# 143783: sandstone, Mu Hills

## *(Carnegie Formation, Amadeus Basin, Centralian Superbasin)*

## Location and sampling

Macdonald (SG 52-10), Emery (4650)
MGA Zone 52, 473709E 7354988N

Sampled on 3 June 2009

This sample was collected from a strike ridge of sandstone within the Mu Hills, about 26.4 km west of the Western Australia – Northern Territory border, 9.0 km northeast of the Sir Frederick Range, and 0.03 km east of the Sandy Blight Junction Track.

## Tectonic unit/relations

The unit sampled is a clastic, sand-dominated, redbed sequence, averaging about 1200 m thick, and assigned to the Carnegie Formation of the western Amadeus Basin (Wells et al., 1964). Cross-bedding and ripple-marks indicate a shallow-water environment, probably deltaic or paralic. In the north, the Carnegie Formation overlies the Julie Formation, probably conformably, although in the south it unconformably overlies much older units such as the Bitter Springs Formation (Haines et al., 2010, 2012). The Carnegie Formation is overlain with uncertain relationship by the Ellis Sandstone or Sir Frederick Conglomerate. Although originally considered to correlate with Neoproterozoic glacigene units (Wells et al., 1964), it is now inferred to be of late Ediacaran age and to correlate with the lower Arumbera Sandstone of the eastern Amadeus Basin and lower Winnall beds of the southern Amadeus Basin in the Northern Territory (Haines et al., 2012).

## Petrographic description

The sample is a quartz-rich, fine- to medium-grained sandstone, consisting of about 60–70% single-crystal quartz grains, 20–25% lithic grains, 5% pore spaces, and accessory tourmaline, zircon, and interstitial clay. Lithic grains are variably rich in microcrystalline quartz, sericite, clays (possibly including kaolinite), and hematite or limonite. Quartz grains vary from <0.05 mm (silt size) to 0.4 mm (fine to medium sand size) and are mostly angular, with lithic grains representing mainly reworked sedimentary rocks, with only rare grains derived from metasedimentary or volcanic rocks.

## Zircon morphology

Zircons isolated from this sample are colourless to dark brown, and range from anhedral and strongly rounded to subhedral. The crystals are up to 250 μm long, and equant to slightly elongate, with aspect ratios up to 5:1. Some crystals have pitted outer surfaces and, in cathodoluminescence (CL) images, many exhibit concentric zoning truncated at grain edges, features consistent with abrasion during sedimentary transport. A CL image of representative zircons is shown in Figure 1.

## Analytical details

This sample was analysed on 19–21 May and 3 June, 2011, using SHRIMP-B. Analyses 1.1 to 50.1 (spot numbers 1–50) were obtained during the first session, together with 24 analyses of the BR266 standard, which indicated an external spot-to-spot (reproducibility) uncertainty of 1.15% (1σ) and a $^{238}U/^{206}Pb^*$ calibration uncertainty of 0.25% (1σ). Analyses 51.1 to 60.1 (spot numbers 51–60) were obtained during the second session, together with eight analyses of the BR266 standard, which indicated an external spot-to-spot (reproducibility) uncertainty of 0.55% (1σ) and a $^{238}U/^{206}Pb^*$ calibration uncertainty of 0.25% (1σ). Calibration uncertainties are included in the errors of $^{238}U/^{206}Pb^*$ ratios and dates listed in Table 1. Isotopic mass fractionation of $^{207}Pb/^{206}Pb$ ratios during session 1 was corrected by reference to the OGC1 standard; measured ratios were increased by 0.81%. Common-Pb corrections were applied to all analyses using contemporaneous isotopic compositions determined according to the model of Stacey and Kramers (1975). Dates from analyses for which 204-corrected $^{238}U/^{206}Pb^*$ ratios indicate ages <1300 Ma are based on 207-corrected $^{238}U/^{206}Pb^*$ ratios; those >1300 Ma are based on 204-corrected $^{207}Pb^*/^{206}Pb^*$ ratios.

