附表1 天宝碱性火山岩中榍石电子探针分析结果

Supplementary table1 EPMA results of titanite from the Tianbao alkaline volcanic rock

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| --- | --- |
| 样品编号 | 元素含量（wt%） |
| F | Al2O3 | TiO2 | CaO | Y2O3 | Ta2O5 | MnO | Nd2O3 | Na2O | MgO | SiO2 | Cl | Nb2O5 | Fe2O3 | Pr2O3 | Ce2O3 | La2O3 | Total |
| tb14-1-01 | 0.06 | 1.09 | 36.1 | 28.9 | 0.00 | 0.00 | 0.11 | 0.22 | 0.03 | 0.01 | 30.2 | 0.01 | 0.45 | 2.03  | 0.06 | 0.00 | 0.16 | 99.5  |
| tb14-1-02 | 0.52 | 3.24 | 32.9 | 29.4 | 0.00 | 0.00 | 0.00 | 0.17 | 0.06 | 0.01 | 31.5 | 0.01 | 1.17 | 1.45  | 0.15 | 0.00 | 0.02 | 100.6  |
| tb14-2-03 | 0.17 | 1.04 | 34.7 | 26.8 | 0.22 | 0.00 | 0.19 | 0.47 | 0.26 | 0.06 | 29.6 | 0.00 | 1.37 | 2.54  | 0.21 | 1.56 | 0.55 | 99.7  |
| tb14-2-04 | 0.18 | 1.08 | 34.9 | 27.4 | 0.15 | 0.00 | 0.25 | 0.81 | 0.25 | 0.08 | 29.7 | 0.00 | 1.17 | 2.52  | 0.10 | 1.37 | 0.47 | 100.4  |
| tb14-2-05 | 0.33 | 1.21 | 34.3 | 27.7 | 0.15 | 0.00 | 0.17 | 0.43 | 0.18 | 0.10 | 30.0 | 0.00 | 0.80 | 2.67  | 0.20 | 1.26 | 0.40 | 99.8  |
| tb14-2-06 | 0.16 | 1.08 | 33.4 | 26.7 | 0.14 | 0.00 | 0.13 | 0.42 | 0.25 | 0.08 | 29.7 | 0.00 | 1.50 | 2.63  | 0.12 | 1.49 | 0.65 | 98.4  |
| tb14-2-07 | 0.38 | 1.14 | 33.6 | 27.5 | 0.18 | 0.00 | 0.18 | 0.42 | 0.19 | 0.09 | 29.9 | 0.00 | 1.16 | 2.77  | 0.06 | 1.16 | 0.45 | 99.2  |
| tb14-2-08 | 0.19 | 1.25 | 35.6 | 28.4 | 0.17 | 0.00 | 0.11 | 0.15 | 0.06 | 0.05 | 29.8 | 0.00 | 0.48 | 2.15  | 0.01 | 0.20 | 0.16 | 98.8  |
| tb14-2-09 | 1.08 | 4.71 | 30.7 | 29.2 | 0.02 | 0.00 | 0.00 | 0.00 | 0.06 | 0.25 | 31.7 | 0.01 | 1.04 | 2.47  | 0.01 | 0.00 | 0.00 | 101.3  |
| tb14-2-10 | 0.36 | 3.57 | 32.5 | 29.6 | 0.02 | 0.00 | 0.02 | 0.00 | 0.08 | 0.05 | 31.6 | 0.01 | 0.70 | 1.59  | 0.00 | 0.00 | 0.00 | 100.0  |
| tb14-2-11 | 0.24 | 1.11 | 34.4 | 27.5 | 0.17 | 0.00 | 0.25 | 0.46 | 0.17 | 0.08 | 30.0 | 0.00 | 1.07 | 2.59  | 0.14 | 1.06 | 0.49 | 99.7  |
