**The Cenozoic multiple-stage uplift of the Qiangtang Terrane, Tibetan Plateau**

**Zhao Zhongbao1,2\*, Lu Haijian1,2, Wang Shiguang3, Li Haibing1,2, Li Chao1, Liu Dongliang1,2, Pan Jiawei1,2, Zheng Yong1,2 and Bai Minkun1**

*1Jiangsu Donghai Continental Deep Hole Crustal Activity National Observation and Research Station, Institute of Geology, Chinese Academy of Geological Sciences, Beijing 100037, China*

*2Southern Marine Science and Engineering Guangdong Laboratory (Guangzhou), Guangzhou 511458, China*

*3National Institute of Natural Hazards, Ministry of Emergency Management of China, Beijing 10085, China*

**Corresponding author:** Zhao Zhongbao (**Email:** zhaozhb04@163.com)

Supplementary material for this paper includes analytical methods, Fig. S1-S3 and Table S1-S4.

**Methods**

Apatite crystals were extracted by standard mineral separation techniques followed by handpicking. AFT and AHe analyses were conducted at the University of Melbourne and results are shown in Figure 3 and Table S1-S3. Details of low temperature thermochronology analytical procedures are described below.

**Apatite Fission Track (AFT) Thermochronology**

After apatite grains picked by standard heavy liquid and magnetic separation process, they were mounted in epoxy resin on glass slides, ground and polished to expose internal grain surfaces. Polished mounts were etched to reveal fossil tracks, and applied an aluminium/gold coating to reduce reflections from grain boundaries under the microscope (Gleadow et al., 2009). Then the homogeneous track distributions were selected using a Zeiss Axio Imager M1m microscope. Analyses were performed on image sets captured by TrackWorks using a 3.2 MP AVT Oscar F-320C camera mounted on a Zeiss AxioImager microscope with a 1000x total magnification and a 100x dry objective (calibration = 0.07/0.07µm/pixel). Spontaneous track densities were measured on prismatic internal apatite surfaces after etching with 5M HNO3 for 20sec at 20ºC. Track counts were obtained by automated counting in FastTracks using the 'coincidence mapping' technique of Gleadow et al. (2009) followed by manual inspection. Uranium concentrations of each grain were determined by LA-ICP-MS single spot analysis using a New Wave Nd:YAG Laser (λ=213nm with 5Hz, spot size=25μm) connected to an Agilent 7700 mass spectrometer. NIST612 was used as an internal LA-ICP-MS standard. Single grain and pooled ages were calculated according to Hasebe et al. (2004). Central ages were estimated from single grain ages and errors according to the formulas given by Galbraith (2005, p.100) using the Newton-Raphson method. All ages are "model" ages obtained using a range factor (Rs) of 7.17μm (average mean track length of Durango and Fish Canyon Tuff standards) and are directly comparable to conventional External Detector Method ages. Confined track lengths (TINTs) were measured as true 3D lengths using FastTracks after irradiation by 252Cf and are corrected for a refractive index of 1.634 for apatite.

**Apatite U-Th/He Thermochronology**

For U-Th/He analysis, inclusion-free apatite and zircon grains were hand-picked after examination under a binocular microscope. Ages were corrected for alpha ejection (Farley et al., 1996). He extraction was performed using fixed laboratory routines (e.g., House et al., 2002). Apatite grains were loaded into platinum capsules and outgassed under vacuum by using a fibre-optically coupled diode laser. 4He abundances were determined as an isotope ratio using a pure 3He spike that has been calibrated against an independent 4He standard. The uncertainty in the 4He measurement is set as <1%. Apatite U-Th-Sm dating was used an Agilent 7700 quadrupole ICP-MS. The same spike amounts were treated equivalently as unspiked reagent blanks. Another bombing in HCl ensured dissolution of fluoride salts and analysis on an Agilent 7700 quadrupole ICP-MS. Analytical uncertainties for the University of Melbourne U-Th/He equipment are estimated at ~6.2% (± 1σ), which include an α-correction related component and in view of an estimated 5 μm uncertainty in grain size measurements, gas analysis and instrumental error. Durango apatite was measured as internal standards and used as an additional monitor for analytical precision.