## Results

Sixty analyses were obtained from 60 zircons. Results are listed in Table 1, and shown in a concordia diagram (Fig. 2), and a probability density diagram (Fig. 3).

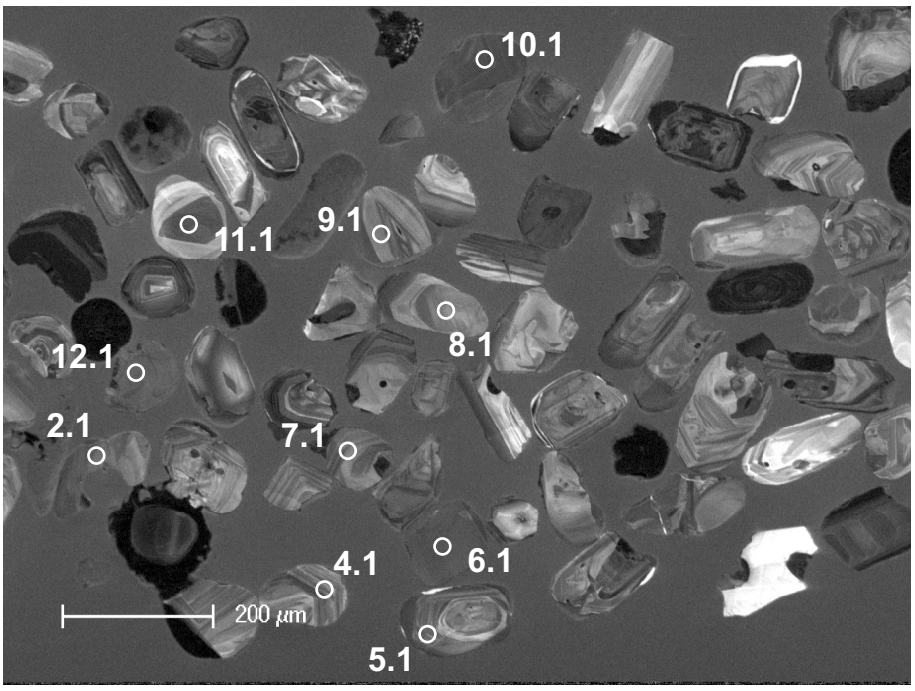


**Figure 1.** **Cathodoluminescence image of representative zircons from sample 143783: sandstone, Mu Hills. Numbered circles indicate the approximate locations of analysis sites.**

