**表1小东山火山岩不同岩性锆石的U-Th-Pb同位素分析结果**

**Table 1 U-Th-Pb isotopic analyses for zircon from the Xiaodongshan volcanic rocks**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| 点号 | ωB/10-6 | Th/U | 同位素比值 | 年龄/Ma |
| Th232 | U238 | 207Pb/206Pb | 1σ | 207Pb/235U | 1σ | 206Pb/238U | 1σ | 207Pb/206Pb | 1σ | 207Pb/235U | 1σ | 206Pb/238U | 1σ |
| 英安斑岩（AQS02） |
| 1 | 47  | 83  | 0.56 | 0.0485  | 0.0023  | 0.3300  | 0.0142  | 0.0494  | 0.0007  | 124.2  | 109.2  | 289.5  | 10.9  | 310.6  | 4.3  |
| 2 | 99  | 162  | 0.61 | 0.0489  | 0.0018  | 0.3257  | 0.0111  | 0.0483  | 0.0006  | 146.4  | 85.2  | 286.3  | 8.5  | 303.8  | 3.4  |
| 3 | 102  | 166  | 0.62 | 0.0550  | 0.0019  | 0.3652  | 0.0121  | 0.0481  | 0.0006  | 413.0  | 84.3  | 316.1  | 9.0  | 303.0  | 3.8  |
| 4 | 92  | 156  | 0.59 | 0.0555  | 0.0019  | 0.3752  | 0.0133  | 0.0490  | 0.0006  | 431.5  | 75.9  | 323.5  | 9.8  | 308.6  | 3.9  |
| 5 | 50  | 95  | 0.52 | 0.0554  | 0.0021  | 0.3796  | 0.0132  | 0.0497  | 0.0007  | 427.8  | 89.8  | 326.7  | 9.8  | 312.5  | 4.1  |
| 6 | 96  | 138  | 0.70 | 0.0552  | 0.0018  | 0.3812  | 0.0123  | 0.0501  | 0.0006  | 420.4  | 70.4  | 327.9  | 9.1  | 315.2  | 3.6  |
| 7 | 110  | 141  | 0.78 | 0.0511  | 0.0018  | 0.3394  | 0.0112  | 0.0481  | 0.0006  | 255.6  | 81.5  | 296.7  | 8.5  | 303.1  | 3.8  |
| 8 | 112  | 136  | 0.83 | 0.0510  | 0.0019  | 0.3407  | 0.0126  | 0.0484  | 0.0006  | 242.7  | 85.2  | 297.7  | 9.5  | 304.7  | 3.7  |
| 9 | 54  | 112  | 0.48 | 0.0537  | 0.0022  | 0.3552  | 0.0126  | 0.0480  | 0.0006  | 366.7  | 97.2  | 308.6  | 9.5  | 302.1  | 3.9  |
| 10 | 93  | 141  | 0.66 | 0.0533  | 0.0018  | 0.3702  | 0.0119  | 0.0503  | 0.0006  | 342.7  | 75.9  | 319.8  | 8.8  | 316.4  | 3.6  |
| 11 | 67  | 125  | 0.54 | 0.0519  | 0.0020  | 0.3553  | 0.0125  | 0.0497  | 0.0007  | 279.7  | 88.9  | 308.7  | 9.4  | 312.6  | 4.0  |
| 12 | 82  | 154  | 0.53 | 0.0522  | 0.0021  | 0.3527  | 0.0125  | 0.0490  | 0.0006  | 294.5  | 92.6  | 306.7  | 9.4  | 308.4  | 3.9  |
| 13 | 97  | 141  | 0.69 | 0.0519  | 0.0019  | 0.3463  | 0.0129  | 0.0484  | 0.0006  | 283.4  | 85.2  | 301.9  | 9.8  | 304.5  | 3.9  |
| 14 | 51  | 98  | 0.52 | 0.0531  | 0.0023  | 0.3651  | 0.0153  | 0.0498  | 0.0007  | 344.5  | 100.0  | 316.0  | 11.4  | 313.6  | 4.3  |
| 15 | 107  | 158  | 0.68 | 0.0524  | 0.0021  | 0.3591  | 0.0145  | 0.0497  | 0.0007  | 301.9  | 90.7  | 311.5  | 10.8  | 312.6  | 4.4  |
| 花岗斑岩（AQS07） |
| 1 | 207  | 245  | 0.85  | 0.0531  | 0.0008  | 0.3701  | 0.0057  | 0.0505  | 0.0004  | 331.5  | 33.3  | 319.8  | 4.2  | 317.8  | 2.2  |
| 2 | 148  | 267  | 0.56  | 0.0522  | 0.0007  | 0.3697  | 0.0055  | 0.0512  | 0.0004  | 300.1  | 31.5  | 319.4  | 4.1  | 322.0  | 2.3  |
| 3 | 116  | 195  | 0.60  | 0.0539  | 0.0009  | 0.3760  | 0.0061  | 0.0506  | 0.0004  | 368.6  | 37.0  | 324.1  | 4.5  | 318.2  | 2.3  |
| 4 | 153  | 245  | 0.62  | 0.0529  | 0.0009  | 0.3648  | 0.0059  | 0.0500  | 0.0004  | 324.1  | 37.0  | 315.8  | 4.4  | 314.3  | 2.2  |
| 5 | 131  | 245  | 0.54  | 0.0549  | 0.0009  | 0.3762  | 0.0058  | 0.0495  | 0.0004  | 409.3  | 39.8  | 324.2  | 4.3  | 311.7  | 2.2  |
| 6 | 248  | 340  | 0.73  | 0.0524  | 0.0007  | 0.3686  | 0.0048  | 0.0510  | 0.0003  | 301.9  | 29.6  | 318.6  | 3.6  | 320.7  | 2.1  |
