表1 哈拉特乌拉花岗闪长斑岩和查希尔矿区黑云母二长花岗岩锆石U-Pb测年结果

Table 1 LA-ICP-MS zircon U-Pb data for the granodiorite porphyry porphyry in Haraat Uul Fe-Zn deposit and biotite monzogranite in Tsahir Fe-Mo deposit

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 点号 | Total Pb | Th232 | U238 | Th232/U238 | 同位素比值 | | | | | | 年龄 (Ma) | | | | | | Con. |
| (×10-6) | (×10-6) | (×10-6) |  | 207Pb/206Pb | ±1σ | 207Pb/235U | ±1σ | 206Pb/238U | ±1σ | 207Pb/206Pb | ±1σ | 207Pb/235U | ±1σ | 206Pb/238U | ±1σ |
| *HL-8* |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1 | 4.8 | 40.5 | 79.3 | 0.51 | 0.04772 | 0.00387 | 0.31498 | 0.02483 | 0.04792 | 0.00135 | 87 | 246 | 278 | 19 | 302 | 8 | 91% |
| 2 | 6.8 | 63.8 | 103.6 | 0.62 | 0.06653 | 0.00485 | 0.44899 | 0.03085 | 0.04962 | 0.00129 | 833 | 153 | 377 | 22 | 312 | 8 | 81% |
| 3 | 6.5 | 71.0 | 119.6 | 0.59 | 0.05649 | 0.00421 | 0.33207 | 0.02534 | 0.04315 | 0.00112 | 472 | 165 | 291 | 19 | 272 | 7 | 93% |
| 4 | 9.1 | 132.1 | 157.0 | 0.84 | 0.05769 | 0.00686 | 0.33876 | 0.03901 | 0.04260 | 0.00147 | 517 | 265 | 296 | 30 | 269 | 9 | 90% |
| 5 | 6.9 | 87.2 | 115.8 | 0.75 | 0.05733 | 0.00444 | 0.33865 | 0.02569 | 0.04364 | 0.00113 | 506 | 170 | 296 | 19 | 275 | 7 | 92% |
| 6 | 18.3 | 317.1 | 284.7 | 1.11 | 0.05387 | 0.00293 | 0.32589 | 0.02014 | 0.04325 | 0.00086 | 365 | 122 | 286 | 15 | 273 | 5 | 95% |
| 7 | 9.8 | 114.8 | 161.5 | 0.71 | 0.05335 | 0.00319 | 0.32647 | 0.02060 | 0.04416 | 0.00095 | 343 | 131 | 287 | 16 | 279 | 6 | 97% |
| 8 | 6.9 | 70.9 | 115.5 | 0.61 | 0.04967 | 0.00335 | 0.30732 | 0.02144 | 0.04477 | 0.00087 | 189 | 157 | 272 | 17 | 282 | 5 | 96% |
| 9 | 5.5 | 48.2 | 93.7 | 0.51 | 0.05428 | 0.00379 | 0.33425 | 0.02431 | 0.04411 | 0.00100 | 383 | 157 | 293 | 18 | 278 | 6 | 94% |
| 10 | 6.1 | 51.9 | 103.1 | 0.50 | 0.05524 | 0.00442 | 0.32252 | 0.02328 | 0.04413 | 0.00110 | 420 | 180 | 284 | 18 | 278 | 7 | 98% |
| 11 | 9.4 | 50.1 | 80.3 | 0.62 | 0.19191 | 0.01350 | 1.59154 | 0.14492 | 0.05962 | 0.00215 | 2758 | 116 | 967 | 57 | 373 | 13 | 11% |