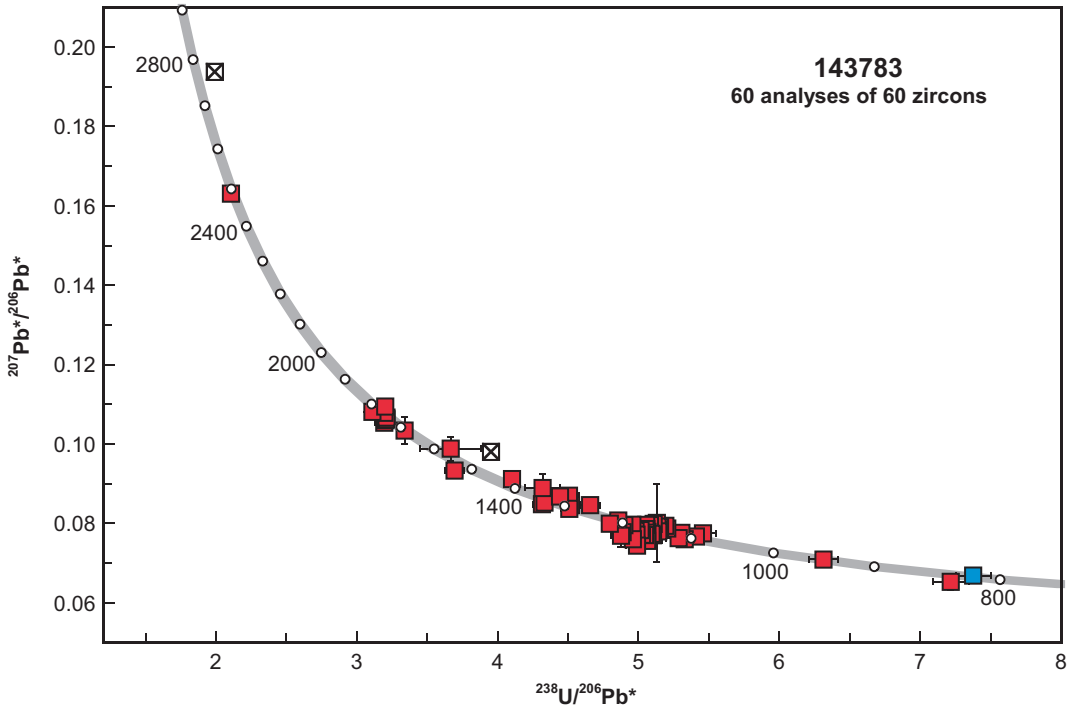


**Figure 2.** **U–Pb analytical data for zircons from sample 143783: sandstone, Mu Hills. Data are corrected for common Pb using measured $^{204}Pb/^{206}Pb$. Blue square indicates Group Y (youngest detrital zircon); red squares indicate Group S (older detrital zircons); crossed squares indicate Group D (date >1300 Ma and discordance >5%).**