**Figure S1.** Inverse HeFTy thermal history modeling results of sample R and RGL series. Etch pit diameters (Dpar) of all analysed grains (age/length) were determined and illustrated.

**Figure S2.** Inverse HeFTy thermal history modeling results of sample G and CBG series. Etch pit diameters (Dpar) of all analysed grains (age/length) were determined and illustrated.

**Figure S3.** Locations of collected and our new thermochronology ages and profiles for Figure 5.

**Table S1.** Sample information.

**Table S2.** Results of apatite (U-Th-Sm)/He dating.

**Table S3.** Results of apatite fission track dating.

**Table S4.** Our new and collected thermochronology ages.

**Table S1,** Sample information.

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Sample ID** | **Sample Number** | **Lithology** | **Latitude** | **Longitude** | **Elevation** | **AFT** | **AHe** | **Protolith****age** |
| **(°E)** | **(°N)** | **(m)** |  |  |
| **1** | G-1 | Granite | 33.342 | 88.407 | 5313 | √ | √ | Late Triassic |
| **2** | G-3 | Granite | 33.340 | 88.406 | 5232 | √ | √ |
| **3** | G-5 | Granite | 33.338 | 88.403 | 5073 | √ | √ |
| **4** | G-7 | Granite | 33.321 | 88.428 | 4900 | √ | √ |
| **5** | G-11 | Granite | 33.264 | 88.371 | 4839 | √ | √ |
| **6** | G-13 | Granite | 33.266 | 88.146 | 4920 | √ | √ |
| **7** | R-1 | Granite | 33.186 | 86.617 | 5802 | √ | √ | ~210 Ma |
| **8** | R-3 | Granite | 33.191 | 86.619 | 5648 | √ | √ |
| **9** | R-5 | Granite | 33.191 | 86.623 | 5461 | √ | √ |
| **10** | R-7 | Granite | 33.191 | 86.628 | 5258 | √ | √ |
| **11** | R-10 | Granite | 33.179 | 86.642 | 4922 | √ | √ |
| **12** | RGL-1 | Granite | 33.202 | 86.381 |  | √ | √ | Late Triassic |
| **13** | RGL-2 | Granite | 33.197 | 86.371 |  | √ | √ |
| **14** | CBG-1 | Granite | 33.723 | 83.678 | 5720 | √ | √ | Jurassic |
| **15** | CBG-5 | Granite | 33.729 | 83.668 | 5551 | √ | √ |
| **16** | CBG-7 | Granite | 33.717 | 83.667 | 5458 |  | √ |
| **17** | CBG-9 | Granite | 33.740 | 83.669 | 5316 | √ | √ |
| **18** | CBG-13 | Granite | 33.690 | 83.805 | 4894 |  | √ |

