|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Table S1** Chemical composition of hydrothermal gas along the Y-shaped fault system in the ETP. | | | | | | | | | | | | | | | | | |  |
| No. | Sample ID | Location | Data | Latitude | Longitude | T | Fault domain | N2 | O2 | | | CO2 | CH4 | | | Ar | He | Distance to fault |
| (°N) | (°E) | (°C) | (%) | | (%) | (%) | | | (%) | (%) | | (ppm) | (km) |
| 1 | QEL-1 | Qiaoelong (QEL) | 09/2020 | 32.363 | 98.298 | 48.5 | YGXFS (YGF) | 72.8 | 0.65 | | | 25.6 | 0.33 | | | 0.61 | 809 | 4.3 |
| QEL-2 | Qiaoelong (QEL) | 09/2020 | 32.363 | 98.298 | 48.5 | 75.3 | 0.78 | | | 22.9 | 0.34 | | | 0.67 | 589 | 4.3 |
| 2 | QR-1 | Quran (QR) | 09/2020 | 32.363 | 98.287 | 58.2 | 45.1 | 0.53 | | | 52.7 | 1.08 | | | 0.60 | 474 | 3.7 |
| QR-2 | Quran (QR) | 09/2020 | 32.363 | 98.287 | 58.2 | 45.5 | 0.58 | | | 52.3 | 1.09 | | | 0.54 | 498 | 3.7 |
| 3 | MR-1 | Marong (MR) | 09/2020 | 32.221 | 98.406 | 40.7 | 4.63 | 0.67 | | | 94.6 | 0.01 | | | 0.05 | 6.50 | -3.0 |
| MR-2 | Marong (MR) | 09/2020 | 32.221 | 98.406 | 40.7 | 9.54 | 2.10 | | | 88.2 | 0.01 | | | 0.10 | 6.20 | -3.0 |
| 4 | PW-1 | Queershan (PW) | 09/2020 | 31.956 | 98.860 | 33.8 | 2.12 | 0.56 | | | 97.3 | <0.01 | | | 0.02 | 0.1 | -15.3 |
| PW-2 | Queershan (PW) | 09/2020 | 31.956 | 98.860 | 33.8 | 3.70 | 0.84 | | | 95.4 | <0.01 | | | 0.03 | 0.1 | -15.3 |
| 5 | MN-1 | Maniganga (MN) | 09/2020 | 31.956 | 99.159 | 32.6 | 3.71 | 0.47 | | | 95.7 | 0.12 | | | 0.03 | 9.7 | -3.7 |
| MN-2 | Maniganga (MN) | 09/2020 | 31.956 | 99.159 | 32.6 | 3.58 | 0.52 | | | 95.8 | 0.07 | | | 0.02 | 9.4 | -3.7 |
| 6 | MDK-1 | Madake (MDK) | 09/2020 | 31.826 | 99.439 | 39.4 | 11.7 | 0.64 | | | 87.1 | 0.34 | | | 0.15 | 44 | -2.3 |
| MDK-2 | Madake (MDK) | 09/2020 | 31.826 | 99.439 | 39.4 | 10.8 | 0.49 | | | 88.1 | 0.43 | | | 0.15 | 37 | -2.3 |
| 7 | ZKX-1 | Zakexiang (ZKX) | 09/2020 | 31.902 | 99.640 | 28.4 | 8.35 | 0.86 | | | 89.5 | 1.19 | | | 0.07 | 121 | 15.0 |
| ZKX-2 | Zakexiang (ZKX) | 09/2020 | 31.902 | 99.640 | 28.4 | 6.58 | 0.62 | | | 92.1 | 0.63 | | | 0.06 | 111 | 15.0 |
| 8 | MYX-1 | Mayulongxi (MYX) | 09/2020 | 31.788 | 99.699 | 40.0 | 22.2 | 0.36 | | | 32.5 | 44.7 | | | 0.26 | 1153 | 6.1 |
| MYX-2 | Mayulongxi (MYX) | 09/2020 | 31.788 | 99.699 | 40.0 | 26.0 | 0.14 | | | 32.1 | 41.4 | | | 0.32 | 1442 | 6.1 |
| 9 | MYD-1 | Mayulongdong (MYD) | 09/2020 | 31.786 | 99.699 | 46.3 | 35.4 | 0.48 | | | 59.7 | 4.00 | | | 0.44 | 2065 | 6.0 |
| MYD-2 | Mayulongdong (MYD) | 09/2020 | 31.786 | 99.699 | 46.3 | 32.2 | 0.19 | | | 63.7 | 3.53 | | | 0.36 | 2087 | 6.0 |
| 10 | LM-1 | Laimajiake (LM) | 09/2020 | 31.688 | 99.778 | 39.4 | 90.2 | 8.62 | | | 0.48 | <0.01 | | | 0.70 | 25 | -2.6 |
| LM-2 | Laimajiake (LM) | 09/2020 | 31.688 | 99.778 | 39.4 | 90.2 | 8.76 | | | 0.35 | <0.01 | | | 0.72 | 34 | -2.6 |
| 11 | DDL-1 | Dingdalong (DDL) | 09/2020 | 31.674 | 99.728 | 13.4 | 31.3 | 0.95 | | | 64.5 | 2.89 | | | 0.35 | 441 | 4.0 |
| DDL-2 | Dingdalong (DDL) | 09/2020 | 31.674 | 99.728 | 13.4 | 33.3 | 1.38 | | | 62.0 | 2.96 | | | 0.36 | 459 | 4.0 |
