附表1 海德乌拉辉绿岩LA⁃ICP⁃MS锆石U⁃Pb同位素分析数据

Table 1 LA⁃ICP⁃MS zircon U⁃Pb dating analysis data of the Haidewula diabase

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | Th | U | Th/U | 测试结果 |  |  |  |  |  | 年龄(Ma) |  |  |  |  |  |
|  | (ppm) | (ppm) |  | *207Pb/206Pb* | 1σ | *207Pb/235U* | 1σ | *206Pb/238U* | 1σ | *207Pb/206Pb* | 1σ | *207Pb/235U* | 1σ | *206Pb/238U* | 1σ |
| HD⁃1 | 112  | 86  | 1.30  | 0.0521  | 0.0024  | 0.2888  | 0.0132  | 0.0404  | 0.0006  | 291 | 79 | 258 | 10 | 255 | 3 |
| HD⁃2 | 1800  | 1115  | 1.62  | 0.0536  | 0.0015  | 0.3773  | 0.0103  | 0.0510  | 0.0006  | 355 | 42 | 325 | 8 | 321 | 3 |
| HD⁃3 | 231  | 200  | 1.16  | 0.0512  | 0.0031  | 0.2956  | 0.0169  | 0.0422  | 0.0006  | 252 | 106 | 263 | 13 | 266 | 4 |
| HD⁃4 | 1162  | 1005  | 1.16  | 0.0595  | 0.0019  | 0.3095  | 0.0155  | 0.0366  | 0.0006  | 587 | 78 | 274 | 12 | 232 | 4 |
| HD⁃5 | 1407  | 1041  | 1.35  | 0.0548  | 0.0023  | 0.2887  | 0.0108  | 0.0384  | 0.0005  | 404 | 59 | 258 | 9 | 243 | 3 |
| HD⁃6 | 1007  | 501  | 2.01  | 0.0536  | 0.0015  | 0.2928  | 0.0083  | 0.0396  | 0.0005  | 356 | 40 | 261 | 7 | 251 | 3 |
| HD⁃7 | 467  | 342  | 1.36  | 0.0518  | 0.0021  | 0.2864  | 0.0115  | 0.0402  | 0.0005  | 275 | 71 | 256 | 9 | 254 | 3 |
| HD⁃8 | 1168  | 794  | 1.47  | 0.0617  | 0.0028  | 0.3133  | 0.0151  | 0.0368  | 0.0006  | 663 | 74 | 277 | 12 | 233 | 4 |
| HD⁃9 | 133  | 142  | 0.94  | 0.0563  | 0.0023  | 0.3076  | 0.0149  | 0.0393  | 0.0007  | 465 | 75 | 272 | 12 | 248 | 4 |
| HD⁃10 | 159  | 155  | 1.03  | 0.0508  | 0.0011  | 0.2782  | 0.0063  | 0.0396  | 0.0004  | 231 | 33 | 249 | 5 | 250 | 2 |
| HD⁃11 | 192  | 187  | 1.03  | 0.0519  | 0.0017  | 0.2692  | 0.0095  | 0.0374  | 0.0004  | 281 | 61 | 242 | 8 | 237 | 2 |
| HD⁃12 | 180  | 183  | 0.98  | 0.0556  | 0.0015  | 0.2895  | 0.0096  | 0.0375  | 0.0004  | 436 | 55 | 258 | 8 | 237 | 2 |
| HD⁃13 | 395  | 292  | 1.35  | 0.0519  | 0.0019  | 0.2670  | 0.0109  | 0.0371  | 0.0006  | 283 | 66 | 240 | 9 | 235 | 3 |
| HD⁃14 | 147  | 146  | 1.00  | 0.0553  | 0.0013  | 0.3295  | 0.0085  | 0.0430  | 0.0004  | 300 | 87 | 273 | 9 | 270 | 2 |
| HD⁃15 | 159  | 153  | 1.04  | 0.0516  | 0.0022  | 0.2720  | 0.0117  | 0.0382  | 0.0005  | 269 | 74 | 244 | 9 | 242 | 3 |
| HD⁃16 | 1184  | 724  | 1.63  | 0.0486  | 0.0017  | 0.2754  | 0.0093  | 0.0413  | 0.0004  | 128 | 59 | 247 | 7 | 261 | 3 |
| HD⁃17 | 1187  | 791  | 1.50  | 0.0502  | 0.0007  | 0.2625  | 0.0040  | 0.0378  | 0.0003  | 206 | 22 | 237 | 3 | 239 | 2 |
| HD⁃18 | 81  | 144  | 0.57  | 0.0508  | 0.0007  | 0.2644  | 0.0041  | 0.0377  | 0.0004  | 230 | 19 | 238 | 3 | 238 | 2 |
| HD⁃19 | 220  | 166  | 1.32  | 0.0591  | 0.0021  | 0.3113  | 0.0110  | 0.0383  | 0.0006  | 571 | 49 | 275 | 9 | 242 | 4 |
| HD⁃20 | 69  | 85  | 0.82  | 0.0512  | 0.0010  | 0.2792  | 0.0054  | 0.0394  | 0.0003  | 251 | 29 | 250 | 4 | 249 | 2 |
| HD⁃21 | 67  | 83  | 0.81  | 0.0512  | 0.0014  | 0.2810  | 0.0081  | 0.0397  | 0.0005  | 252 | 45 | 251 | 6 | 251 | 3 |
| HD⁃22 | 39  | 48  | 0.82  | 0.0511  | 0.0014  | 0.2770  | 0.0082  | 0.0392  | 0.0005  | 246 | 45 | 248 | 7 | 248 | 3 |
| HD⁃23 | 121  | 119  | 1.02  | 0.0521  | 0.0011  | 0.2930  | 0.0060  | 0.0407  | 0.0004  | 292 | 31 | 261 | 5 | 257 | 2 |
| HD⁃24 | 240  | 203  | 1.18  | 0.0517  | 0.0044  | 0.2650  | 0.0209  | 0.0380  | 0.0008  | 273 | 140 | 239 | 17 | 240 | 5 |