| 7 | 182  | 227  | 0.80  | 0.0532  | 0.0007  | 0.3735  | 0.0053  | 0.0510  | 0.0004  | 344.5  | 31.5  | 322.2  | 3.9  | 320.8  | 2.6  |
| 8 | 304  | 329  | 0.92  | 0.0529  | 0.0007  | 0.3625  | 0.0048  | 0.0496  | 0.0003  | 324.1  | 29.6  | 314.1  | 3.6  | 311.9  | 2.0  |
| 9 | 140  | 189  | 0.74  | 0.0550  | 0.0009  | 0.3801  | 0.0067  | 0.0500  | 0.0004  | 413.0  | 37.0  | 327.1  | 4.9  | 314.6  | 2.4  |
| 10 | 144  | 158  | 0.91  | 0.0538  | 0.0010  | 0.3807  | 0.0073  | 0.0512  | 0.0004  | 364.9  | 42.6  | 327.5  | 5.3  | 322.0  | 2.5  |
| 11 | 150  | 199  | 0.76  | 0.0553  | 0.0009  | 0.3858  | 0.0063  | 0.0505  | 0.0003  | 433.4  | 35.2  | 331.3  | 4.6  | 317.4  | 2.1  |
| 12 | 258  | 409  | 0.63  | 0.0526  | 0.0006  | 0.3729  | 0.0049  | 0.0512  | 0.0004  | 322.3  | 27.8  | 321.8  | 3.6  | 322.2  | 2.3  |
| 13 | 142  | 272  | 0.52  | 0.0524  | 0.0007  | 0.3640  | 0.0053  | 0.0503  | 0.0004  | 301.9  | 5.6  | 315.2  | 4.0  | 316.7  | 2.3  |
| 14 | 245  | 330  | 0.74  | 0.0526  | 0.0006  | 0.3704  | 0.0046  | 0.0511  | 0.0004  | 322.3  | 27.8  | 320.0  | 3.4  | 321.2  | 2.3  |
| 15 | 257  | 285  | 0.90  | 0.0529  | 0.0007  | 0.3743  | 0.0052  | 0.0514  | 0.0004  | 324.1  | 26.9  | 322.8  | 3.8  | 323.2  | 2.3  |
| 16 | 70  | 173  | 0.41  | 0.0540  | 0.0009  | 0.3816  | 0.0065  | 0.0514  | 0.0004  | 368.6  | 37.0  | 328.2  | 4.8  | 323.3  | 2.4  |
| 花岗斑岩（AQS08） |
| 1 | 102  | 159  | 0.64  | 0.0534  | 0.0011  | 0.3686  | 0.0078  | 0.0504  | 0.0004  | 346.4  | 46.3  | 318.6  | 5.8  | 316.8  | 2.7  |
| 2 | 74  | 117  | 0.63  | 0.0525  | 0.0010  | 0.3681  | 0.0075  | 0.0511  | 0.0005  | 309.3  | 46.3  | 318.2  | 5.5  | 321.0  | 2.8  |
| 3 | 105  | 190  | 0.56  | 0.0521  | 0.0009  | 0.3630  | 0.0063  | 0.0506  | 0.0004  | 300.1  | 38.9  | 314.4  | 4.7  | 318.0  | 2.3  |
| 4 | 323  | 432  | 0.75  | 0.0527  | 0.0006  | 0.3639  | 0.0045  | 0.0503  | 0.0004  | 322.3  | 27.8  | 315.2  | 3.3  | 316.2  | 2.6  |
| 5 | 201  | 320  | 0.63  | 0.0535  | 0.0007  | 0.3701  | 0.0051  | 0.0501  | 0.0003  | 350.1  | 34.3  | 319.7  | 3.8  | 315.3  | 2.1  |
| 6 | 188  | 201  | 0.93  | 0.0533  | 0.0009  | 0.3669  | 0.0061  | 0.0499  | 0.0004  | 338.9  | 37.0  | 317.4  | 4.6  | 314.0  | 2.2  |
| 7 | 309  | 352  | 0.88  | 0.0554  | 0.0007  | 0.3821  | 0.0051  | 0.0501  | 0.0004  | 431.5  | 31.5  | 328.6  | 3.8  | 315.3  | 2.3  |
| 8 | 185  | 221  | 0.84  | 0.0518  | 0.0008  | 0.3568  | 0.0057  | 0.0499  | 0.0004  | 276.0  | 33.3  | 309.8  | 4.3  | 313.7  | 2.3  |
| 9 | 115  | 218  | 0.53  | 0.0540  | 0.0009  | 0.3757  | 0.0064  | 0.0506  | 0.0004  | 368.6  | 38.9  | 323.9  | 4.8  | 318.1  | 2.3  |
| 10 | 98  | 176  | 0.56  | 0.0554  | 0.0009  | 0.3851  | 0.0063  | 0.0503  | 0.0004  | 431.5  | 35.2  | 330.8  | 4.6  | 316.5  | 2.2  |
| 11 | 159  | 222  | 0.72  | 0.0525  | 0.0008  | 0.3676  | 0.0056  | 0.0508  | 0.0004  | 305.6  | 33.3  | 317.9  | 4.1  | 319.5  | 2.3  |
| 12 | 91  | 143  | 0.64  | 0.0541  | 0.0012  | 0.3756  | 0.0074  | 0.0507  | 0.0004  | 376.0  | 52.8  | 323.8  | 5.5  | 318.7  | 2.5  |
| 橄榄玄武岩（AQS21） |
| 1 | 204  | 272  | 0.75  | 0.0525  | 0.0007  | 0.3667  | 0.0053  | 0.0508  | 0.0004  | 305.6  | 36.1  | 317.2  | 3.9  | 319.2  | 2.5  |