| 12 | GYG-1 | Ganzi (GYG) | 09/2020 | 31.583 | 100.043 | 15.5 | 10.4 | 1.00 | | | 83.9 | 4.66 | | | 0.07 | 158 | 2.3 |
| GYG-2 | Ganzi (GYG) | 09/2020 | 31.583 | 100.043 | 15.5 | 15.0 | 2.53 | | | 78.0 | 4.33 | | | 0.13 | 150 | 2.3 |
| 13 | JX-01 | Jiaxicun (JX) | 09/2020 | 31.356 | 100.230 | 15.5 | 2.76 | 0.16 | | | 96.5 | 0.51 | | | 0.01 | 15 | -25.2 |
| JX-2 | Jiaxicun (JX) | 09/2020 | 31.356 | 100.230 | 15.5 | 3.46 | 0.57 | | | 95.3 | 0.68 | | | 0.03 | 15 | -25.2 |
| 14 | JY-1 | Jiayi (JY) | 09/2020 | 31.602 | 100.767 | 18.4 | YGXFS  (XSF) | 2.62 | 0.62 | | | 96.7 | <0.01 | | | 0.02 | 0.5 |  |
| JY-2 | Jiayi (JY) | 09/2020 | 31.602 | 100.767 | 18.4 | 3.11 | 0.84 | | | 96.0 | 0.01 | | | 0.03 | 0.5 | 23.4 |
| 15 | YD-1 | Yade (YD) | 09/2020 | 31.458 | 100.574 | 27.5 | 45.0 | 0.22 | | | 54.2 | 0.15 | | | 0.44 | 513 | 0 |
| YD-2 | Yade (YD) | 09/2020 | 31.458 | 100.574 | 27.5 | 47.2 | 0.59 | | | 51.6 | 0.16 | | | 0.50 | 537 | 0 |
| 16 | GK-1 | Geka (GK) | 09/2020 | 30.862 | 101.288 | 32.4 | 15.1 | 0.66 | | | 83.8 | 0.20 | | | 0.17 | 86.0 | 2.2 |
| GK-2 | Geka (GK) | 09/2020 | 30.862 | 101.288 | 32.4 | 15.1 | 0.71 | | | 83.8 | 0.19 | | | 0.17 | 86.0 | 2.2 |
| 17 | KM-1 | Kama (KM) | 09/2020 | 30.486 | 101.532 | 26.6 | 24.8 | 0.44 | | | 72.6 | 1.94 | | | 0.24 | 205 | 2.5 |
| KM-2 | Kama (KM) | 09/2020 | 30.486 | 101.532 | 26.6 | 24.0 | 0.89 | | | 73.0 | 1.91 | | | 0.25 | 176 | 2.5 |
| 18 | BM-1 | Bamei (BM) | 09/2020 | 30.532 | 101.618 | 51.2 | 3.03 | 0.46 | | | 96.1 | 0.37 | | | 0.02 | 3.5 | 0 |
| BM-2 | Bamei (BM) | 09/2020 | 30.532 | 101.618 | 51.2 | 4.26 | 0.92 | | | 94.3 | 0.47 | | | 0.03 | 3.6 | 0 |
| 19 | EDQ-1 | Erdaoqiao (EDQ) | 09/2020 | 30.087 | 101.950 | 40.8 | 4.14 | 0.29 | | | 95 | 0.07 | | | 0.04 | 5.9 | 0 |
| EDQ-2 | Erdaoqiao (EDQ) | 09/2020 | 30.087 | 101.950 | 40.8 | 6.38 | 0.81 | | | 93 | 0.09 | | | 0.06 | 7.6 | 0 |
| EDQ-18 | Erdaoqiao (EDQ) | 09/2015 | 30.088 | 102.242 | 41.0 | - | - | | | - | - | | | - | - | 0 |
| 20 | LTG-1 | Longtougou (LTG) | 09/2020 | 29.979 | 101.957 | 71.9 | 2.21 | 0.55 | | | 97.1 | 0.08 | | | 0.02 | 0.8 | 0 |
| LTG-2 | Longtougou (LTG) | 09/2020 | 29.979 | 101.957 | 71.9 | 7.08 | 2.12 | | | 90.6 | 0.11 | | | 0.07 | 0.7 | 0 |
| 21 | GD-1 | Guanding (GD) | 09/2020 | 29.952 | 101.961 | 76.0 | 6.81 | 1.76 | | | 91.0 | 0.36 | | | 0.06 | 4.5 | 0 |
| GD-2 | Guanding (GD) | 09/2020 | 29.952 | 101.961 | 76.0 | 5.86 | 1.36 | | | 92.4 | 0.34 | | | 0.05 | 4.8 | 0 |
| 22 | XX-1 | Xinxinxiang (XX) | 09/2015 | 29.754 | 102.060 | 46.0 | - | - | | | - | - | | | - | - | 0 |
| 23 | HM-12 | Hongmo (HM) | 09/2015 | 28.088 | 102.242 | 50.0 | ANFS | - | - | | | - | - | | | - | - | 5.7 |
| 24 | SQC-1 | Shangqingcun (SQC) | 09/2020 | 31.614 | 104.349 | 19.3 | LMFS | 64.6 | 0.27 | | | 0.94 | 33.6 | | | 0.47 | 1249 | 5.9 |
| SQC-2 | Shangqingcun (SQC) | 09/2020 | 31.614 | 104.349 | 19.3 | 64.3 | 0.21 | | | 0.99 | 33.8 | | | 0.57 | 1259 | 5.9 |
| 25 | JYG-1 | Jiyugou (JYG) | 09/2020 | 31.627 | 103.771 | 26.0 | 93.2 | 0.14 | | | 5.69 | 0.12 | | | 0.71 | 186 | 0.9 |
| 26 | MCG-1 | Muchengou (MCG) | 09/2020 | 31.525 | 103.003 | 43.2 | 96.9 | 0.11 | | | 1.41 | 0.27 | | | 1.27 | 793 | -50.6 |