附表2海德乌拉辉绿岩主量元素(%)和微量元素(ppm)分析结果

Table 2 Major (%) and trace element (ppm) contents of the Haidewula diabase.

|  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 样品 | HD20⁃51 | zk105⁃4 | zk105⁃3 | HD20⁃47 | HD⁃4 | zk105⁃1 | HD20⁃75 | SH⁃01 | SH⁃02 | SH⁃03 | SH⁃04 | SH⁃05 |
| SiO2 | 46.6  | 47.5  | 48.7  | 48.9  | 49.9  | 50.0  | 50.6  | 51.9  | 50.9  | 51.2  | 51.1  | 51.0  |
| TiO2 | 2.46  | 2.43  | 2.28  | 2.19  | 2.47  | 2.23  | 1.79  | 1.75  | 1.85  | 1.87  | 2.05  | 2.04  |
| Al2O3 | 16.8  | 16.0  | 15.1  | 14.7  | 16.9  | 15.0  | 14.9  | 15.3  | 14.7  | 14.7  | 15.9  | 15.8  |
| Fe2O3T | 11.2  | 12.3  | 12.2  | 10.6  | 9.78  | 11.0  | 8.88  | 10.1  | 11.0  | 11.1  | 9.72  | 9.75  |
| MnO | 0.16  | 0.13  | 0.15  | 0.18  | 0.09  | 0.15  | 0.16  | 0.12  | 0.15  | 0.15  | 0.13  | 0.13  |
| MgO | 5.06  | 4.74  | 5.11  | 3.46  | 5.23  | 5.34  | 5.31  | 4.73  | 6.30  | 6.34  | 2.77  | 2.76  |
| CaO | 5.27  | 4.69  | 3.96  | 6.52  | 2.73  | 4.20  | 5.38  | 4.34  | 3.93  | 3.96  | 4.47  | 4.47  |
| Na2O | 4.48  | 5.12  | 3.76  | 4.67  | 5.25  | 3.63  | 4.86  | 4.31  | 3.74  | 3.74  | 6.41  | 6.37  |
| K2O | 1.62  | 1.09  | 2.82  | 1.55  | 2.29  | 3.32  | 1.72  | 2.39  | 1.86  | 1.87  | 1.72  | 1.70  |
| P2O5 | 0.73  | 0.79  | 0.68  | 0.73  | 0.82  | 0.68  | 0.54  | 0.51  | 0.58  | 0.58  | 0.64  | 0.65  |
| LOI | 5.06  | 4.61  | 4.56  | 6.02  | 4.44  | 4.40  | 5.94  | 4.39  | 3.78  | 3.90  | 4.61  | 4.72  |
| 总量 | 99.37  | 99.34  | 99.30  | 99.49  | 99.84  | 99.95  | 100.14  | 99.81  | 98.80  | 99.47  | 99.48  | 99.36  |
| Na2O/K2O | 2.77 | 4.70 | 1.33 | 3.01 | 2.29 | 1.09 | 2.83 | 1.80 | 2.01 | 2.00 | 3.73 | 3.75 |
| K2O+Na2O | 6.10 | 6.21 | 6.58 | 6.22 | 7.54 | 6.95 | 6.58 | 6.70 | 5.60 | 5.61 | 8.13 | 8.07 |
| Mg# | 0.474 | 0.436 | 0.457 | 0.395 | 0.517 | 0.492 | 0.545 | 0.483 | 0.534 | 0.533 | 0.363 | 0.361 |
| FeOt/MgO | 2.00 | 2.33 | 2.14 | 2.75 | 1.68 | 1.86 | 1.51 | 1.93 | 1.57 | 1.57 | 3.16 | 3.18 |
| Sc | 27.1  | 27.9  | 25.3  | 24.9  | 24.6  | 26.0  | 23.1  | 21.8  | 23.8  | 23.0  | 24.1  | 24.1  |