| 2 | 233  | 270  | 0.86  | 0.0525  | 0.0008  | 0.3717  | 0.0060  | 0.0512  | 0.0004  | 309.3  | 35.2  | 320.9  | 4.5  | 322.1  | 2.3  |
| 3 | 131  | 321  | 0.41  | 0.0533  | 0.0008  | 0.3741  | 0.0056  | 0.0508  | 0.0004  | 338.9  | 31.5  | 322.7  | 4.1  | 319.7  | 2.2  |
| 4 | 156  | 237  | 0.66  | 0.0537  | 0.0008  | 0.3721  | 0.0059  | 0.0500  | 0.0004  | 366.7  | 31.5  | 321.2  | 4.4  | 314.7  | 2.2  |
| 5 | 148  | 324  | 0.46  | 0.0519  | 0.0007  | 0.3586  | 0.0052  | 0.0499  | 0.0003  | 283.4  | 36.1  | 311.2  | 3.9  | 314.0  | 2.1  |
| 6 | 328  | 607  | 0.54  | 0.0525  | 0.0006  | 0.3666  | 0.0042  | 0.0505  | 0.0003  | 309.3  | 24.1  | 317.2  | 3.2  | 317.7  | 2.1  |
| 7 | 150  | 289  | 0.52  | 0.0551  | 0.0008  | 0.3815  | 0.0055  | 0.0502  | 0.0003  | 416.7  | 36.1  | 328.2  | 4.0  | 315.8  | 2.0  |
| 8 | 341  | 389  | 0.88  | 0.0537  | 0.0007  | 0.3775  | 0.0051  | 0.0510  | 0.0004  | 366.7  | 29.6  | 325.2  | 3.7  | 320.8  | 2.3  |

**表2小东山火山岩锆石的Lu-Hf同位素分析结果**

**Table 2 Lu-Hf isotopic analyses for zircon from the Xiaodongshan volcanic rocks**

|  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 样号 | 176Yb/177Hf | 1σ | 176Lu/177Hf | 1σ | 176Hf/177Hf | 1σ | 176Hf/177Hfi | εHf(T) | εHf(present) | tDM 1(Ma) | tDMC (Ma) | fLu/Hf |
| 花岗斑岩（AQS07） |
| 1 | 0.055671 | 0.000628 | 0.002016 | 0.000019 | 0.282895 | 0.000016 | 0.282883 | 10.54 | 3.89 | 520 | 632 | -0.94 |
| 2 | 0.058272 | 0.000397 | 0.002227 | 0.000018 | 0.282884 | 0.000015 | 0.282871 | 10.11 | 3.50 | 539 | 660 | -0.93 |
| 3 | 0.054030 | 0.000699 | 0.001931 | 0.000020 | 0.282882 | 0.000010 | 0.282870 | 10.10 | 3.42 | 538 | 661 | -0.94 |
| 4 | 0.039379 | 0.000622 | 0.001391 | 0.000015 | 0.282907 | 0.000008 | 0.282898 | 11.09 | 4.30 | 495 | 597 | -0.96 |
| 5 | 0.064955 | 0.000692 | 0.002365 | 0.000028 | 0.282878 | 0.000011 | 0.282864 | 9.86 | 3.27 | 551 | 676 | -0.93 |
| 6 | 0.073132 | 0.000668 | 0.002622 | 0.000016 | 0.282880 | 0.000013 | 0.282864 | 9.88 | 3.35 | 552 | 675 | -0.92 |
| 7 | 0.064496 | 0.001280 | 0.002262 | 0.000047 | 0.282872 | 0.000011 | 0.282858 | 9.66 | 3.06 | 558 | 689 | -0.93 |
| 8 | 0.079974 | 0.000830 | 0.002813 | 0.000034 | 0.282852 | 0.000011 | 0.282835 | 8.86 | 2.37 | 596 | 740 | -0.92 |
| 9 | 0.074037 | 0.000613 | 0.002801 | 0.000015 | 0.282870 | 0.000019 | 0.282853 | 9.50 | 3.01 | 569 | 699 | -0.92 |
| 10 | 0.067660 | 0.001260 | 0.002388 | 0.000039 | 0.282854 | 0.000013 | 0.282839 | 9.00 | 2.43 | 586 | 731 | -0.93 |
| 11 | 0.059167 | 0.000275 | 0.002278 | 0.000018 | 0.282878 | 0.000013 | 0.282864 | 9.88 | 3.27 | 549 | 675 | -0.93 |
| 12 | 0.086608 | 0.000964 | 0.003044 | 0.000021 | 0.282861 | 0.000013 | 0.282842 | 9.11 | 2.67 | 587 | 724 | -0.91 |
| 13 | 0.064694 | 0.000584 | 0.002242 | 0.000013 | 0.282860 | 0.000009 | 0.282847 | 9.28 | 2.67 | 574 | 714 | -0.93 |
| 14 | 0.085041 | 0.001980 | 0.003007 | 0.000059 | 0.282875 | 0.000012 | 0.282857 | 9.62 | 3.17 | 565 | 692 | -0.91 |
| 15 | 0.052609 | 0.000354 | 0.001877 | 0.000012 | 0.282888 | 0.000010 | 0.282877 | 10.33 | 3.64 | 528 | 646 | -0.94 |
| 16 | 0.051096 | 0.000385 | 0.001936 | 0.000013 | 0.282889 | 0.000016 | 0.282877 | 10.35 | 3.67 | 528 | 645 | -0.94 |
| 花岗斑岩(AQS08) |
| 1 | 0.050282 | 0.000721 | 0.001907 | 0.000028 | 0.282888 | 0.000017 | 0.282876 | 10.31 | 3.62 | 529 | 648 | -0.94 |
