isotopic studies of Late Cretaceous and early Tertiary igneous rocks around the northern Rockall Trough. Journal of the Geological Society, London, 154, 517–521.

Ingersoll, R.V. 1990. Actualistic sandstone petrofacies: discriminating modern and ancient source rocks. Geology, 18, 733–736.

Ingersoll, R.V., Kretchmer, A.G. & Valles, P.K. 1993. The effect of sampling scale on actualistic sandstone petrofacies. Sedimentology, 40, 937–953.

Johnson, H., Ritchie, J.D., Hitchen, K., McInroy, D.B. & Kimbell, G.S. 2005.

Aspects of the Cenozoic deformational history of the northeast Faroe– Shetland Basin, Wyville-Thomson Ridge and Hatton Bank areas. In: Dore´, A.G. & Vining, B. (eds) Petroleum Geology: North-West Europe and Global Perspectives: Proceedings of the 6th Petroleum Geology Conference. Geological Society, London, 993–1007.

Joppen, M. & White, R.S. 1990. The structure and subsidence of Rockall Trough from two-ship seismic experiments. Journal of Geophysical Research, 95, 19821–19837.

Kalsbeek, F. & Taylor, P.N. 1985. Isotopic and chemical variation in granites across a Proterozoic continental margin—the Ketilidian mobile belt of South Greenland. Earth and Planetary Science Letters, 73, 65–80.

Kimbell, G.S., Ritchie, J.D., Johnson, H. & Gatliff, R.W. 2005. Controls on the structure and evolution of the NE Atlantic margin revealed by regional potential field imaging and 3D modelling. In: Dore´, A.G. & Vining, B. (eds) Petroleum Geology: North-West Europe and Global Perspectives: Proceedings of the 6th Petroleum Geology Conference. Geological Society, London, 933– 945.

Kinny, P.D., Friend, C.R.L. & Love, G.J. 2005. Proposal for a terrane-based nomenclature for the Lewisian Gneiss Complex of NW Scotland. Journal of the Geological Society, London, 162, 175–186.

Link, P.K., Fanning, C.M. & Beranek, L.P. 2005. Reliability and longitudinal change of detrital zircon-age data in the Snake River system, Idaho and Wyoming: an example of reproducing the bumpy barcode. Sedimentary Geology, 182, 101–142.

Ludwig, K.R. 1999. User’s manual for Isoplot/Ex, version 2.10, a geochronological toolkit for Microsoft Excel. Berkeley Geochronology Center, Special Publications, 1a.

Ludwig, K.R. 2000. SQUID 1.00, a user’s manual. Berkeley Geochronology

Center, Special Publications, 2.

Marcantonio, F., Dickin, A.P., McNutt, R.H & Heaman, L.M. 1988. A 1800million-year-old Proterozoic gneiss terrane in Islay with implications for the crustal structure and evolution of Britain. Nature, 335, 620–624.

Miller, J.A., Matthews, D.H. & Roberts, D.G. 1973. Rock of Grenville age from Rockall Bank. Nature, Physical Science, 246, 61.

Morton, A.C. 1984. Heavy minerals from Paleogene sediments, Deep Sea Drilling Project Leg 81: their bearing on stratigraphy, sediment provenance and the evolution of the North Atlantic. In: Roberts, D.G., Schnitker, D., et al. (eds) Initial Reports of the Deep Sea Drilling Project, 81. US Government Printing Office, Washington, DC, 653–661.

Morton, A.C. & Taylor, P.N. 1991. Geochemical and isotopic constraints on the nature and age of basement rocks from Rockall Bank, NE Atlantic. Journal of the Geological Society, London, 147, 631–634.

Muir, R.J., Fitches, W.J., Maltman, A.J. & Bentley, M.R. 1994. Precambrian rocks of the southern Inner Hebrides–Malin Sea region: Colonsay, west Islay,

Inishtrahull and Iona. In: Gibbons, W.S. & Harris, A.L. (eds) A Revised Correlation of Precambrian Rocks of the British Isles. Geological Society, London, Special Reports, 22, 54–58.

Paces, J.B. & Miller, J.D. 1993. Precise U–Pb ages of Duluth Complex and related mafic intrusions, northeastern Minnesota: geochronological insights to physical, petrogenetic, paleomagnetic, and tectonomagmatic process associated with the 1.1 Ga Midcontinent Rift System. Journal of Geophysical Research, 98, 13997–14013.

Patchett, J.P. & Bridgwater, D. 1984. Origin of continental crust of 1.9–1.7 Ga age defined by Nd isotopes in the Ketilidian terrain of South Greenland. Contributions to Mineralogy and Petrology, 87, 311–318.

Roberts, D.G. 1975. Marine geology of the Rockall Plateau and Trough. Philosophical Transactions of the Royal Society of London, 278, 447–509.

Roberts, D.G., Ardus, D.A. & Dearnley, R. 1973. Precambrian rocks drilled on Rockall Bank. Nature, Physical Science, 244, 21–23.

Roberts, D.G., Backman, J., Morton, A.C., Murray, J.W. & Keene, J.B. 1984. Evolution of volcanic rifted margins: synthesis of Leg 81 results on the west margin of Rockall Plateau. In: Roberts, D.G., Schnitker, D., et al. (eds) Initial Reports of the Deep Sea Drilling Project, 81. US Government Printing Office, Washington, DC, 883–911.

Roberts, D.G., Ginzburg, A., Nunn, K. & McQuillin, R. 1988. The structure of the Rockall Trough from seismic refraction and wide-angle reflection measurements. Nature, 332, 632–635.

Scanlon, R. & Daly, J.S. 2001. Basement architecture of the rifted Northeast Atlantic margin: evidence from a combined geochronology, fission-track and potential field study. Geological Society of America, Abstracts with Programs, Annual Meeting 2001, paper 64-0.

Scanlon, R.P., Daly, J.S. & Whitehouse, M.J. 2003. The c. 1.8 Ga Stanton Banks Terrane, offshore Western Scotland, a large juvenile Palaeoproterozoic crustal block within the accretionary Lewisian complex. Geophysical Research Abstracts, 5, 13248.

Shipboard Scientific Party 1984. Site 555. In: Roberts, D.G., Schnitker, D., et al. (eds) Initial Reports of the Deep Sea Drilling Project, 81. US Government Printing Office, Washington, DC, 277–399.

So¨derlund, U., Patchett, P.J., Vervoort, J.D. & Isachsen, C.E. 2004. The 176Lu decay constant determined by Lu–Hf and U–Pb systematics of Precambrian mafic intrusions. Earth and Planetary Science Letters, 219, 311–324.

Vervoort, J.D. & Blichert-Toft, J. 1999. Evolution of the depleted mantle: Hf isotope evidence from juvenile rocks through time. Geochimica et Cosmochimica Acta, 63, 533–556.

Williams, I.S. 1998. U–Th–Pb geochronology by ion microprobe. In: McKibben,

M.A., Shanks, W.C., III & Ridley, W.I. (eds) Applications of Microanalytical Techniques to Understanding Mineralising Processes. Society of Economic Geologists, Reviews in Economic Geology, 7, 1–35.

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