| 12 | 8.7 | 103.2 | 133.8 | 0.77 | 0.05472 | 0.00290 | 0.34259 | 0.01958 | 0.04533 | 0.00097 | 467 | 120 | 299 | 15 | 286 | 6 | 95% |
| 13 | 9.2 | 101.7 | 142.7 | 0.71 | 0.06070 | 0.00367 | 0.37197 | 0.02148 | 0.04470 | 0.00093 | 628 | 127 | 321 | 16 | 282 | 6 | 86% |
| 14 | 9.6 | 98.8 | 144.3 | 0.68 | 0.07968 | 0.00678 | 0.47354 | 0.03828 | 0.04369 | 0.00090 | 1191 | 169 | 394 | 26 | 276 | 6 | 64% |
| 15 | 6.9 | 70.9 | 107.7 | 0.66 | 0.06087 | 0.00521 | 0.37094 | 0.03142 | 0.04464 | 0.00105 | 635 | 185 | 320 | 23 | 282 | 7 | 87% |
| 16 | 7.6 | 60.4 | 101.3 | 0.60 | 0.10167 | 0.01097 | 0.81365 | 0.16052 | 0.04891 | 0.00158 | 1655 | 201 | 605 | 90 | 308 | 10 | 34% |
| 17 | 9.7 | 101.7 | 161.5 | 0.63 | 0.05531 | 0.00364 | 0.33188 | 0.02235 | 0.04401 | 0.00110 | 433 | 116 | 291 | 17 | 278 | 7 | 95% |
| 18 | 6.4 | 73.4 | 116.6 | 0.63 | 0.05492 | 0.00361 | 0.29504 | 0.01850 | 0.03963 | 0.00088 | 409 | 148 | 263 | 15 | 251 | 5 | 95% |
| 19 | 5.2 | 58.3 | 93.9 | 0.62 | 0.05722 | 0.00520 | 0.32555 | 0.02956 | 0.04100 | 0.00126 | 498 | 200 | 286 | 23 | 259 | 8 | 90% |
| 20 | 6.4 | 65.3 | 108.0 | 0.60 | 0.05583 | 0.00458 | 0.33431 | 0.02869 | 0.04343 | 0.00126 | 456 | 182 | 293 | 22 | 274 | 8 | 93% |
| *CXE-2* |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1 | 37.6 | 1219 | 619 | 1.97 | 0.06098 | 0.00313 | 0.31859 | 0.01755 | 0.03746 | 0.00057 | 639 | 111 | 281 | 14 | 237 | 4 | 83% |
| 2 | 23.1 | 227 | 303 | 0.75 | 0.05510 | 0.00276 | 0.44748 | 0.02247 | 0.05920 | 0.00105 | 417 | 111 | 376 | 16 | 371 | 6 | 98% |
| 3 | 31.2 | 1265 | 383 | 3.30 | 0.05194 | 0.00305 | 0.28918 | 0.01669 | 0.04067 | 0.00065 | 283 | 135 | 258 | 13 | 257 | 4 | 99% |
| 4 | 35.8 | 920 | 578 | 1.59 | 0.05248 | 0.00251 | 0.30016 | 0.01475 | 0.04126 | 0.00058 | 306 | 109 | 267 | 12 | 261 | 4 | 97% |
| 5 | 27.9 | 448 | 447 | 1.00 | 0.06321 | 0.00546 | 0.38929 | 0.03403 | 0.04419 | 0.00115 | 717 | 190 | 334 | 25 | 279 | 7 | 82% |