*Note:* YGXFS, Yushu-Ganzi-Xianshuihe fault system; YGF, Yushu-Ganzi fault; XSF, Xianshuihe fault; ANFS, Anninghe fault system; LMFS, Longmenshan fault system.

**Table S2** Isotopic composition of hydrothermal gas along the Y-shaped fault system in the ETP.

|  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| No. | Sample ID | 4He/20Ne | Xmb | Rm/Raa | Rc/Rac | CO2/3Hed | δ13CCH4 | δ13CCO2 | Mantle He | Carbon inventoryf | | |
| (109) | (‰) | (‰) | (%) | M (%) | L (%) | S (%) |
| 1 | QEL-1 | 50 | 192 | 0.13 | 0.13 | 1.8 | - | -8.8 | 1.32 | - | - | - |
| QEL-2 | 52 | 199 | 0.13 | 0.13 | 2.2 | - | -8.2 | 1.32 | - | - | - |
| 2 | QR-1 | 50 | 192 | 0.12 | 0.12 | 6.9 | -37.7 | -7.9 | 1.19 | - | - | - |
| QR-2 | 49 | 188 | 0.12 | 0.12 | 6.5 | -30.0 | -6.9 | 1.19 | - | - | - |
| 3 | MR-1 | 36 | 138 | 0.37 | 0.37 | 287 | - | -4.6 | 4.33 | 0.7 | 84.1 | 15.2 |
| MR-2 | 34 | 130 | 0.41 | 0.41 | 253 | - | -4.0 | 4.83 | 0.7 | 86.1 | 13.2 |
| 4 | PW-1 | - | - | - | - | - | - | -4.1 | - | - | - | - |
| PW-2 | 1.7 | 6.5 | 0.36 | 0.24 | - | - | -3.7 | 2.81 | - | - | - |
| 5 | MN-1 | 95 | 364 | 0.17 | 0.17 | 423 | - | -4.8 | 1.85 | 0.5 | 83.6 | 15.9 |
| MN-2 | 99 | 380 | 0.18 | 0.18 | 412 | - | -4.9 | 1.98 | 0.5 | 83.3 | 16.2 |
| 6 | MDK-1 | 42 | 161 | 0.04 | 0.03 | 420 | - | -7.0 | 0.17 | 0.5 | 76.3 | 23.2 |
| MDK-2 | 30 | 115 | 0.04 | 0.03 | 544 | -19.4 | -7.1 | 0.14 | 0.3 | 76.1 | 23.6 |
| 7 | ZKX-1 | 220 | 844 | 0.12 | 0.12 | 45 | -38.8 | -3.1 | 1.24 | 4.4 | 86.2 | 9.4 |
| ZKX-2 | 255 | 978 | 0.12 | 0.12 | 50 | -29.7 | -3.6 | 1.24 | 4.0 | 84.9 | 11.1 |
| 8 | MYX-1 | 397 | 1523 | 0.04 | 0.04 | 5.2 | -49.0 | -8.4 | 0.24 | - | - | - |
| MYX-2 | 374 | 1435 | 0.04 | 0.04 | 4.1 | -48.9 | -8.9 | 0.24 | - | - | - |
| 9 | MYD-1 | 433 | 1661 | 0.04 | 0.04 | 5.3 | -26.8 | -6.2 | 0.24 | - | - | - |
| MYD-2 | 431 | 1654 | 0.04 | 0.04 | 5.5 | -25.8 | -5.3 | 0.25 | - | - | - |
| 10 | LM-1 | 2.3 | 8.8 | 0.45 | 0.38 | 0.4 | - | -5.9 | 4.50 | - | - | - |
| LM-2 | 2.0 | 7.7 | 0.41 | 0.32 | 0.2 | - | -5.9 | 3.77 | - | - | - |
| 11 | DDL-1 | 92 | 353 | 0.08 | 0.08 | 14 | -24.4 | -4.9 | 0.72 | - | - | - |
| DDL-2 | 91 | 349 | 0.07 | 0.07 | 14 | -22.2 | -4.8 | 0.59 | - | - | - |
| 12 | GYG-1 | 184 | 706 | 0.18 | 0.18 | 21 | -26.2 | -3.7 | 1.99 | - | - | - |
| GYG-2 | 200 | 767 | 0.21 | 0.21 | 18 | -25.8 | -4.0 | 2.37 | - | - | - |
| 13 | JX-01 | 153 | 587 | 0.13 | 0.13 | 360 | -32.8 | -0.7 | 1.36 | 0.5 | 97.3 | 2.2 |
| JX-2 | 164 | 629 | 0.12 | 0.12 | 385 | -32.9 | -1.2 | 1.24 | 0.5 | 95.6 | 3.9 |
| 14 | JY-1 | 3.7 | 14 | 0.61 | 0.58 | 2399 | - | -0.2 | 7.02 | 0.1 | 99.3 | 0.6 |
| JY-2 | 3.4 | 13 | 0.65 | 0.62 | 2226 | - | -2.3 | 7.53 | 0.1 | 92.3 | 7.6 |
| 15 | YD-1 | 75 | 288 | 0.21 | 0.21 | 3.7 | - | -2.6 | 2.35 | - | - | - |
| YD-2 | 60 | 230 | 0.21 | 0.21 | 3.3 | - | -3.1 | 2.34 | - | - | - |
| 16 | GK-1 | 58 | 223 | 0.10 | 0.10 | 73 | - | -5.4 | 0.95 | 2.7 | 79.9 | 17.4 |
| GK-2 | 58 | 223 | 0.12 | 0.12 | 60 | - | -5.3 | 1.20 | 3.3 | 79.8 | 16.9 |
| 17 | KM-1 | 58 | 223 | 0.24 | 0.24 | 11 | -18.1 | -4.4 | 2.71 | - | - | - |
| KM-2 | 59 | 226 | 0.25 | 0.25 | 12 | -20.4 | -4.8 | 2.84 | - | - | - |
| 18 | BM-1 | 36 | 138 | 0.22 | 0.21 | 922 | - | -3.9 | 2.43 | 0.2 | 86.8 | 13.0 |
| BM-2 | 33 | 127 | 0.23 | 0.22 | 842 | - | -4.5 | 2.55 | 0.2 | 84.8 | 15.0 |
| 19 | EDQ-1 | 17 | 65 | 1.76 | 1.77 | 66 | - | -4.6 | 22.0 | 3.0 | 82.3 | 14.7 |
| EDQ-2 | 21 | 81 | 1.77 | 1.78 | 49 | - | -2.6 | 22.1 | 4.0 | 88.2 | 7.8 |
| EDQ-18 | 17 | 65 | 2.34 | 2.37 | - | - | -4.9 | 29.4 | - | - | - |
| 20 | LTG-1 | 9.1 | 35 | 1.72 | 1.74 | 502 | - | -2.6 | 21.6 | 0.4 | 91.0 | 8.6 |
| LTG-2 | 9.0 | 35 | 1.87 | 1.90 | 491 | - | -4.8 | 23.5 | 0.4 | 83.7 | 15.9 |
| 21 | GD-1 | 34 | 130 | 2.27 | 2.28 | 64 | -23.6 | -3.7 | 28.3 | 3.1 | 85.2 | 11.7 |
| GD-2 | 32 | 123 | 2.18 | 2.19 | 63 | - | -3.6 | 27.2 | 3.2 | 85.5 | 11.3 |
| 22 | XX-14 | 526 | 2020 | 0.94 | 0.94 | - | - | -8.9 | 11.5 | - | - | - |
| 23 | HM-12 | 235 | 903 | 0.07 | 0.07 | - | - | -8.1 | 0.63 | - | - | - |
| 24 | SQC-1 | 153 | 587 | 0.02 | 0.02 | 0.3 | -47.5 | -15.6 | 0.00 | - | - | - |
| SQC-2 | 154 | 591 | 0.01 | 0.01 | 0.7 | -47.1 | -17.3 | 0.00 | - | - | - |
| 25 | JYG-1 | 151 | 579 | 0.03 | 0.03 | 7.8 | - | -5.2 | 0.10 | - | - | - |
| 26 | MCG-1 | 27 | 104 | 0.04 | 0.03 | 0.4 | - | - | 0.13 | - | - | - |