**Table 1. Ion microprobe analytical results for zircons from sample 143783: sandstone, Mu Hills**

| Group ID | Spot no. | Grain. spot | $^{238}U$ (ppm) | $^{232}Th$ (ppm) | $\frac{^{232}Th}{^{238}U}$ | $f204$ (%) | $^{238}U/^{206}Pb$ ± 1σ | | $^{207}Pb/^{206}Pb$ ± 1σ | | $^{238}U/^{206}Pb^*$ ± 1σ | | $^{207}Pb^*/^{206}Pb^*$ ± 1σ | | $^{238}U/^{206}Pb^*$ date (Ma) ±1σ | | $^{207}Pb^*/^{206}Pb^*$ date (Ma) ±1σ | | Disc. (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Y | 1 | 1.1 | 119 | 122 | 1.06 | 0.115 | 7.367 | 0.124 | 0.06805 | 0.00211 | 7.375 | 0.124 | 0.06708 | 0.00221 | 820 | 13 | 840 | 69 | 2.4 |
| S | 21 | 21.1 | 97 | 103 | 1.09 | 0.506 | 7.181 | 0.128 | 0.06972 | 0.00217 | 7.218 | 0.129 | 0.06551 | 0.00269 | 836 | 14 | 791 | 86 | -5.7 |
| S | 7 | 7.1 | 128 | 45 | 0.36 | 0.043 | 6.311 | 0.102 | 0.07153 | 0.00206 | 6.313 | 0.102 | 0.07117 | 0.00209 | 948 | 14 | 962 | 60 | 1.5 |
| S | 8 | 8.1 | 112 | 33 | 0.30 | -0.127 | 5.465 | 0.091 | 0.07667 | 0.00208 | 5.458 | 0.091 | 0.07774 | 0.00217 | 1084 | 17 | 1140 | 55 | 4.9 |
| S | 4 | 4.1 | 151 | 145 | 1.00 | 0.172 | 5.399 | 0.086 | 0.07843 | 0.00205 | 5.408 | 0.086 | 0.07697 | 0.00215 | 1094 | 16 | 1120 | 56 | 2.3 |
| S | 10 | 10.1 | 268 | 279 | 1.07 | 0.095 | 5.323 | 0.075 | 0.07711 | 0.00195 | 5.328 | 0.075 | 0.07630 | 0.00197 | 1109 | 15 | 1103 | 52 | -0.5 |
| S | 17 | 17.1 | 377 | 205 | 0.56 | -0.022 | 5.305 | 0.072 | 0.07769 | 0.00192 | 5.304 | 0.072 | 0.07788 | 0.00193 | 1113 | 14 | 1144 | 49 | 2.7 |
| S | 3 | 3.1 | 98 | 84 | 0.89 | 0.307 | 5.268 | 0.090 | 0.07914 | 0.00209 | 5.285 | 0.090 | 0.07654 | 0.00231 | 1117 | 18 | 1109 | 60 | -0.7 |
| S | 23 | 23.1 | 110 | 84 | 0.79 | 0.044 | 5.202 | 0.089 | 0.07939 | 0.00209 | 5.204 | 0.089 | 0.07902 | 0.00213 | 1133 | 18 | 1173 | 53 | 3.4 |
| S | 52 | 52.1 | 120 | 123 | 1.05 | 0.044 | 5.188 | 0.067 | 0.07976 | 0.00096 | 5.191 | 0.067 | 0.07938 | 0.00104 | 1136 | 14 | 1182 | 26 | 3.9 |
| S | 26 | 26.1 | 211 | 445 | 2.18 | -0.042 | 5.155 | 0.075 | 0.07896 | 0.00198 | 5.153 | 0.075 | 0.07932 | 0.00199 | 1143 | 16 | 1180 | 50 | 3.1 |
| S | 9 | 9.1 | 127 | 140 | 1.14 | 0.069 | 5.139 | 0.083 | 0.07929 | 0.00205 | 5.143 | 0.083 | 0.07870 | 0.00209 | 1145 | 17 | 1165 | 53 | 1.7 |
| S | 48 | 48.1 | 352 | 317 | 0.93 | 0.013 | 5.140 | 0.070 | 0.07840 | 0.00193 | 5.140 | 0.070 | 0.07829 | 0.00194 | 1146 | 14 | 1154 | 49 | 0.7 |
| S | 18 | 18.1 | 58 | 74 | 1.33 | -0.075 | 5.139 | 0.103 | 0.07887 | 0.00224 | 5.135 | 0.103 | 0.07950 | 0.00233 | 1147 | 21 | 1185 | 58 | 3.2 |
| S | 57 | 57.1 | 47 | 79 | 1.73 | 0.190 | 5.120 | 0.096 | 0.08169 | 0.00973 | 5.130 | 0.096 | 0.08008 | 0.00981 | 1148 | 20 | 1199 | 242 | 4.3 |
| S | 30 | 30.1 | 33 | 28 | 0.86 | 0.149 | 5.101 | 0.126 | 0.08142 | 0.00258 | 5.108 | 0.126 | 0.08015 | 0.00288 | 1152 | 27 | 1201 | 71 | 4.1 |