| V | 189  | 161  | 149  | 174  | 128  | 148  | 149  | 147  | 145  | 145  | 141  | 147  |
| Cr | 100  | 118  | 114  | 110  | 118  | 116  | 200  | 180  | 170  | 180  | 200  | 200  |
| Co | 33.6  | 39.1  | 31.7  | 29.9  | 56.1  | 32.8  | 29.7  | 28.1  | 28.4  | 29.7  | 28.8  | 27.6  |
| Ni | 39.8  | 44.3  | 44.2  | 40.6  | 79.2  | 48.3  | 65.6  | 57.8  | 65.1  | 65.2  | 66.1  | 66.2  |
| Rb | 68.1  | 46.5  | 149  | 61.9  | 81.5  | 155  | 72.5  | 103  | 78.4  | 77.5  | 63.0  | 63.4  |
| Ba | 666  | 640  | 363  | 737  | 474  | 603  | 673  | 521  | 440  | 431  | 356  | 348  |
| Sr | 338  | 419  | 187  | 294  | 366  | 245  | 402  | 245  | 305  | 301  | 131  | 133  |
| Y | 51.2  | 55.6  | 49.3  | 53.9  | 58.0  | 49.7  | 46.1  | 44.4  | 46.8  | 47.0  | 54.0  | 53.4  |
| Hf | 8.10  | 8.30  | 7.10  | 7.30  | 8.40  | 7.60  | 7.20  | 7.10  | 6.90  | 6.90  | 8.00  | 7.80  |
| Zr | 348  | 376  | 335  | 320  | 383  | 333  | 312  | 311  | 311  | 309  | 354  | 351  |
| Ta | 1.09  | 0.98  | 0.87  | 0.94  | 0.99  | 0.86  | 1.00  | 0.91  | 0.91  | 0.91  | 0.98  | 0.99  |
| Nb | 19.0  | 19.2  | 16.8  | 17.2  | 19.7  | 16.6  | 16.5  | 15.8  | 15.8  | 15.5  | 16.9  | 17.3  |
| Pb | 13.5  | 16.4  | 9.5  | 14.9  | 59.5  | 12.9  | 14.3  | 10.2  | 11.9  | 11.9  | 76.0  | 74.4  |
| Th | 6.21  | 6.52  | 5.67  | 5.62  | 7.46  | 5.84  | 7.07  | 6.50  | 5.96  | 6.01  | 7.04  | 7.07  |
| U | 2.15  | 2.04  | 1.78  | 2.02  | 8.76  | 2.01  | 2.41  | 1.50  | 1.43  | 1.44  | 4.05  | 4.08  |
| La | 32.7  | 39.6  | 34.4  | 33.2  | 36.0  | 37.0  | 31.6  | 34.5  | 35.4  | 34.5  | 39.3  | 38.7  |
| Ce | 81.3  | 87.1  | 76.1  | 76.5  | 81.8  | 79.3  | 73.8  | 76.4  | 78.3  | 76.6  | 88.4  | 88.3  |
| Pr | 10.4  | 11.7  | 10.1  | 10.4  | 10.9  | 10.3  | 9.66  | 9.45  | 9.58  | 9.46  | 10.9  | 11.1  |
| Nd | 43.6  | 49.4  | 41.8  | 44.2  | 47.0  | 43.3  | 40.4  | 39.1  | 41.2  | 40.4  | 46.4  | 45.9  |
| Sm | 10.02  | 10.90  | 9.87  | 10.15  | 10.55  | 9.82  | 8.84  | 8.21  | 8.69  | 8.59  | 9.80  | 9.76  |