a Measured 3He/4He ratios of samples (Rm/Ra) are divided by the 3He/4He ratio of air (1.39 × 10−6).

b Xm = (4He/20Ne)measured/(4He/20Ne)air × *ß*Ne/*ß*He, where Xm is air contamination factor and the air saturated water (ASW) normalized 4He/20Ne ratio taken as 0.26; *ß* represents Bunsen solubility coefficients for He and Ne in pure water (*ß*Ne/*ß*He = 1.22, Holocher et al., 2002), assuming a groundwater recharge temperature of 15 °C (see details in Hilton, 1996).

c Rc/Ra is the air-corrected He isotope ratio = [(Rm/Ra × Xm) – 1] / (Xm – 1).

d CO2/3He is calculated based on air-corrected 3He content.

e Mantle He proportion (*f* mantle ) = [(Rc / Ra)measured − (R / Ra)crust] / [(R / Ra)mantle − (R / Ra)crust], where (R/Ra)mantle and(R/Ra)crust are 3He/4He ratios of mantle (8 Ra, Graham, 2002) and crust (0.02 Ra, Ozima and Podosek, 2002), respectively.

f Mantle (M), carbonate (CAR) and organic matter (ORG) proportions in total carbon inventory are calculated using the following the approach (Sano and Marty, 1995): ƒM + ƒCAR+ ƒORG = 1; (13C / 12C)sam = (13C / 12C)M × ƒM + (13C / 12C)CAR × ƒCAR + (13C / 12C)ORG × ƒORG; 1 / (12C / 3He)sam = ƒM / (12C / 3He)M + ƒCAR / (12C / 3He)CAR + ƒORG / (12C / 3He)ORG, where ƒM, ƒCAR and ƒORG are the fraction contribution by M, CAR and ORG end-members to the total CO2 inventory, respectively; sam is the observed ratio of samples. he assumed endmembers compositions are reported: δ13CCO2 = −6.5 ± 2.5‰, CO2/3He = 2 × 109 for M, δ13CCO2 = 0 ± 2‰, CO2/3He = 1013 for CAR; δ13CCO2 = −30 ± 10‰, CO2/3He = 1013 for ORG (Sano and Marty, 1995).

**Table S3** The compiled He-isotope data for geothermal fluids and distance along different strike-slip faults fault in the world.