| tb14-2-12 | 0.18 | 1.05 | 34.3 | 27.2 | 0.22 | 0.00 | 0.18 | 0.48 | 0.28 | 0.08 | 29.5 | 0.01 | 1.50 | 2.59  | 0.06 | 1.42 | 0.61 | 99.6  |
| tb14-2-13 | 0.74 | 3.98 | 33.2 | 30.2 | 0.00 | 0.00 | 0.01 | 0.09 | 0.03 | 0.01 | 31.7 | 0.00 | 0.19 | 1.34  | 0.02 | 0.00 | 0.00 | 101.5  |
| tb14-2-14 | 0.37 | 3.39 | 34.5 | 29.6 | 0.00 | 0.00 | 0.00 | 0.06 | 0.00 | 0.15 | 31.8 | 0.00 | 0.32 | 1.07  | 0.00 | 0.00 | 0.01 | 101.3  |
| tb14-2-15 | 0.53 | 3.59 | 33.9 | 30.1 | 0.03 | 0.00 | 0.00 | 0.00 | 0.05 | 0.12 | 31.8 | 0.01 | 0.26 | 1.33  | 0.00 | 0.00 | 0.03 | 101.7  |
| tb14-2-16 | 0.75 | 3.68 | 32.6 | 29.8 | 0.08 | 0.00 | 0.00 | 0.14 | 0.06 | 0.01 | 31.5 | 0.00 | 0.95 | 1.43  | 0.00 | 0.00 | 0.00 | 100.9  |
| tb14-2-17 | 0.48 | 3.41 | 32.3 | 29.2 | 0.04 | 0.00 | 0.01 | 0.12 | 0.07 | 0.03 | 31.4 | 0.00 | 0.93 | 1.13  | 0.03 | 0.00 | 0.00 | 99.1  |
| tb3-3-01 | 0.39 | 3.90 | 32.8 | 30.0 | 0.00 | 0.00 | 0.03 | 0.00 | 0.05 | 0.00 | 31.8 | 0.03 | 0.10 | 1.66  | 0.00 | 0.00 | 0.01 | 100.7  |
| tb3-3-02 | 0.01 | 2.47 | 35.8 | 29.7 | 0.05 | 0.00 | 0.00 | 0.07 | 0.01 | 0.15 | 31.5 | 0.00 | 0.37 | 1.08  | 0.00 | 0.00 | 0.00 | 101.1  |
| tb3-4-03 | 0.75 | 3.97 | 33.6 | 30.0 | 0.03 | 0.00 | 0.01 | 0.20 | 0.07 | 0.02 | 31.5 | 0.00 | 0.08 | 1.18  | 0.00 | 0.00 | 0.00 | 101.5  |
| tb3-4-04 | 0.09 | 2.51 | 36.4 | 30.0 | 0.00 | 0.00 | 0.00 | 0.00 | 0.03 | 0.00 | 31.2 | 0.00 | 0.46 | 0.27  | 0.01 | 0.00 | 0.00 | 101.0  |
| tb3-5-05 | 0.01 | 2.54 | 35.0 | 29.8 | 0.00 | 0.00 | 0.01 | 0.09 | 0.01 | 0.01 | 31.5 | 0.01 | 0.08 | 1.11  | 0.00 | 0.00 | 0.07 | 100.2  |
| tb3-5-06 | 0.43 | 4.16 | 32.8 | 30.2 | 0.02 | 0.00 | 0.00 | 0.00 | 0.02 | 0.00 | 31.7 | 0.00 | 0.04 | 1.20  | 0.06 | 0.00 | 0.00 | 100.7  |
| tb3-5-08 | 0.64 | 4.31 | 32.5 | 30.5 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.02 | 31.7 | 0.02 | 0.08 | 1.18  | 0.01 | 0.00 | 0.00 | 101.0  |