| 2 | 0.033363 | 0.000390 | 0.001185 | 0.000013 | 0.282927 | 0.000013 | 0.282920 | 11.86 | 5.02 | 463 | 548 | -0.96 |
| 3 | 0.064076 | 0.000547 | 0.002156 | 0.000016 | 0.282904 | 0.000015 | 0.282891 | 10.83 | 4.20 | 509 | 614 | -0.94 |
| 4 | 0.091591 | 0.000398 | 0.002908 | 0.000013 | 0.282906 | 0.000010 | 0.282889 | 10.75 | 4.28 | 517 | 620 | -0.91 |
| 5 | 0.081377 | 0.000989 | 0.002540 | 0.000033 | 0.282888 | 0.000008 | 0.282873 | 10.19 | 3.64 | 538 | 655 | -0.92 |
| 6 | 0.090139 | 0.001620 | 0.002858 | 0.000037 | 0.282905 | 0.000011 | 0.282888 | 10.71 | 4.23 | 518 | 622 | -0.91 |
| 7 | 0.081273 | 0.002130 | 0.002515 | 0.000059 | 0.282896 | 0.000011 | 0.282881 | 10.49 | 3.94 | 525 | 636 | -0.93 |
| 8 | 0.070634 | 0.000310 | 0.002395 | 0.000025 | 0.282943 | 0.000014 | 0.282929 | 12.18 | 5.60 | 454 | 528 | -0.93 |
| 9 | 0.058434 | 0.000673 | 0.001999 | 0.000025 | 0.282908 | 0.000015 | 0.282896 | 11.02 | 4.35 | 501 | 602 | -0.94 |
| 10 | 0.088150 | 0.000422 | 0.002781 | 0.000013 | 0.282891 | 0.000009 | 0.282875 | 10.26 | 3.76 | 537 | 651 | -0.92 |
| 11 | 0.067503 | 0.000266 | 0.002150 | 0.000006 | 0.282912 | 0.000009 | 0.282900 | 11.14 | 4.51 | 497 | 595 | -0.94 |
| 12 | 0.070490 | 0.001210 | 0.002342 | 0.000049 | 0.282914 | 0.000011 | 0.282900 | 11.15 | 4.56 | 497 | 594 | -0.93 |
| 橄榄玄武岩(AQS21) |
| 1 | 0.090575 | 0.000541 | 0.002987 | 0.000020 | 0.282906 | 0.000010 | 0.282888 | 10.72 | 4.26 | 518 | 621 | -0.91 |
| 2 | 0.069729 | 0.001070 | 0.002425 | 0.000021 | 0.282916 | 0.000013 | 0.282902 | 11.22 | 4.65 | 494 | 589 | -0.93 |
| 3 | 0.081259 | 0.000740 | 0.002541 | 0.000018 | 0.282886 | 0.000009 | 0.282870 | 10.10 | 3.56 | 542 | 661 | -0.92 |
| 4 | 0.116341 | 0.001720 | 0.003489 | 0.000054 | 0.282905 | 0.000011 | 0.282884 | 10.57 | 4.23 | 527 | 631 | -0.90 |
| 5 | 0.058187 | 0.000599 | 0.001909 | 0.000031 | 0.282908 | 0.000008 | 0.282896 | 11.01 | 4.33 | 500 | 602 | -0.94 |
| 6 | 0.072253 | 0.000223 | 0.002410 | 0.000008 | 0.282753 | 0.000011 | 0.282739 | 5.45 | -1.12 | 734 | 958 | -0.93 |
| 7 | 0.091412 | 0.000247 | 0.002863 | 0.000012 | 0.282905 | 0.000009 | 0.282888 | 10.73 | 4.25 | 517 | 620 | -0.91 |
| 8 | 0.083076 | 0.000546 | 0.002894 | 0.000016 | 0.282900 | 0.000012 | 0.282883 | 10.55 | 4.07 | 525 | 632 | -0.91 |

**表3 小东山火山岩的主量元素和微量元素组成分析结果
Table 3 Major and trace element contents of the Xiaodongshan volcanic rocks**

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 组分 | 19AQS-01 | 19AQS-02 | 19AQS-03 | 19AQS-04 | 19AQS-05 | 19AQS-11 | 19AQS-12 | 19AQS-13 | 19AQS-06 | 19AQS-07 | 19AQS-08 |
| 岩石类型 | 英安斑岩 | 花岗斑岩 |
| 主量元素 (%) |
| SiO2 | 60.81 | 61.83 | 73.56 | 63.41 | 60.63 | 62.61 | 63.37 | 60.81 | 75.27 | 76.82 | 76.54 |
| TiO2 | 0.89 | 0.69 | 0.25 | 0.60 | 0.80 | 0.71 | 0.71 | 0.89 | 0.21 | 0.16 | 0.30 |
| A12O3 | 15.52 | 15.96 | 13.41 | 14.61 | 15.53 | 16.84 | 16.71 | 15.52 | 13.04 | 11.68 | 12.29 |
| TFe2O3 | 8.36 | 6.17 | 1.06 | 6.96 | 8.15 | 3.94 | 3.60 | 8.36 | 0.61 | 0.97 | 0.99 |
| MnO | 0.45 | 0.28 | 0.04 | 0.16 | 0.22 | 0.11 | 0.10 | 0.45 | 0.02 | 0.03 | 0.02 |
| MgO | 2.88 | 2.43 | 0.74 | 2.07 | 3.26 | 2.97 | 2.59 | 2.88 | 0.40 | 0.45 | 0.37 |
| CaO | 1.23 | 2.47 | 0.87 | 4.79 | 1.92 | 1.89 | 1.99 | 1.23 | 0.76 | 0.90 | 0.63 |