**Table S2,** Results of apatite (U-Th-Sm)/He dating.

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Sample number** | **4He gas** **(ncc)** | **Mass****(mg)** | **aMean****FT** | **U****(ppm)** | **Th****(ppm)** | **Sm****(ppm)** | **Th/U**  | **b[eU]****(ppm)** | **Corrected Age****(Ma)** | **Error ±1s** **(Ma)** | **Grain length** **(mm)** | **Grain half-width (mm)** | **Agec****(Ma±1σ)** |
| G-1d | 1.930 | 0.0079 | 0.76 | 16.0 | 35.4 | 162.7 | 2.22 | 24.3 | **106.8** | **6.6** | 239.0 | 63.1 | 64**±**12 |
| G-1 | 1.701 | 0.0057 | 0.76 | 26.6 | 65.3 | 253.5 | 2.46 | 41.9 | **76.1** | **4.7** | 254.8 | 56.4 |
| G-1 | 0.421 | 0.0046 | 0.71 | 13.1 | 29.7 | 137.9 | 2.26 | 20.1 | **52.2** | **3.2** | 206.8 | 51.6 |
| G-3 | 1.863 | 0.0084 | 0.75 | 19.4 | 49.8 | 172.8 | 2.57 | 31.1 | **77.1** | **4.8** | 293.9 | 58.5 | 63**±**6.7 |
| G-3 | 0.547 | 0.0055 | 0.72 | 13.2 | 29.8 | 117.0 | 2.26 | 20.2 | **55.1** | **3.4** | 236.6 | 53.0 |
| G-3 | 0.868 | 0.0074 | 0.75 | 14.4 | 29.5 | 145.6 | 2.04 | 21.3 | **59.4** | **3.7** | 252.2 | 59.3 |
| G-5 | 0.900 | 0.0060 | 0.73 | 15.9 | 42.2 | 153.9 | 2.66 | 25.8 | **64.6** | **4.0** | 254.8 | 53.4 | 55**±** 4.7 |
| G-5 | 0.455 | 0.0037 | 0.69 | 17.5 | 46.0 | 166.7 | 2.62 | 28.3 | **51.0** | **3.2** | 192.4 | 48.2 |
| G-5 | 0.540 | 0.0057 | 0.73 | 13.4 | 33.3 | 141.8 | 2.49 | 21.2 | **50.3** | **3.1** | 240.0 | 53.3 |
| G-7 | 1.248 | 0.0081 | 0.77 | 14.6 | 40.0 | 173.9 | 2.73 | 24.0 | **68.2** | **4.2** | 224.2 | 65.8 | 71**±**2.8 |
| G-7d | 1.908 | 0.0066 | 0.75 | 20.1 | 58.2 | 131.8 | 2.90 | 33.8 | **92.2** | **5.7** | 197.4 | 63.6 |
| G-7 | 1.261 | 0.0076 | 0.77 | 14.8 | 37.8 | 159.9 | 2.55 | 23.7 | **73.8** | **4.6** | 202.0 | 67.5 |
| G-11 | 0.476 | 0.0052 | 0.71 | 10.9 | 42.7 | 123.0 | 3.92 | 20.9 | **49.7** | **3.1** | 249.7 | 50.3 | 56**±** 3.7 |
| G-11 | 0.907 | 0.0058 | 0.72 | 15.9 | 65.6 | 143.4 | 4.14 | 31.3 | **56.3** | **3.5** | 254.7 | 52.5 |
| G-11 | 0.982 | 0.0076 | 0.75 | 10.2 | 51.6 | 178.6 | 5.05 | 22.3 | **62.6** | **3.9** | 269.5 | 58.4 |
| G-13 | 1.557 | 0.0072 | 0.75 | 18.8 | 50.1 | 145.9 | 2.66 | 30.6 | **76.0** | **4.7** | 225.1 | 62.1 | 76**±**0.6 |
| G-13 | 1.065 | 0.0103 | 0.76 | 9.2 | 22.2 | 146.3 | 2.41 | 14.4 | **76.1** | **4.7** | 371.8 | 57.7 |
| G-13 | 2.158 | 0.0121 | 0.81 | 14.3 | 37.2 | 119.9 | 2.60 | 23.0 | **77.7** | **4.8** | 236.5 | 71.4 |