| tb3-5-09 | 0.77 | 4.14 | 33.1 | 30.3 | 0.01 | 0.00 | 0.00 | 0.03 | 0.00 | 0.02 | 31.9 | 0.00 | 0.06 | 1.28  | 0.00 | 0.00 | 0.00 | 101.6  |
| tb3-5-10 | 0.36 | 4.25 | 31.1 | 29.6 | 0.00 | 0.00 | 0.04 | 0.14 | 0.17 | 0.08 | 31.9 | 0.00 | 0.01 | 1.88  | 0.02 | 0.00 | 0.00 | 99.5  |
| tb3-5-11 | 0.21 | 3.07 | 34.7 | 30.0 | 0.02 | 0.00 | 0.00 | 0.00 | 0.03 | 0.00 | 31.4 | 0.00 | 0.08 | 1.00  | 0.00 | 0.00 | 0.01 | 100.6  |
| tb8-1-01 | 0.04 | 1.00 | 36.3 | 29.2 | 0.04 | 0.00 | 0.03 | 0.09 | 0.04 | 0.02 | 30.4 | 0.00 | 0.12 | 1.46  | 0.06 | 0.00 | 0.03 | 98.8  |
| tb8-1-03 | 0.00 | 0.88 | 36.8 | 29.1 | 0.07 | 0.00 | 0.10 | 0.10 | 0.05 | 0.04 | 30.4 | 0.00 | 0.21 | 1.05  | 0.00 | 0.00 | 0.02 | 98.9  |
| tb8-1-04 | 0.00 | 1.70 | 37.6 | 29.7 | 0.00 | 0.00 | 0.01 | 0.11 | 0.00 | 0.00 | 31.2 | 0.00 | 0.08 | 0.46  | 0.02 | 0.00 | 0.00 | 100.9  |
| tb8-2-05 | 0.12 | 1.41 | 36.7 | 28.7 | 0.11 | 0.00 | 0.05 | 0.00 | 0.00 | 0.05 | 29.8 | 0.00 | 0.32 | 1.50  | 0.00 | 0.12 | 0.08 | 98.9  |
| tb8-2-06 | 0.01 | 1.24 | 37.3 | 28.7 | 0.11 | 0.00 | 0.00 | 0.35 | 0.03 | 0.07 | 29.6 | 0.01 | 0.38 | 1.29  | 0.00 | 0.28 | 0.07 | 99.5  |
| tb8-2-07 | 0.00 | 1.11 | 38.4 | 30.0 | 0.02 | 0.00 | 0.02 | 0.00 | 0.02 | 0.00 | 31.1 | 0.01 | 0.18 | 0.64  | 0.08 | 0.00 | 0.00 | 101.6  |
| tb8-2-08 | 0.13 | 2.65 | 33.0 | 28.6 | 0.00 | 0.00 | 0.00 | 0.00 | 0.17 | 0.16 | 31.6 | 0.02 | 0.19 | 2.45  | 0.05 | 0.00 | 0.00 | 99.0  |
| tb8-3-09 | 0.17 | 1.36 | 37.1 | 29.3 | 0.17 | 0.00 | 0.04 | 0.09 | 0.04 | 0.06 | 30.1 | 0.00 | 0.23 | 1.26  | 0.00 | 0.14 | 0.09 | 100.2  |
| tb8-3-10 | 0.11 | 1.37 | 37.7 | 29.3 | 0.10 | 0.00 | 0.05 | 0.00 | 0.04 | 0.07 | 29.9 | 0.00 | 0.22 | 1.48  | 0.00 | 0.07 | 0.04 | 100.5  |
| tb8-3-12 | 0.37 | 3.14 | 33.4 | 29.6 | 0.00 | 0.00 | 0.02 | 0.00 | 0.05 | 0.13 | 31.5 | 0.00 | 0.20 | 1.75  | 0.00 | 0.00 | 0.00 | 100.2  |
| tb8-4-13 | 0.00 | 1.08 | 37.8 | 29.0 | 0.12 | 0.00 | 0.01 | 0.01 | 0.00 | 0.05 | 29.9 | 0.00 | 0.42 | 1.32  | 0.08 | 0.13 | 0.01 | 99.9  |