| 6 | 16.9 | 253 | 337 | 0.75 | 0.05643 | 0.00378 | 0.32236 | 0.02436 | 0.04101 | 0.00085 | 478 | 144 | 284 | 19 | 259 | 5 | 90% |
| 7 | 33.4 | 761 | 562 | 1.35 | 0.04775 | 0.00272 | 0.26392 | 0.01389 | 0.04095 | 0.00072 | 87 | 130 | 238 | 11 | 259 | 4 | 91% |
| 8 | 23.5 | 564 | 300 | 1.88 | 0.09371 | 0.00806 | 0.57658 | 0.04541 | 0.04556 | 0.00110 | 1502 | 163 | 462 | 29 | 287 | 7 | 53% |
| 9 | 14.0 | 312 | 245 | 1.27 | 0.06021 | 0.00422 | 0.31900 | 0.02092 | 0.04007 | 0.00079 | 613 | 156 | 281 | 16 | 253 | 5 | 89% |
| 10 | 21.7 | 251 | 459 | 0.55 | 0.05776 | 0.00306 | 0.30907 | 0.01599 | 0.03905 | 0.00072 | 520 | 117 | 273 | 12 | 247 | 4 | 89% |
| 11 | 8.1 | 219 | 130 | 1.68 | 0.06039 | 0.00614 | 0.30078 | 0.02736 | 0.03937 | 0.00113 | 617 | 222 | 267 | 21 | 249 | 7 | 92% |
| 12 | 21.0 | 563 | 320 | 1.76 | 0.05714 | 0.00438 | 0.33033 | 0.02563 | 0.04184 | 0.00078 | 498 | 170 | 290 | 20 | 264 | 5 | 90% |
| 13 | 18.2 | 180 | 381 | 0.47 | 0.05113 | 0.00344 | 0.28352 | 0.01849 | 0.04062 | 0.00071 | 256 | 156 | 253 | 15 | 257 | 4 | 98% |
| 14 | 23.4 | 380 | 442 | 0.86 | 0.05626 | 0.00335 | 0.31469 | 0.02009 | 0.04007 | 0.00063 | 461 | 133 | 278 | 16 | 253 | 4 | 90% |
| 15 | 19.2 | 194 | 362 | 0.54 | 0.05242 | 0.00268 | 0.31916 | 0.01572 | 0.04435 | 0.00078 | 306 | 117 | 281 | 12 | 280 | 5 | 99% |
| 16 | 11.0 | 245 | 175 | 1.40 | 0.06962 | 0.00831 | 0.39649 | 0.04424 | 0.04310 | 0.00192 | 917 | 248 | 339 | 32 | 272 | 12 | 78% |
| 17 | 15.4 | 331 | 238 | 1.39 | 0.06200 | 0.00713 | 0.36242 | 0.03913 | 0.04331 | 0.00136 | 676 | 248 | 314 | 29 | 273 | 8 | 86% |
| 18 | 6.6 | 189 | 95.8 | 1.97 | 0.07134 | 0.00724 | 0.37951 | 0.03220 | 0.04065 | 0.00144 | 969 | 207 | 327 | 24 | 257 | 9 | 76% |
| 19 | 19.3 | 471 | 301 | 1.57 | 0.06311 | 0.00424 | 0.37094 | 0.02533 | 0.04262 | 0.00104 | 722 | 144 | 320 | 19 | 269 | 6 | 82% |
| 20 | 15.4 | 285 | 285 | 1.00 | 0.04742 | 0.00430 | 0.25816 | 0.02104 | 0.04012 | 0.00105 | 78 | 194 | 233 | 17 | 254 | 7 | 91% |