| Na2O | 6.38 | 5.52 | 4.57 | 3.93 | 5.32 | 4.94 | 5.04 | 6.38 | 4.84 | 3.25 | 5.33 |
| K2O | 1.17 | 2.08 | 3.98 | 0.96 | 1.87 | 3.03 | 3.00 | 1.17 | 3.87 | 4.46 | 2.05 |
| P2O5 | 0.16 | 0.17 | 0.05 | 0.08 | 0.11 | 0.16 | 0.18 | 0.16 | 0.05 | 0.05 | 0.08 |
| LOI | 1.89 | 2.15 | 1.16 | 2.12 | 2.01 | 2.35 | 2.26 | 1.89 | 0.67 | 0.96 | 0.91 |
| 总和 | 99.75 | 99.74 | 99.69 | 99.70 | 99.82 | 99.52 | 99.54 | 99.75 | 99.74 | 99.72 | 99.49 |
| FeOT | 4.51 | 7.53 | 5.55 | 6.26 | 7.33 | 4.40 | 3.54 | 3.24 | 0.96 | 0.55 | 0.87 |
| Mg# | 45 | 41 | 44 | 37 | 44 | 60 | 60 | 59 | 58 | 56 | 48 |
| FeOT/MgO | 2.22 | 2.61 | 2.28 | 3.02 | 2.25 | 1.19 | 1.20 | 1.25 | 1.29 | 1.39 | 1.93 |
| 组分 | 19AQS-09 | 19AQS-10 | 19AQS-14 | 19AQS-15 | 19AQS-16 | 19AQS-17 | 19AQS-18 | 19AQS-19 | 19AQS-20 | 19AQS-21 |
| 岩石类型 | 花岗斑岩 | 安山岩 | 玄武岩 | 橄榄玄武岩 |
| 主量元素 (%) |
| SiO2 | 71.56 | 71.07 | 67.94 | 61.61 | 72.47 | 54.97 | 54.08 | 48.49 | 48.10 | 52.32 |
| TiO2 | 0.48 | 0.48 | 0.42 | 0.71 | 0.32 | 0.75 | 0.66 | 1.12 | 1.18 | 1.17 |
| A12O3 | 14.07 | 14.14 | 15.30 | 16.64 | 13.37 | 18.99 | 15.98 | 19.24 | 19.35 | 18.72 |
| TFe2O3 | 1.99 | 1.99 | 1.16 | 4.89 | 1.89 | 7.16 | 8.95 | 10.10 | 10.41 | 9.20 |
| MnO | 0.22 | 0.22 | 0.04 | 0.13 | 0.18 | 0.36 | 0.23 | 0.30 | 0.29 | 0.23 |
| MgO | 1.19 | 1.33 | 0.87 | 3.70 | 1.02 | 2.17 | 1.70 | 3.12 | 3.35 | 2.98 |
| CaO | 1.49 | 1.64 | 2.39 | 1.73 | 1.46 | 6.37 | 11.23 | 6.22 | 7.64 | 4.50 |
| Na2O | 7.13 | 7.21 | 5.97 | 4.15 | 6.63 | 3.37 | 1.91 | 5.01 | 4.30 | 6.19 |
| K2O | 0.09 | 0.08 | 3.22 | 3.21 | 0.85 | 2.33 | 0.82 | 1.34 | 0.89 | 0.71 |
| P2O5 | 0.13 | 0.13 | 0.10 | 0.15 | 0.05 | 0.14 | 0.10 | 0.16 | 0.18 | 0.17 |
| LOI | 1.56 | 1.56 | 2.28 | 2.75 | 1.64 | 2.82 | 3.97 | 4.62 | 4.01 | 3.64 |
| 总和 | 99.89 | 99.87 | 99.69 | 99.67 | 99.88 | 99.42 | 99.64 | 99.70 | 99.70 | 99.83 |
| FeOT | 1.79 | 1.79 | 0.89 | 1.05 | 1.70 | 6.44 | 8.05 | 9.08 | 9.37 | 8.28 |
| Mg# | 54 | 57 | 42 | 60 | 52 | 38 | 27 | 38 | 39 | 39 |
| FeOT/MgO | 1.51 | 1.35 | 2.43 | 1.20 | 1.67 | 2.96 | 4.75 | 2.91 | 2.80 | 2.78 |
| 组分 | 19AQS-01 | 19AQS-02 | 19AQS-03 | 19AQS-04 | 19AQS-05 | 19AQS-11 | 19AQS-12 | 19AQS-13 | 19AQS-06 | 19AQS-07 | 19AQS-08 |
| 稀土和微量元素 (×10-6) |
| Li | 28.28 | 33.10 | 28.91 | 11.81 | 19.79 | 35.42 | 28.34 | 24.15 | 12.34 | 7.59 | 7.55 |
| Sc | 14.51 | 19.28 | 21.64 | 19.29 | 16.49 | 16.13 | 16.41 | 15.93 | 4.81 | 3.86 | 4.30 |
| V | 98.76 | 130.24 | 114.64 | 150.81 | 144.02 | 60.08 | 56.30 | 56.05 | 19.01 | 13.38 | 15.64 |
| Ni | 2.66 | 8.86 | 7.17 | 9.70 | 14.56 | 6.23 | 5.37 | 5.36 | 1.21 | 0.50 | 0.73 |
| Co | 2.49 | 3.58 | 3.95 | 12.88 | 10.21 | 8.12 | 6.34 | 5.57 | 1.72 | 0.71 | 3.23 |
| Cu | 9.40 | 1.00 | 202.56 | 1.49 | 0.95 | 0.62 | 0.77 | 0.66 | 1.75 | 28.33 | 2.66 |
| Ga | 15.38 | 14.32 | 15.80 | 14.16 | 13.91 | 18.07 | 16.76 | 16.86 | 12.20 | 11.51 | 11.63 |
| Rb | 49.38 | 37.24 | 68.22 | 23.95 | 63.25 | 145.88 | 134.66 | 134.37 | 98.92 | 90.20 | 104.91 |
| Sr | 241.79 | 139.63 | 296.88 | 388.33 | 250.11 | 552.27 | 509.28 | 567.71 | 219.66 | 194.77 | 169.12 |
| Y | 21.24 | 24.86 | 25.73 | 20.74 | 22.04 | 34.94 | 34.06 | 34.77 | 19.43 | 17.60 | 18.79 |
| Zr | 74.35 | 117.01 | 104.87 | 89.99 | 93.22 | 219.12 | 213.02 | 216.13 | 164.86 | 165.01 | 136.46 |
| Nb | 2.43 | 3.97 | 4.01 | 3.09 | 3.60 | 8.78 | 8.88 | 9.20 | 5.98 | 6.60 | 6.09 |