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Sample ID | Latitude (°N) | Longitude (°E) | Sample type | 4He/20Ne | R/Ra | Rc/Ra | Distance from fault (km) | Reference |
| **Itoigawa-Shizuoka tectonic line (IST)** | | |  |  |  |  |  | a |
| Kan1 | 36.489 | 137.912 | W | 1.06 | 3.0 | 3.6 | - |
| Sas2 | 36.448 | 137.981 | W | 0.67 | 0.9 | 0.8 | - |
| Kus3 | 36.437 | 138.074 | W | 0.52 | 1.7 | 2.4 | - |
| Azu4 | 36.311 | 137.826 | W | 0.87 | 3.1 | 4 | - |
| Ana5 | 36.333 | 138.002 | G | 11.4 | 0.7 | 0.7 | - |
| Uts6 | 36.248 | 138.001 | W | 2.04 | 2.5 | 2.7 | - |
| Tob7 | 36.185 | 138.085 | W | 0.75 | 0.8 | 0.7 | - |
| Ten8 | 36.141 | 138.006 | W | 0.33 | 1.0 | 1.1 | - |
| Cho9 | 36.165 | 137.948 | W | 4.14 | 1.6 | 1.7 | - |
| Myo10 | 36.19 | 137.83 | W | 24.7 | 2.1 | 2.1 | - |
| Shi11 | 36.077 | 138.091 | G | 16.3 | 4.7 | 4.8 | - |
| Kam12 | 36.052 | 138.114 | G | 20.6 | 5.3 | 5.4 | - |
| Tat13 | 35.966 | 137.992 | G | 93.3 | 0.8 | 0.8 | - |
| Mid14 | 36.090 | 138.002 | G | 29 | 1.1 | 1.1 | - |
| Kob15 | 35.878 | 138.317 | G | 297 | 4.6 | 4.6 | - |
| Shi16 | 35.877 | 138.257 | G | 184 | 6.0 | 6 | - |
| Oji17 | 35.808 | 138.34 | G | 2150 | 4.9 | 4.9 | - |
| Muk18 | 35.784 | 138.379 | G | 419 | 3.9 | 3.9 | - |
| Mah19 | 35.882 | 137.919 | G | 111 | 1.6 | 1.6 | - |
| Oya20 | 35.762 | 138.32 | W | 11.8 | 5.3 | 5.4 | - |
| Kof21 | 35.662 | 138.57 | W | 33 | 4.0 | 4.1 | - |
| Tog22 | 35.651 | 138.41 | W | 0.52 | 0.7 | 0.4 | - |
| Nis23 | 35.554 | 138.307 | G | 17.6 | 2.9 | 2.9 | - |
| Mom24 | 35.624 | 138.357 | G | 1.82 | 2.5 | 2.9 | - |
| Jik25 | 35.505 | 138.394 | W | 235 | 6.8 | 6.8 | - |
| Fun26 | 35.294 | 138.421 | W | 0.34 | 1.3 | 2.2 | - |
| Jya27 | 35.933 | 138.105 | W | 0.33 | 1.2 | 1.8 | - |
| Kas28 | 35.587 | 138.056 | W | 39.7 | 1.4 | 1.4 | - |
| Toy29 | 35.322 | 137.929 | G | 1210 | 2.4 | 2.4 | - |
| Hon30 | 34.879 | 137.426 | G | 649 | 0.5 | 0.5 | - |
| Soe31 | 35.108 | 137.575 | W | 8.8 | 0.9 | 0.9 | - |
| Shr32 | 35.124 | 137.29 | W | 8.7 | 0.8 | 0.8 | - |
| War33 | 35.079 | 137.118 | G | 2620 | 0.3 | 0.3 | - |
| Kuz34 | 36.494 | 137.75 | W | 3.69 | 2.5 | 2.6 | - |
| Nan35 | 36.494 | 137.724 | W | 0.41 | 0.9 | 0.7 | - |
| **Southeastern Korean Peninsula (SeKP)** | | |  |  |  |  |  | b |
| G1 | 35.785 | 129.325 | W | 0.4 | 1.09 | 1.2 | - |
| G2 | 35.930 | 129.206 | W | 38 | 5.51 | 5.54 | - |
| U1 | 35.553 | 129.126 | W | 0.4 | 0.84 | 0.55 | - |
| U3 | 35.593 | 129.116 | W | 0.7 | 0.7 | 0.55 | - |
| U4 | 35.570 | 129.337 | W | 0.3 | 0.96 | 0.87 | - |
| U5a | 35.624 | 129.223 | W | 12 | 0.07 | 0.05 | - |
| U5b | 35.624 | 129.223 | W | 2.8 | 0.17 | 0.09 | - |
| U8a | 35.538 | 129.256 | W | 17 | 4.84 | 4.9 | - |
| U8b | 35.538 | 129.256 | W | 38 | 5.66 | 5.69 | - |
| P1a | 36.159 | 129.278 | W | 19 | 1.38 | 1.39 | - |
| P1b | 36.159 | 129.278 | W | 33 | 1.27 | 1.27 | - |
| P3 | 36.195 | 129.327 | W | 0.5 | 1.34 | 1.68 | - |
| B1a | 35.162 | 129.166 | W | 24 | 0.34 | 0.33 | - |
| B1b | 35.162 | 129.166 | W | 39 | 0.31 | 0.3 | - |
| B2a | 35.221 | 129.081 | W | 37 | 0.34 | 0.34 | - |
| B2b | 35.221 | 129.081 | W | 25 | 0.46 | 0.46 | - |
| **North Anatolian fault (NAF)** | | | | | | | | |
| M03 | ‐ | ‐ | G | 13 | 0.35 | 0.34 | -20.1 | c |
| M05 | ‐ | ‐ | G | 81 | 0.26 | 0.25 | -26.6 |
| M07 | ‐ | ‐ | G | 4.19 | 0.52 | 0.48 | -69.8 |
| M09 | ‐ | ‐ | G | 0.38 | 0.95 | ‐ | -92.23 |
| M11‐1 | ‐ | ‐ | G | 111 | 0.28 | 0.28 | -35.4 |
| M11‐2 | ‐ | ‐ | G | 23.3 | 0.29 | 0.28 | -35.3 |
| M12‐R1 | ‐ | ‐ | G | 7.9 | 2.74 | 2.81 | 18.5 |
| M13 | ‐ | ‐ | G | 0.57 | 0.84 | 0.63 | -13.63 |
| M14 | ‐ | ‐ | G | 484 | 0.59 | 0.59 | -13.63 |
| M15 | ‐ | ‐ | G | 81 | 0.66 | 0.66 | 8.4 |
| M16 | ‐ | ‐ | G | 59 | 0.61 | 0.61 | -2 |
| M65 | ‐ | ‐ | G | 68 | 0.97 | 0.97 | 49.9 |
| M66 | ‐ | ‐ | G | 2050 | 1.32 | 1.32 | -22.81 |
| M01 | ‐ | ‐ | W | 42.6 | 0.65 | 0.65 | -15.4 |
| M02 | ‐ | ‐ | W | 0.43 | 0.83 | 0.33 | -49.0 |