| S | 43 | 43.1 | 143 | 131 | 0.95 | 0.033 | 5.100 | 0.080 | 0.07753 | 0.00203 | 5.102 | 0.080 | 0.07726 | 0.00205 | 1154 | 17 | 1128 | 53 | -2.3 |
| S | 13 | 13.1 | 40 | 38 | 0.99 | 0.104 | 5.086 | 0.115 | 0.07855 | 0.00236 | 5.092 | 0.115 | 0.07767 | 0.00252 | 1156 | 24 | 1138 | 65 | -1.6 |
| S | 55 | 55.1 | 83 | 67 | 0.83 | -0.130 | 5.089 | 0.077 | 0.07842 | 0.00116 | 5.083 | 0.077 | 0.07952 | 0.00139 | 1158 | 16 | 1185 | 35 | 2.3 |
| S | 46 | 46.1 | 109 | 141 | 1.34 | 0.045 | 5.061 | 0.085 | 0.07853 | 0.00209 | 5.064 | 0.085 | 0.07815 | 0.00213 | 1162 | 18 | 1151 | 54 | -1.0 |
| S | 27 | 27.1 | 68 | 91 | 1.39 | 0.462 | 5.037 | 0.108 | 0.07977 | 0.00220 | 5.061 | 0.108 | 0.07586 | 0.00265 | 1162 | 23 | 1091 | 70 | -6.5 |
| S | 58 | 58.1 | 97 | 161 | 1.72 | 0.102 | 5.051 | 0.071 | 0.07940 | 0.00103 | 5.056 | 0.071 | 0.07853 | 0.00120 | 1163 | 15 | 1160 | 30 | -0.3 |
| S | 32 | 32.1 | 191 | 241 | 1.31 | 0.000 | 5.055 | 0.076 | 0.07798 | 0.00200 | 5.055 | 0.076 | 0.07798 | 0.00200 | 1164 | 16 | 1146 | 51 | -1.6 |
| S | 25 | 25.1 | 141 | 152 | 1.11 | 0.000 | 5.054 | 0.082 | 0.07995 | 0.00206 | 5.054 | 0.082 | 0.07995 | 0.00206 | 1164 | 17 | 1196 | 51 | 2.7 |
| S | 34 | 34.1 | 129 | 143 | 1.15 | 0.000 | 5.050 | 0.081 | 0.07878 | 0.00204 | 5.050 | 0.081 | 0.07878 | 0.00204 | 1165 | 17 | 1167 | 51 | 0.2 |
| S | 35 | 35.1 | 164 | 239 | 1.50 | 0.108 | 5.040 | 0.077 | 0.07824 | 0.00201 | 5.046 | 0.077 | 0.07733 | 0.00206 | 1166 | 16 | 1130 | 53 | -3.2 |
| S | 14 | 14.1 | 146 | 141 | 1.00 | 0.061 | 5.022 | 0.094 | 0.07792 | 0.00202 | 5.025 | 0.094 | 0.07740 | 0.00206 | 1170 | 20 | 1132 | 53 | -3.4 |
| S | 51 | 51.1 | 162 | 287 | 1.83 | 0.090 | 5.011 | 0.057 | 0.07902 | 0.00080 | 5.015 | 0.058 | 0.07827 | 0.00091 | 1172 | 12 | 1154 | 23 | -1.6 |
| S | 37 | 37.1 | 173 | 173 | 1.04 | 0.081 | 4.985 | 0.076 | 0.07533 | 0.00208 | 4.989 | 0.076 | 0.07465 | 0.00211 | 1178 | 17 | 1059 | 57 | -11.2 |
| S | 38 | 38.1 | 110 | 124 | 1.16 | 0.041 | 4.984 | 0.083 | 0.07778 | 0.00207 | 4.986 | 0.083 | 0.07743 | 0.00210 | 1178 | 18 | 1132 | 54 | -4.1 |
| S | 53 | 53.1 | 136 | 113 | 0.86 | 0.106 | 4.974 | 0.061 | 0.07907 | 0.00086 | 4.979 | 0.061 | 0.07817 | 0.00100 | 1180 | 13 | 1151 | 25 | -2.5 |
| S | 22 | 22.1 | 125 | 154 | 1.27 | 0.070 | 4.956 | 0.081 | 0.07692 | 0.00204 | 4.960 | 0.081 | 0.07632 | 0.00208 | 1184 | 18 | 1104 | 55 | -7.2 |
| S | 2 | 2.1 | 188 | 122 | 0.67 | -0.024 | 4.957 | 0.074 | 0.07978 | 0.00199 | 4.956 | 0.074 | 0.07999 | 0.00200 | 1185 | 16 | 1197 | 49 | 1.0 |
| S | 39 | 39.1 | 87 | 80 | 0.95 | 0.000 | 4.899 | 0.086 | 0.07985 | 0.00213 | 4.899 | 0.086 | 0.07985 | 0.00213 | 1197 | 20 | 1193 | 53 | -0.3 |
| S | 33 | 33.1 | 246 | 136 | 0.57 | 0.057 | 4.885 | 0.070 | 0.07858 | 0.00197 | 4.887 | 0.070 | 0.07810 | 0.00198 | 1200 | 16 | 1149 | 50 | -4.4 |
| S | 50 | 50.1 | 195 | 154 | 0.82 | 0.069 | 4.873 | 0.072 | 0.07771 | 0.00343 | 4.876 | 0.072 | 0.07712 | 0.00344 | 1202 | 16 | 1124 | 89 | -6.9 |