| tb8-4-15 | 0.00 | 3.09 | 33.4 | 26.4 | 0.05 | 0.00 | 0.04 | 0.04 | 0.01 | 0.90 | 30.9 | 0.00 | 0.16 | 3.58  | 0.00 | 0.00 | 0.00 | 98.5  |
| tb8-4-16 | 0.03 | 1.26 | 37.1 | 29.3 | 0.00 | 0.00 | 0.07 | 0.15 | 0.00 | 0.04 | 30.2 | 0.01 | 0.47 | 1.33  | 0.01 | 0.14 | 0.04 | 100.1  |
| tb8-4-17 | 0.60 | 3.37 | 32.9 | 29.7 | 0.03 | 0.00 | 0.00 | 0.00 | 0.06 | 0.11 | 31.0 | 0.00 | 0.16 | 1.75  | 0.02 | 0.00 | 0.03 | 99.8  |
| zk116-1-01 | 0.00 | 0.64 | 39.2 | 29.8 | 0.02 | 0.00 | 0.02 | 0.00 | 0.00 | 0.00 | 30.9 | 0.01 | 0.13 | 0.28  | 0.08 | 0.00 | 0.00 | 101.1  |
| zk116-1-02 | 0.00 | 0.56 | 39.3 | 29.9 | 0.17 | 0.00 | 0.00 | 0.03 | 0.00 | 0.00 | 31.0 | 0.01 | 0.20 | 0.40  | 0.00 | 0.00 | 0.00 | 101.6  |
| zk116-1-03 | 0.00 | 0.61 | 39.5 | 30.0 | 0.06 | 0.00 | 0.03 | 0.00 | 0.06 | 0.05 | 30.9 | 0.00 | 0.21 | 0.35  | 0.00 | 0.00 | 0.00 | 101.8  |
| zk116-2-04 | 0.11 | 1.48 | 35.9 | 28.3 | 0.25 | 0.00 | 0.12 | 0.47 | 0.03 | 0.07 | 29.8 | 0.00 | 0.57 | 1.69  | 0.12 | 0.52 | 0.18 | 99.5  |
| zk116-2-05 | 0.00 | 1.42 | 37.0 | 28.8 | 0.17 | 0.00 | 0.11 | 0.38 | 0.00 | 0.08 | 29.9 | 0.01 | 0.29 | 1.66  | 0.17 | 0.32 | 0.06 | 100.3  |
| zk116-3-06 | 0.00 | 0.63 | 39.3 | 30.2 | 0.00 | 0.00 | 0.00 | 0.00 | 0.02 | 0.00 | 31.0 | 0.01 | 0.16 | 0.29  | 0.01 | 0.00 | 0.02 | 101.7  |
| zk116-3-07 | 0.00 | 0.62 | 39.1 | 30.0 | 0.05 | 0.00 | 0.01 | 0.00 | 0.02 | 0.00 | 31.1 | 0.00 | 0.22 | 0.29  | 0.19 | 0.00 | 0.00 | 101.6  |
| zk116-4-08 | 0.00 | 0.65 | 39.0 | 29.9 | 0.09 | 0.00 | 0.04 | 0.21 | 0.00 | 0.11 | 31.3 | 0.01 | 0.17 | 0.48  | 0.23 | 0.00 | 0.00 | 102.2  |
| zk116-4-09 | 0.00 | 0.57 | 39.2 | 29.5 | 0.00 | 0.00 | 0.02 | 0.06 | 0.02 | 0.00 | 31.3 | 0.01 | 0.13 | 0.59  | 0.15 | 0.00 | 0.00 | 101.6  |
| zk116-6-10 | 0.00 | 0.51 | 39.5 | 30.0 | 0.00 | 0.00 | 0.00 | 0.03 | 0.02 | 0.02 | 31.3 | 0.00 | 0.22 | 0.39  | 0.00 | 0.00 | 0.00 | 102.0  |