| M04‐1 | ‐ | ‐ | W | 44.8 | 0.29 | 0.28 | -11.2 |
| M04‐2 | ‐ | ‐ | W | 43.7 | 0.27 | 0.26 | -10.9 |
| M06 | ‐ | ‐ | W | 1.81 | 0.28 | 0.13 | -34.4 |
| M08 | ‐ | ‐ | W | 9.31 | 0.68 | 0.66 | -89.7 |
| M10‐1 | ‐ | ‐ | W | 9.82 | 1.07 | 1.07 | 1 |
| M10‐2 | ‐ | ‐ | W | 4.1 | 0.88 | 0.87 | 0.5 |
| M12‐3 | ‐ | ‐ | W | 4.61 | 2.14 | 2.22 | -19.9 |
| M17 | ‐ | ‐ | W | 0.47 | 0.87 | 0.6 | -30.4 |
| M50 | ‐ | ‐ | W | 28.1 | 0.56 | 0.55 | 9.2 |
| M51 | ‐ | ‐ | W | 7.5 | 0.54 | 0.52 | 9.0 |
| M52 | ‐ | ‐ | W | 0.31 | 0.95 | ‐ | 24.0 |
| M53 | ‐ | ‐ | W | 0.34 | 0.88 | ‐ | 23.7 |
| M54 | ‐ | ‐ | W | 0.37 | 0.82 | ‐ | 22.1 |
| M56 | ‐ | ‐ | W | 0.25 | 0.99 | ‐ | 6.2 |
| M59 | ‐ | ‐ | W | 0.32 | 0.94 | ‐ | 7.1 |
| M62 | ‐ | ‐ | W | 0.35 | 0.87 | ‐ | 15.3 |
| M63 | ‐ | ‐ | W | 0.66 | 0.42 | ‐ | 15.6 |
| M64 | ‐ | ‐ | W | 0.95 | 0.53 | 0.29 | 64.1 |
| M67 | ‐ | ‐ | W | 1.93 | 4.22 | 4.85 | 0 |
| M68‐1 | ‐ | ‐ | W | 0.33 | 1.25 | ‐ | 0 |
| M68‐2 | ‐ | ‐ | W | 0.34 | 1.36 | ‐ | 0 |
| **Karakoram fault (KKF)** | | | | | | | | |
| ZP02 | 31.131 | 80.719 | G | 22.6 | 2.225 | 2.23 | -0.2 | d |
| ZZD12-1 | 31.091 | 80.571 | G | 166 | 0.032 | 0.03 | -15.9 |
| ZZD09 - 2 | 31.062 | 80.546 | G | 355 | 0.030 | 0.03 | -19.7 |
| ZGR15 | 31.372 | 80.489 | G | 1374 | 0.032 | 0.03 | -0.6 |
| ZGR09 | 31.446 | 80.405 | G | 1053 | 0.024 | 0.02 | -1.6 |
| ZGR06 | 31.923 | 80.166 | G | 2620 | 0.026 | 0.03 | 2.2 |
| ZGR05 | 32.243 | 79.877 | G | 141 | 0.032 | 0.03 | -0.6 |
| K13G | 33.559 | 78.141 | W | 133 | 0.020 | 0.02 | -33.7 |
| K13C | 33.360 | 78.324 | G | 3212 | 0.023 | 0.02 | -37.1 |
| K13P | 33.223 | 78.327 | G | 5935 | 0.009 | 0.01 | -48.8 |
| ZGR08 | 32.363 | 80.361 | G | 519 | 0.192 | 0.19 | 47.7 |
| **San Andreas fault (SAF)** | | | | | | | | |
| CUY-01 | ‐ | ‐ | W | 3.41 | 0.78 | 0.5 | 17.7 | e |
| CUY-02 | ‐ | ‐ | W | 1.78 | 0.4 | 0.3 | 16.9 |
| CUY-03 | ‐ | ‐ | W | 0.38 | 0.97 | 0.2 | 11.9 |
| CUY-04 |  |  | W | 1.01 | 0.93 | 1 | 11.9 |
| CUY-05 | ‐ | ‐ | W | 2.65 | 0.52 | 0.47 | 15.5 |
| CUY-06 |  |  | W | 0.75 | 1.04 | 1 | 10 |
| CUY-07 |  |  | W | 1.35 | 1.02 | 1 | 9.5 |
| CUY-08 |  |  | W | 0.59 | 1.17 | 1 | 11.2 |
| CUY-11 | ‐ | ‐ | W | 1.17 | 0.82 | 0.49 | 21.0 |
| CUY-12 | ‐ | ‐ | W | 0.41 | 0.94 | 0.09 | 11.4 |
| CUY-09 | ‐ | ‐ | W | 3.47 | 0.68 | 0.64 | 0.19 |
| CUY-10 | ‐ | ‐ | W | 3.98 | 3 | 3.1 | 0.58 |
| CUYU-01 |  |  | W | 1.92 | 1.62 | 1.33 | 0.13 |
| CUYU-02 |  |  | W | 3.58 | 2.4 | 2.3 | 0.28 |
| CUYU-03 | ‐ | ‐ | W | 2.11 | 2.07 | 2.16 | 0.1 |
| CUYU-04 | ‐ | ‐ | W | 6.64 | 3.47 | 3.52 | 0.29 |
| CUYU-05 | ‐ | ‐ | W | 0.74 | 0.93 | 0.1 | -0.84 |
| CUYU-06 | ‐ | ‐ | W | 0.80 | 1.27 | 1.02 | 17.7 |
| **Red River fault (RRF)** | | | | | | | | |
| Glc1 | 23.998 | 104.433 | G | 14.63 |  | 0.09 | 153 | f |
| Lcc2 | 23.639 | 104.412 | G | 0.53 |  | 0.47 | 121 |
| Pzh3 | 23.429 | 104.152 | G | 2.39 |  | 0.10 | 86 |
| Bsp4 | 23.423 | 104.146 | G | 13.02 |  | 0.04 | 85 |
| Rsc5 | 23.531 | 104.055 | G | 2.20 |  | 0.07 | 88 |
| Cjz6 | 23.354 | 103.981 | G | 37.92 |  | 0.09 | 68 |
| Ehg7 | 23.298 | 103.968 | G | 251.91 |  | 0.10 | 63 |
| Yd8 | 23.311 | 103.942 | G | 222.62 |  | 0.11 | 62 |
| Xf9 | 23.322 | 103.796 | G | 216.85 |  | 0.16 | 53 |
| Bhq10 | 22.940 | 103.861 | G | 167.18 |  | 0.19 | 27 |
| Mp11 | 22.914 | 103.489 | G | 6.05 |  | 0.47 | -1 |
| Mlz12 | 22.931 | 103.429 | G | 37.48 |  | 0.46 | -4 |
| Mpy13 | 22.902 | 103.457 | G | 24.00 |  | 0.43 | -4 |
| Ddp14 | 22.990 | 103.362 | G | 38.40 |  | 0.39 | -2 |
| Fcl15 | 22.998 | 103.115 | G | 53.19 |  | 0.09 | -10 |
| Slc116 | 22.704 | 103.287 | G | 11.37 |  | 0.11 | -33 |
| Nx17 | 22.533 | 103.028 | G | 98.11 |  | 0.05 | -64 |
| Pe18 | 22.653 | 103.044 | G | 23.65 |  | 0.05 | -51 |
| Yx19 | 22.762 | 102.755 | G | 43.91 |  | 0.10 | -50 |
| Js20 | 23.356 | 102.942 | G | 83.49 |  | 0.14 | 18 |
| Lcc21 | 23.430 | 102.973 | G | 57.46 |  | 0.06 | 27 |