**Table 1. continued**

| Group ID | Spot no. | Grain. spot | $^{238}U$ (ppm) | $^{232}Th$ (ppm) | $\frac{^{232}Th}{^{238}U}$ | ƒ204 (%) | $^{238}U/^{206}Pb$ ± 1σ | | $^{207}Pb/^{206}Pb$ ± 1σ | | $^{238}U/^{206}Pb^*$ ± 1σ | | $^{207}Pb^*/^{206}Pb^*$ ± 1σ | | $^{238}U/^{206}Pb^*$ date (Ma) ±1σ | | $^{207}Pb^*/^{206}Pb^*$ date (Ma) ±1σ | | Disc. (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| S | 11 | 11.1 | 259 | 63 | 0.25 | 0.016 | 4.856 | 0.069 | 0.08119 | 0.00196 | 4.857 | 0.069 | 0.08105 | 0.00196 | 1207 | 16 | 1223 | 48 | 1.3 |
| S | 54 | 54.1 | 144 | 274 | 1.97 | -0.032 | 4.799 | 0.058 | 0.07967 | 0.00081 | 4.797 | 0.058 | 0.07993 | 0.00086 | 1221 | 13 | 1195 | 21 | -2.1 |
| S | 40 | 40.1 | 157 | 102 | 0.67 | 0.055 | 4.654 | 0.073 | 0.08537 | 0.00203 | 4.656 | 0.073 | 0.08490 | 0.00205 | 1254 | 18 | 1313 | 47 | 4.5 |
| S | 12 | 12.1 | 195 | 61 | 0.33 | -0.039 | 4.521 | 0.067 | 0.08465 | 0.00198 | 4.520 | 0.067 | 0.08498 | 0.00199 | 1289 | 18 | 1315 | 46 | 2.0 |
| S | 44 | 44.1 | 455 | 550 | 1.25 | 0.009 | 4.507 | 0.060 | 0.08404 | 0.00192 | 4.508 | 0.060 | 0.08396 | 0.00192 | 1292 | 16 | 1292 | 45 | 0.0 |
| S | 28 | 28.1 | 126 | 169 | 1.39 | -0.060 | 4.510 | 0.073 | 0.08678 | 0.00204 | 4.507 | 0.073 | 0.08729 | 0.00208 | 1292 | 19 | 1367 | 46 | 5.5 |
| S | 56 | 56.1 | 100 | 131 | 1.35 | -0.041 | 4.445 | 0.061 | 0.08641 | 0.00099 | 4.443 | 0.061 | 0.08676 | 0.00105 | 1309 | 17 | 1355 | 23 | 3.4 |
| S | 60 | 60.1 | 176 | 141 | 0.83 | 0.023 | 4.332 | 0.049 | 0.08542 | 0.00073 | 4.333 | 0.049 | 0.08522 | 0.00076 | 1339 | 14 | 1321 | 17 | -1.4 |
| S | 19 | 19.1 | 23 | 38 | 1.75 | 0.463 | 4.300 | 0.122 | 0.09326 | 0.00317 | 4.320 | 0.123 | 0.08927 | 0.00392 | 1342 | 35 | 1410 | 84 | 4.8 |
| S | 45 | 45.1 | 272 | 160 | 0.61 | 0.000 | 4.314 | 0.061 | 0.08513 | 0.00195 | 4.314 | 0.061 | 0.08513 | 0.00195 | 1344 | 17 | 1318 | 44 | -2.0 |
| S | 20 | 20.1 | 325 | 185 | 0.59 | 0.033 | 4.102 | 0.057 | 0.09178 | 0.00194 | 4.103 | 0.057 | 0.09149 | 0.00195 | 1406 | 18 | 1457 | 40 | 3.5 |