| Cs | 3.48 | 1.45 | 0.62 | 0.57 | 0.95 | 4.72 | 4.45 | 4.57 | 0.92 | 0.90 | 1.07 |
| Ba | 265.70 | 229.59 | 271.54 | 135.32 | 311.99 | 883.02 | 857.55 | 836.30 | 1136.58 | 1070.34 | 1207.26 |
| La | 7.57 | 8.22 | 14.43 | 9.99 | 3.72 | 22.75 | 23.72 | 22.97 | 12.82 | 15.95 | 21.58 |
| Ce | 18.11 | 20.41 | 30.22 | 21.50 | 9.82 | 51.75 | 52.99 | 51.02 | 26.28 | 30.38 | 40.04 |
| Pr | 2.54 | 2.72 | 3.51 | 2.65 | 1.29 | 5.97 | 6.05 | 5.96 | 2.96 | 3.29 | 4.36 |
| Nd | 11.92 | 12.89 | 15.18 | 11.71 | 6.17 | 24.70 | 24.74 | 23.88 | 11.34 | 12.40 | 15.86 |
| Sm | 3.16 | 3.50 | 3.73 | 3.01 | 1.80 | 5.29 | 5.32 | 5.27 | 2.57 | 2.43 | 3.02 |
| Eu | 1.20 | 1.08 | 1.32 | 0.89 | 0.54 | 1.17 | 1.11 | 1.13 | 0.83 | 0.72 | 1.02 |
| Gd | 3.33 | 3.81 | 3.95 | 3.16 | 2.08 | 5.18 | 5.13 | 5.11 | 2.47 | 2.18 | 2.77 |
| Tb | 0.55 | 0.63 | 0.66 | 0.54 | 0.38 | 0.83 | 0.83 | 0.85 | 0.44 | 0.37 | 0.43 |
| Dy | 3.59 | 4.13 | 4.30 | 3.50 | 2.99 | 5.36 | 5.28 | 5.46 | 2.93 | 2.50 | 2.76 |
| Ho | 0.77 | 0.90 | 0.90 | 0.73 | 0.73 | 1.15 | 1.13 | 1.13 | 0.64 | 0.57 | 0.62 |
| Er | 2.17 | 2.59 | 2.48 | 2.16 | 2.34 | 3.40 | 3.33 | 3.42 | 1.96 | 1.84 | 1.94 |
| Tm | 0.33 | 0.39 | 0.37 | 0.34 | 0.37 | 0.53 | 0.53 | 0.56 | 0.32 | 0.32 | 0.32 |
| Yb | 2.10 | 2.52 | 2.31 | 2.32 | 2.46 | 3.57 | 3.51 | 3.74 | 2.23 | 2.19 | 2.19 |
| Lu | 0.31 | 0.39 | 0.36 | 0.35 | 0.35 | 0.57 | 0.57 | 0.58 | 0.37 | 0.36 | 0.36 |
| Hf | 1.85 | 3.02 | 2.79 | 2.51 | 2.59 | 5.50 | 5.43 | 5.40 | 4.14 | 4.33 | 3.68 |
| Ta | 0.14 | 0.27 | 0.29 | 0.50 | 0.26 | 0.65 | 0.65 | 0.69 | 0.42 | 0.51 | 0.49 |
| Pb | 3.69 | 1.84 | 1.74 | 5.95 | 1.48 | 4.81 | 4.48 | 4.78 | 1.58 | 0.97 | 1.08 |
| Th | 1.20 | 2.29 | 3.63 | 2.47 | 3.21 | 9.33 | 9.45 | 9.43 | 6.52 | 7.68 | 7.53 |
| U | 0.48 | 0.61 | 0.91 | 0.74 | 0.81 | 2.03 | 1.99 | 2.06 | 1.36 | 1.21 | 1.43 |
| ∑REE | 57.66 | 64.19 | 83.72 | 62.85 | 35.04 | 132.22 | 134.21 | 131.09 | 68.15 | 75.51 | 97.26 |
| LREE | 44.50 | 48.82 | 68.39 | 49.75 | 23.35 | 111.64 | 113.91 | 110.24 | 56.80 | 65.18 | 85.88 |
| HREE | 13.15 | 15.37 | 15.33 | 13.10 | 11.69 | 20.58 | 20.29 | 20.84 | 11.35 | 10.33 | 11.38 |
| (La/Yb)N | 2.43 | 2.19 | 4.21 | 2.90 | 1.02 | 4.30 | 4.55 | 4.14 | 3.88 | 4.90 | 6.64 |
| (La/Sm)N | 1.50 | 1.48 | 2.43 | 2.09 | 1.30 | 2.70 | 2.81 | 2.74 | 3.14 | 4.12 | 4.50 |
| (Gd/Yb)N | 1.28 | 1.22 | 1.38 | 1.10 | 0.68 | 1.17 | 1.18 | 1.10 | 0.89 | 0.80 | 1.02 |
| Zr/Hf | 40.19 | 38.75 | 37.59 | 35.85 | 35.99 | 39.84 | 39.23 | 40.02 | 39.82 | 38.11 | 37.08 |
| Eu/Eu\* | 1.13 | 0.90 | 1.05 | 0.88 | 0.86 | 0.67 | 0.64 | 0.66 | 0.99 | 0.94 | 1.06 |
| δCe | 0.99 | 1.04 | 0.99 | 0.99 | 1.08 | 1.05 | 1.04 | 1.03 | 0.99 | 0.96 | 0.94 |
| 组分 | 19AQS-09 | 19AQS-10 | 19AQS-14 | 19AQS-15 | 19AQS-16 | 19AQS-17 | 19AQS-18 | 19AQS-19 | 19AQS-20 | 19AQS-21 |
| 稀土和微量元素 (×10-6) |
| Li | 9.53 | 0.54 | 6.66 | 10.96 | 18.15 | 12.94 | 19.02 | 14.26 | 20.43 | 5.72 |
| Sc | 8.70 | 5.57 | 5.65 | 8.38 | 7.88 | 18.54 | 23.54 | 23.92 | 24.09 | 18.26 |
| V | 59.73 | 58.54 | 28.05 | 44.07 | 27.08 | 185.96 | 198.51 | 373.36 | 475.53 | 325.02 |
| Ni | 1.91 | 1.89 | 3.11 | 1.80 | 2.38 | 5.77 | 4.73 | 13.30 | 15.57 | 13.58 |
| Co | 4.64 | 5.66 | 1.35 | 2.49 | 7.27 | 15.91 | 12.64 | 24.47 | 27.41 | 24.17 |