| R-1 | 7.925 | 0.0231 | 0.85 | 20.8 | 11.4 | 215.5 | 0.55 | 23.5 | **138.6** | **8.6** | 347.2 | 81.4 | 123**±**7.8 |
| R-1 | 9.392 | 0.0222 | 0.84 | 29.7 | 27.0 | 275.2 | 0.91 | 36.0 | **113.0** | **7.0** | 367.2 | 77.5 |
| R-1 | 1.934 | 0.0078 | 0.77 | 19.9 | 9.0 | 196.8 | 0.45 | 22.0 | **118.7** | **7.4** | 326.1 | 48.7 |
| R-3d | 10.767 | 0.0112 | 0.81 | 33.2 | 12.6 | 226.7 | 0.38 | 36.2 | **262.7** | **16.3** | 285.0 | 62.6 | 134**±**8.3 |
| R-3 | 2.989 | 0.0069 | 0.76 | 30.9 | 14.2 | 265.2 | 0.46 | 34.2 | **134.1** | **8.3** | 289.2 | 48.8 |
| R-3d | 2.285 | 0.0045 | 0.71 | 27.1 | 16.3 | 285.6 | 0.60 | 30.9 | **186.3** | **11.6** | 344.3 | 41.3 |
| R-5 | 4.984 | 0.0181 | 0.84 | 27.3 | 10.8 | 206.4 | 0.39 | 29.8 | **89.4** | **5.5** | 314.2 | 75.6 | 81**±**4.8 |
| R-5 | 7.312 | 0.0220 | 0.85 | 40.7 | 13.2 | 207.7 | 0.32 | 43.8 | **72.9** | **4.5** | 356.0 | 78.4 |
| R-5 | 3.602 | 0.0079 | 0.79 | 50.9 | 28.1 | 240.9 | 0.55 | 57.5 | **81.8** | **5.1** | 216.9 | 60.2 |
| R-7 | 1.288 | 0.0066 | 0.76 | 19.9 | 14.4 | 240.6 | 0.73 | 23.3 | **89.1** | **5.5** | 238.5 | 52.4 | 97**±** 7.9 |
| R-7d | 7.476 | 0.0068 | 0.76 | 30.9 | 13.0 | 259.4 | 0.42 | 34.0 | **341.6** | **21.2** | 356.5 | 50.1 |
| R-7 | 1.224 | 0.0046 | 0.73 | 24.2 | 16.1 | 238.1 | 0.67 | 28.0 | **104.9** | **6.5** | 228.3 | 44.9 |
| R-10d | 5.987 | 0.0064 | 0.77 | 35.3 | 21.1 | 291.9 | 0.60 | 40.3 | **242.2** | **15.0** | 289.9 | 55.2 |  |
| R-10d | 6.035 | 0.0066 | 0.76 | 47.4 | 45.8 | 295.6 | 0.97 | 58.2 | **166.8** | **10.3** | 302.3 | 54.6 |
| R-10d | 9.483 | 0.0081 | 0.77 | 30.2 | 25.3 | 297.4 | 0.84 | 36.1 | **333.2** | **20.7** | 363.6 | 54.6 |
| RGL-1 | 3.637 | 0.0149 | 0.82 | 28.9 | 112.3 | 107.3 | 3.88 | 55.3 | **43.9** | **2.7** | 146.2 | 100.8 | 39**±**4.1 |
| RGL-1 | 1.898 | 0.0194 | 0.83 | 10.9 | 68.0 | 121.7 | 6.23 | 26.9 | **35.6** | **2.2** | 227.4 | 92.0 |
| RGL-1d | 5.834 | 0.0106 | 0.82 | 40.7 | 8.9 | 254.9 | 0.22 | 42.8 | **127.8** | **7.9** | 199.0 | 72.6 |
| RGL-2d | 5.523 | 0.0072 | 0.79 | 46.1 | 11.7 | 204.9 | 0.25 | 48.8 | **160.9** | **10.0** | 209.2 | 58.6 | 100**±**6.3 |
| RGL-2d | 13.386 | 0.0066 | 0.80 | 58.6 | 18.9 | 252.6 | 0.32 | 63.0 | **321.7** | **19.9** | 199.1 | 72.3 |
| RGL-2 | 8.062 | 0.0118 | 0.85 | 63.1 | 6.2 | 320.5 | 0.10 | 64.6 | **100.9** | **6.3** | 213.7 | 97.8 |
| CBG-1 | 1.274 | 0.0063 | 0.75 | 17.8 | 61.3 | 47.8 | 3.45 | 32.2 | **68.3** | **4.2** | 199.2 | 56.0 | 65**±**1.5 |