| S | 36 | 36.1 | 72 | 91 | 1.30 | 0.090 | 3.692 | 0.069 | 0.09445 | 0.00217 | 3.695 | 0.069 | 0.09368 | 0.00224 | 1544 | 26 | 1502 | 45 | -2.8 |
| S | 5 | 5.1 | 147 | 118 | 0.83 | 0.000 | 3.666 | 0.217 | 0.09921 | 0.00356 | 3.666 | 0.217 | 0.09921 | 0.00356 | 1555 | 86 | 1609 | 67 | 3.4 |
| S | 59 | 59.1 | 205 | 283 | 1.42 | 0.000 | 3.340 | 0.035 | 0.10339 | 0.00346 | 3.340 | 0.035 | 0.10339 | 0.00346 | 1689 | 16 | 1686 | 62 | -0.2 |
| S | 6 | 6.1 | 183 | 156 | 0.88 | 0.078 | 3.209 | 0.048 | 0.10730 | 0.00197 | 3.211 | 0.048 | 0.10662 | 0.00199 | 1748 | 23 | 1742 | 34 | -0.3 |
| S | 31 | 31.1 | 141 | 82 | 0.60 | 0.018 | 3.209 | 0.050 | 0.10720 | 0.00201 | 3.210 | 0.050 | 0.10705 | 0.00202 | 1748 | 24 | 1750 | 34 | 0.1 |
| S | 41 | 41.1 | 161 | 133 | 0.86 | 0.017 | 3.202 | 0.049 | 0.10657 | 0.00200 | 3.202 | 0.049 | 0.10642 | 0.00201 | 1752 | 24 | 1739 | 35 | -0.7 |
| S | 16 | 16.1 | 107 | 113 | 1.09 | 0.000 | 3.201 | 0.053 | 0.10983 | 0.00205 | 3.201 | 0.053 | 0.10983 | 0.00205 | 1752 | 26 | 1797 | 34 | 2.5 |
| S | 24 | 24.1 | 202 | 282 | 1.44 | 0.038 | 3.196 | 0.047 | 0.10861 | 0.00203 | 3.197 | 0.047 | 0.10827 | 0.00204 | 1754 | 23 | 1771 | 34 | 1.0 |
| S | 42 | 42.1 | 59 | 80 | 1.40 | 0.000 | 3.195 | 0.064 | 0.10577 | 0.00222 | 3.195 | 0.064 | 0.10577 | 0.00222 | 1755 | 31 | 1728 | 39 | -1.6 |
| S | 47 | 47.1 | 88 | 66 | 0.77 | 0.058 | 3.109 | 0.055 | 0.10902 | 0.00211 | 3.111 | 0.055 | 0.10851 | 0.00214 | 1797 | 28 | 1775 | 36 | -1.2 |
| S | 49 | 49.1 | 111 | 173 | 1.61 | 0.040 | 2.106 | 0.034 | 0.16406 | 0.00207 | 2.107 | 0.034 | 0.16371 | 0.00208 | 2504 | 34 | 2494 | 21 | -0.4 |
| D | 29 | 29.1 | 287 | 137 | 0.49 | 0.012 | 3.953 | 0.058 | 0.09848 | 0.00196 | 3.953 | 0.058 | 0.09838 | 0.00196 | 1454 | 19 | 1594 | 37 | 8.8 |
| D | 15 | 15.1 | 194 | 88 | 0.47 | 0.095 | 1.990 | 0.029 | 0.19536 | 0.00201 | 1.992 | 0.029 | 0.19451 | 0.00202 | 2622 | 32 | 2781 | 17 | 5.7 |