Abbreviations: G = gas sample; W = water sample. Literature data are from: a, Umeda et al. (2013); b, Lee et al. (2019); c, Doǧan et al. (2009); d, Klemperer et al. (2022); e, Kulongoski et al. (2013); f, Wang et al. (2020).

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Table S4** Calculation of the mantle fluid flux and using reference parameters in hydrothermal gases along the YGXFS and ANFS. | | | | | | | | | | | |
| Sample ID | 4He in spring watera  (cm3 STP g-1 H2O) | Original 4He mantle concentrationa  (cm3 STP g-1 H2O) | Crust thickness, *H*crustb  (km) | Porosity, Øc  (kg m-1 s-1) | Bulk rock density, ρsc  (g cm-3) | 4He production rate, P(4He)  (cm3 STP g-1 yr-1) | U contentd  (ppm) | Th contentd  (ppm) | 3He flow rate  (mm yr-1) | Total 3He flux  (mol km-2 yr-1) | Mantle CO2 flux  (mol km-2 yr-1) |
| QEL-1 | 4.54E-06 | 5.99E-08 | 60 | 0.09 | 2.78 | 8.53E-13 | 3.38 | 15.53 | 32 | 1.11E-06 | 2.23E+03 |
| QEL-2 | 3.30E-06 | 4.37E-08 | 60 | 0.09 | 2.78 | 8.53E-13 | 3.38 | 15.53 | 44 | 1.12E-06 | 2.23E+03 |
| QR-1 | 2.76E-06 | 3.27E-08 | 60 | 0.09 | 2.78 | 8.53E-13 | 3.38 | 15.53 | 52 | 1.01E-06 | 2.03E+03 |
| QR-2 | 2.90E-06 | 3.46E-08 | 60 | 0.09 | 2.78 | 8.53E-13 | 3.38 | 15.53 | 50 | 1.02E-06 | 2.04E+03 |
| MR-1 | 3.46E-08 | 1.50E-09 | 60 | 0.09 | 2.78 | 8.53E-13 | 3.38 | 15.53 | - | - | - |
| MR-2 | 3.30E-08 | 1.59E-09 | 60 | 0.09 | 2.78 | 8.53E-13 | 3.38 | 15.53 | - | - | - |
| PW-2 | 4.38E-10 | 1.23E-11 | 60 | 0.09 | 2.78 | 8.53E-13 | 3.38 | 15.53 | - | - | - |
| MN-1 | 5.24E-08 | 9.70E-10 | 60 | 0.09 | 2.78 | 8.53E-13 | 3.38 | 15.53 | - | - | - |
| MN-2 | 5.08E-08 | 1.00E-09 | 60 | 0.09 | 2.78 | 8.53E-13 | 3.38 | 15.53 | - | - | - |
| ZKX-1 | 6.90E-07 | 8.56E-09 | 60 | 0.09 | 2.78 | 8.53E-13 | 3.38 | 15.53 | 208 | 1.06E-06 | 2.11E+03 |
| ZKX-2 | 6.33E-07 | 7.87E-09 | 60 | 0.09 | 2.78 | 8.53E-13 | 3.38 | 15.53 | 227 | 1.06E-06 | 2.11E+03 |
| DDL-1 | 3.10E-06 | 2.23E-08 | 60 | 0.09 | 2.78 | 8.53E-13 | 3.38 | 15.53 | 36 | 5.39E-07 | 1.08E+03 |
| DDL-2 | 3.22E-06 | 1.91E-08 | 60 | 0.09 | 2.78 | 8.53E-13 | 3.38 | 15.53 | 44 | 5.93E-07 | 1.19E+03 |
| GYG-1 | 1.16E-06 | 2.31E-08 | 60 | 0.09 | 2.78 | 8.53E-13 | 3.38 | 15.53 | 125 | 1.60E-06 | 3.20E+03 |
| GYG-2 | 1.10E-06 | 2.61E-08 | 60 | 0.09 | 2.78 | 8.53E-13 | 3.38 | 15.53 | 132 | 1.88E-06 | 3.75E+03 |
| JX-1 | 8.99E-08 | 1.22E-09 | 60 | 0.09 | 2.78 | 8.53E-13 | 3.38 | 15.53 | - | - | - |
| JX-2 | 8.99E-08 | 1.11E-09 | 60 | 0.09 | 2.78 | 8.53E-13 | 3.38 | 15.53 | - | - | - |
| JY-1 | 2.35E-09 | 1.65E-10 | 60 | 0.09 | 2.78 | 8.53E-13 | 3.38 | 15.53 | - | - | - |
| YJ-2 | 2.62E-09 | 1.98E-10 | 60 | 0.09 | 2.78 | 8.53E-13 | 3.38 | 15.53 | - | - | - |
| YD-1 | 3.00E-06 | 7.05E-08 | 60 | 0.09 | 2.78 | 8.53E-13 | 3.38 | 15.53 | 48 | 1.86E-06 | 3.72E+03 |
| YD-2 | 3.14E-06 | 7.34E-08 | 60 | 0.09 | 2.78 | 8.53E-13 | 3.38 | 15.53 | 46 | 1.85E-06 | 3.71E+03 |