| Cu | 1.13 | 0.78 | 1.77 | 1.14 | 0.72 | 2.70 | 0.62 | 0.56 | 0.70 | 0.85 |
| Ga | 12.36 | 10.62 | 11.12 | 15.36 | 12.39 | 17.52 | 18.54 | 17.39 | 17.22 | 12.79 |
| Rb | 3.75 | 3.31 | 44.14 | 70.57 | 22.77 | 98.62 | 39.46 | 68.66 | 44.79 | 37.75 |
| Sr | 121.68 | 89.16 | 126.02 | 201.48 | 63.48 | 369.77 | 661.44 | 439.00 | 434.81 | 283.35 |
| Y | 28.25 | 23.85 | 18.65 | 30.11 | 24.87 | 22.19 | 24.94 | 27.19 | 27.00 | 24.44 |
| Zr | 192.49 | 180.86 | 193.16 | 222.75 | 176.79 | 81.80 | 86.52 | 69.33 | 75.01 | 74.71 |
| Nb | 4.96 | 4.86 | 5.39 | 6.63 | 6.18 | 2.89 | 2.82 | 2.10 | 2.15 | 2.14 |
| Cs | 0.23 | 0.20 | 0.58 | 1.57 | 0.26 | 1.98 | 1.09 | 3.98 | 2.90 | 3.51 |
| Ba | 16.38 | 15.80 | 472.62 | 970.29 | 76.24 | 522.83 | 109.54 | 190.74 | 123.52 | 92.99 |
| La | 8.35 | 3.90 | 21.19 | 16.74 | 8.06 | 8.30 | 10.07 | 6.35 | 7.55 | 3.93 |
| Ce | 19.54 | 12.01 | 29.53 | 34.26 | 18.38 | 19.13 | 21.40 | 16.06 | 18.15 | 10.86 |
| Pr | 2.56 | 1.38 | 4.53 | 3.91 | 2.43 | 2.47 | 2.78 | 2.21 | 2.53 | 1.64 |
| Nd | 11.97 | 6.94 | 16.67 | 15.85 | 10.88 | 11.52 | 12.62 | 11.10 | 12.61 | 8.80 |
| Sm | 3.38 | 2.30 | 3.39 | 3.83 | 2.95 | 3.11 | 3.26 | 3.29 | 3.57 | 2.94 |
| Eu | 0.70 | 0.54 | 0.85 | 0.86 | 0.61 | 0.97 | 1.00 | 1.05 | 1.11 | 0.86 |
| Gd | 3.77 | 2.80 | 2.99 | 4.00 | 3.18 | 3.39 | 3.62 | 3.88 | 4.16 | 3.58 |
| Tb | 0.64 | 0.52 | 0.49 | 0.67 | 0.55 | 0.58 | 0.62 | 0.67 | 0.69 | 0.63 |
| Dy | 4.40 | 3.64 | 3.18 | 4.45 | 3.68 | 3.80 | 4.06 | 4.48 | 4.60 | 4.24 |
| Ho | 0.94 | 0.79 | 0.67 | 0.97 | 0.79 | 0.78 | 0.85 | 0.93 | 0.95 | 0.89 |
| Er | 2.84 | 2.41 | 2.02 | 2.86 | 2.39 | 2.27 | 2.50 | 2.71 | 2.74 | 2.52 |
| Tm | 0.46 | 0.40 | 0.32 | 0.45 | 0.40 | 0.34 | 0.39 | 0.41 | 0.42 | 0.39 |
| Yb | 3.07 | 2.68 | 2.07 | 3.00 | 2.75 | 2.27 | 2.55 | 2.58 | 2.64 | 2.47 |
| Lu | 0.46 | 0.41 | 0.33 | 0.48 | 0.44 | 0.33 | 0.39 | 0.39 | 0.40 | 0.37 |
| Hf | 4.77 | 4.52 | 4.61 | 5.25 | 4.36 | 2.25 | 2.34 | 1.98 | 2.13 | 2.13 |
| Ta | 0.35 | 0.34 | 0.38 | 0.47 | 0.53 | 0.21 | 0.24 | 0.17 | 0.15 | 0.20 |
| Pb | 10.03 | 13.60 | 1.33 | 1.32 | 1.15 | 6.08 | 5.92 | 6.06 | 5.63 | 8.34 |
| Th | 4.04 | 2.89 | 5.39 | 6.01 | 7.41 | 2.13 | 2.63 | 0.93 | 0.95 | 0.93 |
| U | 1.20 | 1.18 | 1.17 | 0.97 | 2.07 | 0.62 | 1.08 | 0.42 | 0.60 | 0.40 |
| ∑REE | 63.09 | 40.73 | 88.24 | 92.32 | 57.48 | 59.26 | 66.10 | 56.12 | 62.12 | 44.09 |
| LREE | 46.50 | 27.08 | 76.17 | 75.45 | 43.31 | 45.50 | 51.12 | 40.07 | 45.52 | 29.02 |
| HREE | 16.59 | 13.65 | 12.07 | 16.87 | 14.17 | 13.76 | 14.98 | 16.05 | 16.59 | 15.07 |
| (La/Yb)N | 1.83 | 0.98 | 6.89 | 3.76 | 1.98 | 2.47 | 2.66 | 1.66 | 1.93 | 1.07 |
| (La/Sm)N | 1.55 | 1.07 | 3.93 | 2.75 | 1.72 | 1.68 | 1.95 | 1.21 | 1.33 | 0.84 |
| (Gd/Yb)N | 0.99 | 0.84 | 1.16 | 1.07 | 0.93 | 1.21 | 1.14 | 1.21 | 1.27 | 1.17 |
| Zr/Hf | 40.35 | 40.01 | 41.90 | 42.43 | 40.55 | 36.36 | 36.97 | 35.02 | 35.22 | 35.08 |
| Eu/Eu\* | 0.60 | 0.65 | 0.80 | 0.67 | 0.60 | 0.91 | 0.89 | 0.89 | 0.88 | 0.81 |
| δCe | 1.01 | 1.24 | 0.69 | 0.99 | 0.99 | 1.01 | 0.96 | 1.03 | 1.00 | 1.03 |

注：Mg#= MgO/(MgO+FeOT),为分子比。