表2 哈拉特乌拉花岗闪长斑岩和查希尔矿区黑云母二长花岗岩锆石Hf同位素分析结果

Table 2 LA-ICP-MS zircon Hf isotopic data for the granodiorite porphyry porphyry in Haraat Uul Fe-Zn deposit and biotite monzogranite in Tsahir Fe-Mo deposit

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 点号 | 年龄(Ma) | 176Yb/177Hf | 176Lu/177Hf | 176Hf/177Hf | 2σ | εHf() | εHf(t) | TDM | TDMC | *f*Lu/Hf |
| *HL-8* |  |  |  |  |  |  |  |  |  |  |
| 1 | 302 | 0.047190 | 0.001815 | 0.282942 | 0.000030 | 6.0 | 12.3 | 449 | 531 | -0.95 |
| 3 | 272 | 0.030149 | 0.001162 | 0.282832 | 0.000046 | 2.1 | 7.9 | 598 | 789 | -0.97 |
| 5 | 275 | 0.033122 | 0.001329 | 0.282834 | 0.000042 | 2.2 | 8.0 | 597 | 783 | -0.96 |
| 6 | 273 | 0.036774 | 0.001385 | 0.282822 | 0.000028 | 1.8 | 7.5 | 616 | 813 | -0.96 |
| 7 | 279 | 0.051127 | 0.001871 | 0.282886 | 0.000030 | 4.0 | 9.8 | 531 | 672 | -0.94 |
| 8 | 282 | 0.028852 | 0.001107 | 0.282789 | 0.000026 | 0.6 | 6.6 | 657 | 877 | -0.97 |
| 9 | 278 | 0.028859 | 0.001089 | 0.282804 | 0.000030 | 1.1 | 7.1 | 636 | 846 | -0.97 |
| 10 | 278 | 0.029294 | 0.001158 | 0.282800 | 0.000031 | 1.0 | 6.9 | 643 | 856 | -0.97 |
| 12 | 286 | 0.042543 | 0.001628 | 0.282813 | 0.000030 | 1.5 | 7.4 | 632 | 828 | -0.95 |
| 17 | 278 | 0.057711 | 0.002027 | 0.282826 | 0.000031 | 1.9 | 7.7 | 620 | 807 | -0.94 |
| 18 | 251 | 0.032487 | 0.001193 | 0.282854 | 0.000031 | 2.9 | 8.2 | 567 | 752 | -0.96 |
| 19 | 259 | 0.046823 | 0.001796 | 0.282807 | 0.000043 | 1.2 | 6.6 | 644 | 859 | -0.95 |
| 20 | 274 | 0.037169 | 0.001414 | 0.282809 | 0.000030 | 1.3 | 7.1 | 635 | 842 | -0.96 |
|  |  |  |  |  |  |  |  |  |  |  |
| *CXE-2* |  |  |  |  |  |  |  |  |  |  |
| 2 | 371 | 0.051790 | 0.001492 | 0.282662 | 0.000022 | -3.9 | 3.9 | 846 | 1118 | -0.96 |
| 3 | 257 | 0.148175 | 0.004061 | 0.282855 | 0.000031 | 2.9 | 7.9 | 613 | 777 | -0.88 |
| 4 | 261 | 0.164464 | 0.004327 | 0.282874 | 0.000032 | 3.6 | 8.6 | 587 | 734 | -0.87 |
| 6 | 259 | 0.045315 | 0.001305 | 0.282847 | 0.000023 | 2.6 | 8.1 | 579 | 763 | -0.96 |
| 11 | 249 | 0.082033 | 0.002183 | 0.282888 | 0.000034 | 4.1 | 9.2 | 533 | 686 | -0.93 |
| 12 | 264 | 0.161560 | 0.004078 | 0.282937 | 0.000033 | 5.8 | 10.9 | 485 | 587 | -0.88 |
| 13 | 257 | 0.054313 | 0.001505 | 0.282834 | 0.000026 | 2.2 | 7.6 | 600 | 796 | -0.95 |
| 14 | 253 | 0.078038 | 0.002031 | 0.282836 | 0.000027 | 2.3 | 7.5 | 606 | 799 | -0.94 |
| 15 | 280 | 0.053319 | 0.001398 | 0.282802 | 0.000022 | 1.0 | 6.9 | 645 | 855 | -0.96 |
| 20 | 254 | 0.111628 | 0.002845 | 0.282942 | 0.000040 | 6.0 | 11.1 | 461 | 568 | -0.91 |

表3 哈拉特乌拉花岗闪长斑岩和查希尔矿区黑云母二长花岗岩主量元素(×10−2)、微量和稀土元素(×10−6)分析结果

Table 3 Major elements (×10−2), rare earth and trace elements (×10−6) analyses of granodiorite porphyry in Haraat Uul Fe-Zn deposit and biotite monzogranite in Tsahir Fe-Mo deposit