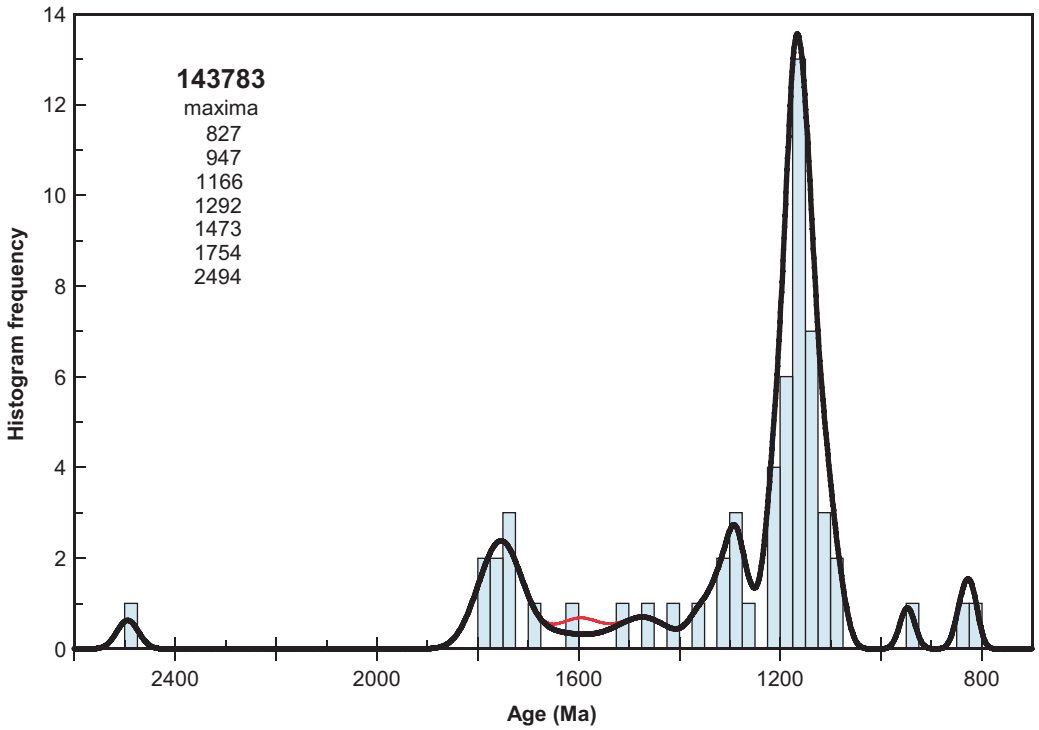


**Figure 3. Probability density diagram and histogram for sample 143783: sandstone, Mu Hills. Dates <1300 Ma are based on 207-corrected $^{238}U/^{206}Pb^*$ ratios. Thick curve, maxima values, and frequency histogram (bin width 25 Ma) include only accepted data (58 analyses of 58 zircons). Thin curve includes all data (60 analyses of 60 zircons).**

## Interpretation

Most analyses are concordant to slightly discordant (Fig. 3). Two analyses >1300 Ma are >5% discordant. The dates obtained from these two analyses (Group D; Table 1) are unreliable, and are considered not to be geologically significant. The remaining 58 analyses can be divided into two groups, based on their $^{207}Pb^*/^{206}Pb^*$ and $^{238}U/^{206}Pb^*$ ratios.

Group Y comprises one analysis (Table 1), which yields a 207-corrected $^{238}U/^{206}Pb^*$ date of 819 ± 13 Ma (1σ).

Group S comprises 57 analyses (Table 1), which yield $^{207}Pb^*/^{206}Pb^*$ or $^{238}U/^{206}Pb^*$ dates of 2494–838 Ma.

It is possible that all of the analyses are of unmodified detrital zircons, in which case the date of 819 ± 13 Ma (1σ) for the single analysis in Group Y represents a maximum depositional age for the sandstone. A more conservative estimate of the maximum depositional age can be based on the weighted mean 207-corrected $^{238}U/^{206}Pb^*$ date of 1124 ± 13 Ma (MSWD = 1.6) for the youngest coherent group of 13 analyses in Group S.

The data for Group S indicate significant age components at c. 1754, 1292, and 1166 Ma (Fig. 3). These are interpreted as the ages of zircon-crystallizing rocks in the detrital source region(s), or as the ages of detrital components within sediments that have been reworked into this rock.

## References

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## Recommended reference for this publication

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