| Eu | 2.75  | 2.81  | 2.57  | 2.73  | 2.32  | 2.56  | 2.40  | 2.12  | 2.32  | 2.29  | 2.36  | 2.42  |
| Gd | 11.1  | 11.4  | 10.2  | 11.1  | 10.7  | 10.1  | 9.64  | 8.55  | 9.11  | 9.00  | 9.84  | 9.74  |
| Tb | 1.65  | 1.79  | 1.59  | 1.62  | 1.77  | 1.63  | 1.43  | 1.31  | 1.38  | 1.37  | 1.50  | 1.50  |
| Dy | 9.71  | 10.3  | 9.04  | 9.63  | 10.4  | 8.72  | 8.30  | 7.82  | 8.29  | 8.26  | 9.12  | 9.18  |
| Ho | 1.98  | 2.30  | 2.04  | 2.02  | 2.30  | 1.97  | 1.73  | 1.61  | 1.71  | 1.68  | 1.86  | 1.90  |
| Er | 5.43  | 5.81  | 5.09  | 5.39  | 6.09  | 5.22  | 4.69  | 4.59  | 4.86  | 4.42  | 5.07  | 5.12  |
| Tm | 0.79  | 0.87  | 0.72  | 0.76  | 0.92  | 0.81  | 0.67  | 0.67  | 0.68  | 0.68  | 0.77  | 0.72  |
| Yb | 4.86  | 5.29  | 4.84  | 4.84  | 5.82  | 4.90  | 4.29  | 4.18  | 4.33  | 4.28  | 4.79  | 4.81  |
| Lu | 0.71  | 0.82  | 0.63  | 0.73  | 0.88  | 0.67  | 0.65  | 0.63  | 0.66  | 0.67  | 0.74  | 0.75  |
| ΣREE | 217.00  | 240.09  | 208.99  | 213.27  | 227.45  | 216.30  | 198.10  | 199.14  | 206.51  | 202.20  | 230.85  | 229.90  |
| δEu | 0.8 | 0.77 | 0.78 | 0.79 | 0.67 | 0.79 | 0.79 | 0.77 | 0.8 | 0.8 | 0.73 | 0.76 |
| Sm/Yb | 2.06 | 2.06 | 2.04 | 2.1 | 1.81 | 2 | 2.06 | 1.96 | 2.01 | 2.01 | 2.05 | 2.03 |
| Zr/Hf | 43 | 45.3 | 47.2 | 43.8 | 45.6 | 43.8 | 43.3 | 43.8 | 45.1 | 44.8 | 44.3 | 45 |
| Nb/Ta | 17.4 | 19.6 | 19.3 | 18.3 | 19.9 | 19.3 | 16.5 | 17.4 | 17.4 | 17.03297 | 17.2 | 17.5 |
| Zr/Nb | 18.3 | 19.6 | 19.9 | 18.6 | 19.4 | 20.1 | 18.9 | 19.7 | 19.7 | 19.9 | 20.9 | 20.3 |
| Nb/La | 0.581 | 0.485 | 0.488 | 0.518 | 0.547 | 0.449 | 0.522 | 0.458 | 0.446 | 0.449 | 0.43 | 0.447 |
| Nb/Yb | 3.91 | 3.63 | 3.47 | 3.55 | 3.38 | 3.39 | 3.85 | 3.78 | 3.65 | 3.62 | 3.53 | 3.6 |
| Th/Yb | 1.28 | 1.23 | 1.17 | 1.16 | 1.28 | 1.19 | 1.65 | 1.56 | 1.38 | 1.4 | 1.47 | 1.47 |
| Nb/Th | 3.06 | 2.94 | 2.96 | 3.06 | 2.64 | 2.84 | 2.33 | 2.43 | 2.65 | 2.58 | 2.4 | 2.45 |
| Th/Zr | 0.0178 | 0.0173 | 0.0169 | 0.0176 | 0.0195 | 0.0175 | 0.0227 | 0.0209 | 0.0192 | 0.0194 | 0.0199 | 0.0201 |