| zk116-6-11 | 0.00 | 0.49 | 39.5 | 30.0 | 0.06 | 0.00 | 0.03 | 0.00 | 0.04 | 0.02 | 31.1 | 0.00 | 0.22 | 0.40  | 0.01 | 0.00 | 0.00 | 101.9  |
| zk116-8-12 | 0.00 | 0.60 | 39.3 | 30.1 | 0.01 | 0.00 | 0.02 | 0.00 | 0.01 | 0.01 | 31.0 | 0.00 | 0.20 | 0.22  | 0.09 | 0.00 | 0.00 | 101.5  |
| zk116-8-13 | 0.00 | 0.59 | 38.9 | 30.1 | 0.04 | 0.00 | 0.00 | 0.11 | 0.02 | 0.00 | 31.0 | 0.01 | 0.19 | 0.21  | 0.03 | 0.00 | 0.00 | 101.2  |
| zk37-1-01 | 0.14 | 1.10 | 35.1 | 26.8 | 0.32 | 0.00 | 0.25 | 0.80 | 0.30 | 0.12 | 29.4 | 0.01 | 0.82 | 2.18  | 0.33 | 1.38 | 0.46 | 99.5  |
| zk37-1-02 | 0.08 | 0.95 | 34.4 | 26.2 | 0.33 | 0.00 | 0.12 | 0.82 | 0.31 | 0.12 | 29.2 | 0.00 | 1.37 | 2.42  | 0.16 | 1.84 | 0.60 | 98.9  |
| zk37-1-03 | 0.12 | 1.05 | 35.1 | 26.8 | 0.31 | 0.00 | 0.17 | 0.71 | 0.29 | 0.12 | 29.5 | 0.02 | 0.85 | 2.13  | 0.28 | 1.23 | 0.41 | 99.1  |
| zk37-2-04 | 0.00 | 0.97 | 35.5 | 26.9 | 0.26 | 0.00 | 0.14 | 0.74 | 0.26 | 0.09 | 29.7 | 0.01 | 0.77 | 2.15  | 0.16 | 1.35 | 0.47 | 99.4  |
| zk37-3-05 | 0.25 | 1.05 | 34.5 | 26.6 | 0.13 | 0.00 | 0.19 | 0.38 | 0.26 | 0.10 | 29.4 | 0.01 | 0.90 | 2.24  | 0.22 | 1.31 | 0.44 | 98.0  |
| zk37-3-06 | 0.12 | 1.01 | 34.2 | 26.4 | 0.31 | 0.00 | 0.17 | 0.33 | 0.31 | 0.11 | 29.3 | 0.01 | 1.03 | 2.26  | 0.16 | 1.39 | 0.50 | 97.6  |
| zk37-4-07 | 0.19 | 1.06 | 35.1 | 27.0 | 0.30 | 0.00 | 0.19 | 0.50 | 0.31 | 0.12 | 29.6 | 0.00 | 0.91 | 2.41  | 0.15 | 1.45 | 0.52 | 99.7  |
| zk51-1-01 | 0.21 | 1.07 | 34.8 | 26.6 | 0.30 | 0.00 | 0.22 | 0.72 | 0.25 | 0.12 | 29.5 | 0.01 | 0.89 | 2.30  | 0.35 | 1.24 | 0.41 | 99.0  |
| zk51-1-02 | 0.05 | 0.98 | 34.9 | 26.4 | 0.26 | 0.00 | 0.19 | 0.74 | 0.35 | 0.09 | 29.4 | 0.00 | 1.10 | 1.94  | 0.36 | 1.60 | 0.60 | 99.0  |
| zk51-2-03 | 0.19 | 1.04 | 34.1 | 26.5 | 0.33 | 0.00 | 0.13 | 0.74 | 0.28 | 0.11 | 29.3 | 0.01 | 0.94 | 2.45  | 0.01 | 1.23 | 0.50 | 97.8  |
| zk51-2-04 | 0.07 | 0.99 | 34.4 | 26.2 | 0.37 | 0.00 | 0.21 | 0.63 | 0.35 | 0.11 | 29.1 | 0.00 | 1.15 | 2.25  | 0.23 | 1.59 | 0.49 | 98.2  |