**表4 小东山火山岩全岩Rb-Sr、Sm-Nd 同位素组成**

**Table 4 Rb-Sr and Sm-Nd isotopic analyses for zircon from the Xiaodongshan volcanic rocks**

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **样品编号** | **岩石类型** | **年龄 (Ma)** | **Rb(ppm)** | **Sr(ppm)** | **87Rb/86Sr** | **87Sr/86Sr** | **2σ** | **(87Sr/86Sr)i** |  **Sm(ppm)** | **Nd(ppm)** | **147Sm144Nd** | **143Nd/144Nd** | **2σ** | **(143Nd/144Nd)i** | **εNd(t)** | ***T*DM(Ga)** |
| 19AQS-01 | 英安斑岩 | 308 | 49.4 | 242 | 0.591324  | 0.708406  | 0.000008 | 0.705814 | 3.16  | 11.9  | 0.161457  | 0.512852  | 0.000004 | 0.512527  | 5.57  | 0.87  |
| 19AQS-02 | 308 | 37.2 | 140 | 0.772300  | 0.709179  | 0.000011 | 0.705794 | 3.50  | 12.9  | 0.165048  | 0.512750  | 0.000004 | 0.512417  | 3.43  | 1.25  |
| 19AQS-03 | 308 | 68.2 | 297 | 0.665374  | 0.709264  | 0.000007 | 0.706347 | 3.73  | 15.2  | 0.149537  | 0.512705  | 0.000004 | 0.512403  | 3.16  | 1.06  |
| 19AQS-04 | 308 | 24.0 | 388 | 0.178598  | 0.706419  | 0.000009 | 0.705636 | 3.01  | 11.7  | 0.156284  | 0.512745  | 0.000004 | 0.512430  | 3.68  | 1.07  |
| 19AQS-05 | 308 | 63.2 | 250 | 0.732245  | 0.708793  | 0.000008 | 0.705584 | 1.80  | 6.17  | 0.177485  | 0.512815  | 0.000004 | 0.512457  | 4.20  | 1.41  |
| 19AQS-11 | 308 | 146 | 552 | 0.764873  | 0.709267  | 0.000009 | 0.705914 | 5.29  | 24.7  | 0.130465  | 0.512686  | 0.000004 | 0.512423  | 3.55  | 0.85  |
| 19AQS-12 | 308 | 135 | 509 | 0.765605  | 0.708932  | 0.000008 | 0.705576 | 5.32  | 24.7  | 0.130823  | 0.512695  | 0.000004 | 0.512431  | 3.70  | 0.84  |
| 19AQS-13 | 308 | 134 | 568 | 0.685346  | 0.708702  | 0.000009 | 0.705698 | 5.27  | 23.9  | 0.134424  | 0.512690  | 0.000004 | 0.512419  | 3.47  | 0.88  |
| 19AQS-06 | 花岗斑岩 | 316 | 98.9 | 220 | 1.303975  | 0.712200  | 0.000006 | 0.706335 | 2.57  | 11.3  | 0.138039  | 0.512755  | 0.000004 | 0.512470  | 4.66  | 0.80  |
| 19AQS-07 | 316 | 90.2 | 195 | 1.340998  | 0.711966  | 0.000011 | 0.705935 | 2.43  | 12.4  | 0.119477  | 0.512714  | 0.000005 | 0.512467  | 4.60  | 0.71  |
| 19AQS-08 | 316 | 105 | 169 | 1.796215  | 0.713575  | 0.000008 | 0.705497 | 3.02  | 15.9  | 0.115843  | 0.512718  | 0.000004 | 0.512478  | 4.83  | 0.67  |
| 19AQS-09 | 316 | 44.1 | 126 | 1.014336  | 0.710958  | 0.000009 | 0.706397 | 3.39  | 16.7  | 0.123758  | 0.512743  | 0.000005 | 0.512487  | 5.00  | 0.69  |
| 19AQS-10 | 318 | 70.6 | 201 | 1.014162  | 0.710730  | 0.000008 | 0.706140 | 3.83  | 15.9  | 0.146895  | 0.512771  | 0.000004 | 0.512465  | 4.62  | 0.87  |
| 19AQS-14 | 318 | 3.75 | 122 | 0.089243  | 0.707545  | 0.000007 | 0.707141 | 3.38  | 12.0  | 0.172043  | 0.512879  | 0.000004 | 0.512521  | 5.71  | 0.99  |
| 19AQS-15 | 318 | 3.31 | 89.2 | 0.107572  | 0.706903  | 0.000007 | 0.706416 | 2.30  | 6.94  | 0.201657  | 0.512915  | 0.000004 | 0.512495  | 5.20  | 2.96  |
| 19AQS-16 | 318 | 22.8 | 63.5 | 1.038888  | 0.710807  | 0.000006 | 0.706106 | 2.95  | 10.9  | 0.164774  | 0.512830  | 0.000004 | 0.512487  | 5.05  | 1.00  |
| 19AQS-17 | 安山岩 | 318 | 98.6 | 370 | 0.772283  | 0.707994  | 0.000008 | 0.704499 | 3.11  | 11.5  | 0.164594  | 0.512755  | 0.000005 | 0.512413  | 3.59  | 1.22  |
| 19AQS-18 | 318 | 39.5 | 661 | 0.172737  | 0.706544  | 0.000009 | 0.705762 | 3.26  | 12.6  | 0.157104  | 0.512763  | 0.000004 | 0.512436  | 4.05  | 1.04  |
| 19AQS-21 | 橄榄玄武岩 | 318 | 25.8 | 389 | 0.192103  | 0.707403  | 0.000007 | 0.706534 | 3.22  | 13.4  | 0.146250  | 0.512703  | 0.000004 | 0.512399  | 3.32  | 1.01  |