附表3 海德乌拉辉绿岩Sr⁃Nd同位素组成

Table 3 Sr⁃Nd isotopic compositions of the Haidewula diabase

|  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 样品 | Sm (10-6) | Nd (10-6) | 147Sm/144Nd | 143Nd/144Nd (2σ) | εNd(*t*) | 2σ | TDMC (Ma) | Rb (10-6) | Sr (10-6) | 87Rb/86Sr | 87Sr/86Sr (2σ) | (87Sr/86Sr)i |
| SH⁃01 | 8.21 | 39.1 | 0.126 868 | 0.512 363 6(8) | ⁃3.2 | 0.2 | 127 6 | 103.0 | 245 | 1.210 584 | 0.717 087(10) | 0.712 954 |
| SH⁃02 | 8.69 | 41.2 | 0.127 440 | 0.512 377 2(8) | -3.0 | 0.2 | 125 6 | 78.4 | 305 | 0.743 795 | 0.714 213(10) | 0.711 674 |
| SH⁃03 | 8.59 | 40.4 | 0.128 468 | 0.512 373 6(10) | -3.1 | 0.2 | 126 4 | 77.5 | 301 | 0.745 027 | 0.714 158(14) | 0.711 614 |
| SH⁃04 | 9.80 | 46.4 | 0.127 612 | 0.512 387 3(8) | -2.8 | 0.2 | 124 0 | 63.0 | 131 | 1.391 574 | 0.716 538(8) | 0.711 788 |
| SH⁃05 | 9.76 | 45.9 | 0.128 476 | 0.512 378 9(10) | -3.0 | 0.2 | 125 6 | 63.4 | 133 | 1.384 556 | 0.716 596(10) | 0.711 869 |

 注：表中εNd(t) = [(143Nd/144Nd)S(t)/(143Nd/144Nd)CHUR(t) – 1] × 10000; (143Nd/144Nd)CHUR(t) = (143Nd/144Nd)CHUR(0) – (147Sm/144Nd)CHUR(0) × (eλt – 1);

TDMC(Nd) = 1/λ × ln (1 + ((143Nd/144Nd)S – (143Nd/144Nd)DM – ((147Sm/144Nd)S – (147Sm/144Nd)C) ×(eλt – 1))/( (147Sm/144Nd)C – (147Sm/144Nd)DM)), 其中 (143Nd/144Nd)S 和 (147Sm/144Nd)S代表样品测量值, λ = 6.54×10–12(Lugmair and Marti, 1978), (143Nd/144Nd)CHUR = 0.512638 (Goldstein *et al*., 1984), (147Sm/144Nd)CHUR = 0.1967 (Jacobsen and Wasserburg, 1980), (143Nd/144Nd)DM = 0.513151, (147Sm/144Nd)DM = 0.2136 (Liew and Hofmann, 1988) and (147Sm/144Nd)C = 0.118 (Jahn and Condie, 1995).

(87Sr/88Sr)i、εNd(*t*)和TDMC校正到*t* = 238 Ma.

表4 图6a中模拟计算中所用参数

Table 4 Parameter data of the end⁃menbers used for mixing modelling in Figure 6a

|  |  |  |  |
| --- | --- | --- | --- |
|  | MORB | OIB | S型花岗岩 |
| Nd (ppm) | 8.93 | 39.0 | 30.4 |
| εNd(t)\* | 12.9 | 4.0 | -13.2 |
| Sr (ppm) | 192 | 582 | 187 |
| (87Sr/86Sr)i\* | 0.707729 | 0.703894 | 0.74205 |
| 参考文献 | 郭安林等(2007a) | 郭安林等(2007a)；马丽艳等(2007) | 余能等(2005)；巴金等(2012) |

\*同位素初始值均校正到*t*= 238 Ma.