| zk51-2-05 | 0.10 | 0.74 | 36.5 | 27.5 | 0.27 | 0.00 | 0.04 | 0.04 | 0.67 | 0.02 | 30.8 | 0.01 | 0.83 | 1.72  | 0.02 | 0.00 | 0.00 | 99.3  |
| zk51-3-06 | 0.27 | 1.12 | 34.9 | 26.8 | 0.25 | 0.00 | 0.22 | 0.36 | 0.25 | 0.13 | 29.5 | 0.00 | 0.74 | 2.33  | 0.12 | 1.41 | 0.41 | 98.9  |
| zk51-3-07 | 0.00 | 0.98 | 34.8 | 26.4 | 0.35 | 0.00 | 0.28 | 0.72 | 0.38 | 0.11 | 29.2 | 0.01 | 0.96 | 2.25  | 0.34 | 1.82 | 0.55 | 99.2  |
| zk51-4-08 | 0.17 | 1.02 | 34.3 | 26.9 | 0.29 | 0.00 | 0.24 | 0.68 | 0.30 | 0.07 | 29.2 | 0.00 | 1.01 | 2.39  | 0.05 | 1.23 | 0.42 | 98.3  |
| zk51-4-09 | 0.14 | 1.04 | 34.3 | 26.7 | 0.25 | 0.00 | 0.14 | 0.61 | 0.34 | 0.12 | 29.5 | 0.01 | 1.12 | 2.24  | 0.26 | 1.43 | 0.48 | 98.7  |
| zk51-5-10 | 0.14 | 1.04 | 34.7 | 26.8 | 0.24 | 0.00 | 0.13 | 0.47 | 0.23 | 0.09 | 29.7 | 0.00 | 0.88 | 2.34  | 0.23 | 1.30 | 0.44 | 98.7  |
| zk51-5-11 | 0.00 | 0.91 | 34.3 | 26.0 | 0.35 | 0.00 | 0.15 | 1.21 | 0.35 | 0.09 | 29.6 | 0.00 | 1.08 | 2.24  | 0.18 | 1.76 | 0.55 | 98.7  |
| zk51-6-12 | 0.15 | 1.06 | 35.1 | 26.8 | 0.42 | 0.00 | 0.14 | 0.57 | 0.28 | 0.08 | 29.6 | 0.00 | 0.86 | 2.34  | 0.10 | 1.37 | 0.32 | 99.2  |
| zk51-6-13 | 0.19 | 1.03 | 33.4 | 26.6 | 0.23 | 0.00 | 0.19 | 0.39 | 0.38 | 0.11 | 29.6 | 0.00 | 1.22 | 2.47  | 0.33 | 1.11 | 0.49 | 97.8  |
| zk51-6-14 | 0.17 | 1.18 | 36.6 | 27.1 | 0.20 | 0.00 | 0.10 | 0.37 | 0.80 | 0.06 | 31.5 | 0.01 | 0.72 | 1.66  | 0.12 | 0.10 | 0.00 | 100.7  |
| zk51-8-15 | 0.18 | 0.43 | 37.2 | 28.1 | 0.07 | 0.00 | 0.04 | 0.07 | 0.61 | 0.00 | 30.9 | 0.01 | 0.66 | 2.22  | 0.00 | 0.00 | 0.00 | 100.5  |
| zk51-9-16 | 0.14 | 0.83 | 36.6 | 27.2 | 0.10 | 0.00 | 0.06 | 0.22 | 0.67 | 0.15 | 31.0 | 0.01 | 0.89 | 2.07  | 0.04 | 0.03 | 0.01 | 100.0  |
| zk51-9-17 | 0.00 | 0.47 | 36.9 | 27.7 | 0.32 | 0.00 | 0.02 | 0.33 | 0.85 | 0.00 | 30.9 | 0.00 | 0.95 | 1.86  | 0.11 | 0.21 | 0.05 | 100.7  |