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| 样品编号 | CXE-2 | CXE-3 | CXE-4 | CXE-5 | HL-8 |
| SiO2 | 66.00 | 66.02 | 66.30 | 67.32 | 66.40 |
| TiO2 | 0.34 | 0.37 | 0.33 | 0.33 | 0.55 |
| Al2O3 | 17.62 | 17.63 | 17.67 | 17.06 | 16.13 |
| Fe2O3 | 0.89 | 0.39 | 0.59 | 0.58 | 1.64 |
| FeO | 1.19 | 1.69 | 1.33 | 1.29 | 1.15 |
| MnO | 0.05 | 0.05 | 0.06 | 0.04 | 0.08 |
| MgO | 0.65 | 0.69 | 0.58 | 0.62 | 0.98 |
| CaO | 2.01 | 1.96 | 1.98 | 1.60 | 2.99 |
| Na2O | 6.31 | 6.21 | 6.22 | 5.72 | 4.47 |
| K2O | 3.32 | 3.41 | 3.54 | 3.69 | 4.44 |
| P2O5 | 0.07 | 0.08 | 0.07 | 0.07 | 0.17 |
| LOI | 0.81 | 0.75 | 0.70 | 0.93 | 0.86 |
| Total | 99.26 | 99.25 | 99.37 | 99.25 | 99.86 |
| K2O+Na2O | 9.63 | 9.62 | 9.76 | 9.41 | 8.91 |
| A/CNK | 1.00 | 1.01 | 1.00 | 1.05 | 0.92 |
| A/NK | 1.26 | 1.27 | 1.26 | 1.27 | 1.33 |
| Mg# | 37 | 38 | 36 | 38 | 40 |
| FeOT | 1.99 | 2.04 | 1.86 | 1.81 | 2.63 |
| FeOT/MgO | 3.06 | 2.96 | 3.21 | 2.92 | 2.68 |
| FeOT/(FeOT+MgO) | 0.75 | 0.75 | 0.76 | 0.75 | 0.73 |
|  |  |  |  |  |  |
| Cu | 15.7 | 5.04 | 2.2 | 6.58 | 4.38 |
| Zn | 54.9 | 30.7 | 40.0 | 38.3 | 55.0 |
| Rb | 84.3 | 75.9 | 91.3 | 91.7 | 142 |
| Sr | 306 | 266 | 303 | 277 | 440 |
| Mo | 23.8 | 6.36 | 1.31 | 19.1 | 0.63 |
| Ba | 1285 | 1244 | 1372 | 1295 | 1243 |
| Pb | 29.9 | 14.4 | 19.5 | 18.5 | 12.7 |
| Th | 31.6 | 29.0 | 34.4 | 32.0 | 12.9 |
| U | 3.71 | 4.34 | 4.47 | 4.07 | 3.85 |
| Nb | 8.76 | 9.27 | 7.88 | 8.41 | 8.89 |
| Ta | 0.75 | 0.95 | 0.74 | 0.87 | 0.69 |
| Zr | 328 | 317 | 317 | 318 | 274 |
| Hf | 8.88 | 8.61 | 8.54 | 8.52 | 7.37 |
| Ti | 2060 | 2063 | 1884 | 1862 | 3181 |
| Y | 16.0 | 15.7 | 18.7 | 15.6 | 22.2 |
| Ga | 20.2 | 19.8 | 20.2 | 19.3 | 18.7 |
|  |  |  |  |  |  |
| La | 111 | 104 | 145 | 113 | 38.2 |
| Ce | 174 | 162 | 241 | 185 | 77.1 |
| Pr | 17.5 | 16.4 | 22.6 | 17.5 | 7.95 |
| Nd | 54.7 | 52.5 | 81.6 | 55.0 | 28.2 |
| Sm | 7.20 | 7.09 | 9.16 | 7.12 | 5.34 |
| Eu | 2.15 | 1.86 | 2.12 | 1.93 | 1.38 |
| Gd | 4.67 | 4.62 | 5.38 | 4.47 | 4.50 |
| Tb | 0.61 | 0.60 | 0.70 | 0.57 | 0.70 |
| Dy | 3.30 | 3.18 | 3.76 | 3.06 | 4.37 |
| Ho | 0.64 | 0.62 | 0.72 | 0.59 | 0.87 |
| Er | 1.80 | 1.74 | 1.95 | 1.72 | 2.43 |
| Tm | 0.29 | 0.29 | 0.34 | 0.29 | 0.41 |
| Yb | 2.12 | 2.11 | 2.40 | 2.17 | 2.85 |
| Lu | 0.33 | 0.35 | 0.39 | 0.37 | 0.43 |
| ΣREE | 380.31 | 357.36 | 517.12 | 392.79 | 174.73 |
| Eu/Eu\* | 1.06 | 0.93 | 0.85 | 0.97 | 0.84 |
| 10000Ga/Al | 2.17 | 2.12 | 2.16 | 2.14 | 2.19 |
| Nb/Ta | 11.68 | 9.76 | 10.65 | 9.67 | 12.88 |
| t'/℃ | 833 | 831 | 830 | 839 | 807 |

t'/℃ = 12900/[ln(496000/ωZr-全岩) + 3.80 + 0.85 × (M-1)] - 273.15, 其中, M = (2Ca+K+Na) / (Si×Al) 离子数比值 (Watson and Harrison, 1983).