| GK-1 | 4.81E-07 | 4.58E-09 | 60 | 0.09 | 2.78 | 8.53E-13 | 3.38 | 15.53 | 298 | 8.49E-07 | 1.70E+03 |
| GK-2 | 4.81E-07 | 5.79E-09 | 60 | 0.09 | 2.78 | 8.53E-13 | 3.38 | 15.53 | 299 | 1.03E-06 | 2.06E+03 |
| KM-1 | 1.14E-06 | 3.09E-08 | 60 | 0.09 | 2.78 | 8.53E-13 | 3.38 | 15.53 | 128 | 2.13E-06 | 4.26E+03 |
| KM-2 | 9.79E-07 | 2.78E-08 | 60 | 0.09 | 2.78 | 8.53E-13 | 3.38 | 15.53 | 149 | 2.22E-06 | 4.45E+03 |
| BM-1 | 2.03E-08 | 4.93E-10 | 60 | 0.09 | 2.78 | 8.53E-13 | 3.38 | 15.53 | - | - | - |
| BM-2 | 2.08E-08 | 5.32E-10 | 60 | 0.09 | 2.78 | 8.53E-13 | 3.38 | 15.53 | - | - | - |
| ZGC01\* | 6.94E-08 | 1.35E-08 | 60 | 0.09 | 2.78 | 8.53E-13 | 3.38 | 15.53 | - | - | - |
| EDQ-1 | 3.71E-08 | 8.13E-09 | 60 | 0.09 | 2.78 | 8.53E-13 | 3.38 | 15.53 | - | - | - |
| EDQ-2 | 4.79E-08 | 1.06E-08 | 60 | 0.09 | 2.78 | 8.53E-13 | 3.38 | 15.53 | - | - | - |
| EDQ04\* | 1.15E-07 | 3.58E-08 | 60 | 0.09 | 2.78 | 8.53E-13 | 3.38 | 15.53 | 1797 | 3.19E-05 | 6.38E+04 |
| LTG-1 | 5.29E-09 | 1.14E-09 | 60 | 0.09 | 2.78 | 8.53E-13 | 3.38 | 15.53 | - | - | - |
| LTG-2 | 4.63E-09 | 1.09E-09 | 60 | 0.09 | 2.78 | 8.53E-13 | 3.38 | 15.53 | - | - | - |
| LTG02\* | 2.95E-08 | 5.96E-09 | 60 | 0.09 | 2.78 | 8.53E-13 | 3.38 | 15.53 | - | - | - |
| GD-1 | 3.08E-08 | 8.74E-09 | 60 | 0.09 | 2.78 | 8.53E-13 | 3.38 | 15.53 | - | - | - |
| GD-2 | 3.29E-08 | 8.94E-09 | 60 | 0.09 | 2.78 | 8.53E-13 | 3.38 | 15.53 | - | - | - |
| GD02\* | 2.07E-07 | 7.01E-08 | 60 | 0.09 | 2.78 | 8.53E-13 | 3.38 | 15.53 | 1039 | 3.61E-05 | 7.23E+04 |
| EHY01\* | 2.17E-07 | 3.78E-08 | 60 | 0.09 | 2.78 | 8.53E-13 | 3.38 | 15.53 | 794 | 1.50E-05 | 3.00E+04 |
| CK02\* | 5.31E-06 | 5.70E-07 | 60 | 0.09 | 2.78 | 8.53E-13 | 3.38 | 15.53 | 30 | 8.61E-06 | 1.72E+04 |
| GYH01\* | 1.45E-04 | 7.74E-07 | 60 | 0.09 | 2.78 | 8.53E-13 | 3.38 | 15.53 | 1 | 5.51E-07 | 1.10E+03 |
| HM01\* | 1.42E-04 | 1.31E-06 | 60 | 0.09 | 2.78 | 8.53E-13 | 3.38 | 15.53 | 1 | 8.28E-07 | 1.66E+03 |

*Note*: Hot springs with Rc/Ra < 0.05 are not used for calculation of mantle fluid flux along the YGXFS.

a Detail about calculation of 4He contents in spring water and original 4He mantle concentration are described in Zhang et al. (2022).

b The average of crust thickness (*H*crust) in the eastern Tibet Plateau is cited from Jiang et al. (2015).

c Porosity (Ø) and bulk rock density (*ρ*s) are cited from Hu (1985).

d U and Th contents in rocks are from 523 rock samples in study region.

-: 3He flow rate is not considered due to low helium content and significant atmospheric contamination (Xm < 10 or < 4) for gas samples that is suspicious in causing large uncertainty of calculating mantle fluid flow rate.

\* Literature data are from Xu et al. (2022) along the YGXFS and ANFS.

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