| CBG-1 | 1.643 | 0.0083 | 0.75 | 18.7 | 65.5 | 47.6 | 3.51 | 34.1 | **63.0** | **3.9** | 294.5 | 58.3 |
| CBG-1 | 1.178 | 0.0062 | 0.72 | 17.2 | 65.1 | 61.7 | 3.78 | 32.5 | **65.5** | **4.1** | 311.0 | 44.7 |
| CBG-5 | 7.452 | 0.0295 | 0.86 | 19.9 | 71.8 | 65.0 | 3.61 | 36.8 | **65.2** | **4.0** | 415.1 | 101.1 | 59**±**3.5 |
| CBG-5 | 1.712 | 0.0119 | 0.79 | 15.6 | 53.3 | 39.4 | 3.43 | 28.1 | **53.1** | **3.3** | 322.9 | 60.5 |
| CBG-5 | 1.515 | 0.0112 | 0.79 | 13.9 | 39.4 | 32.3 | 2.83 | 23.2 | **60.7** | **3.8** | 315.4 | 59.4 |
| CBG-7 | 2.097 | 0.0080 | 0.80 | 25.4 | 84.3 | 65.7 | 3.31 | 45.2 | **59.6** | **3.7** | 221.6 | 74.7 | 60**±**3.6 |
| CBG-7 | 4.830 | 0.0119 | 0.82 | 42.9 | 74.1 | 52.7 | 1.73 | 60.3 | **67.3** | **4.2** | 280.5 | 79.2 |
| CBG-7 | 2.788 | 0.0111 | 0.80 | 29.6 | 71.9 | 55.7 | 2.43 | 46.5 | **54.9** | **3.4** | 317.9 | 70.2 |
| CBG-9 | 1.901 | 0.0076 | 0.76 | 28.6 | 41.6 | 95.3 | 1.45 | 38.4 | **69.9** | **4.3** | 234.6 | 62.3 | 52**±**9.2 |
| CBG-9 | 3.047 | 0.0081 | 0.76 | 56.3 | 100.9 | 138.8 | 1.79 | 80.0 | **50.1** | **3.1** | 257.2 | 61.7 |
| CBG-9 | 1.839 | 0.0160 | 0.83 | 22.2 | 30.9 | 75.0 | 1.39 | 29.5 | **38.5** | **2.4** | 254.5 | 79.1 |
| CBG-13d | 3.662 | 0.0140 | 0.81 | 55.2 | 156.1 | 96.4 | 2.83 | 91.9 | **28.7** | **1.8** | 372.2 | 72.1 | 57**±**12.6 |
| CBG-13 | 0.871 | 0.0046 | 0.73 | 16.1 | 60.5 | 60.2 | 3.76 | 30.3 | **70.0** | **4.3** | 134.5 | 58.1 |
| CBG-13 | 0.515 | 0.0065 | 0.77 | 10.3 | 35.8 | 55.8 | 3.48 | 18.7 | **44.9** | **2.8** | 149.0 | 66.1 |

**Note:**

aFT is the -ejection correction after Wolf et al. (1996).

bEffective uranium concentration (U ppm + 0.235 × Th ppm) (Flowers et al., 2009).

cAge = Average age ± standard deviation.

dExcluded in the calculation of average age.

**Table S3,** Results of apatite fission track dating.

|  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Sample ID** | **Sample number** | **No. of****Grains** | **Ns** | **ρs****(105cm-2)** | **Mean 238U and SD****(ppm)** | **P(χ2)****(%)** | **Dpar****(μm)** | **Pooled Age****(Ma±1σ)** | **Central Age****(Ma±1σ)** | **Non-projected****Mean track length** | **Projected****Mean track length** | **Nlength** |
| 1 | G-1 | 21 | 1791 | 12.0122 | 24.21 ± 5.34 | 40 | 1.67 | 101±3.7 | 104±3.3 | 13.27 ± 1.94 | 14.30 ± 1.38 | 128 |
| 2 | G-3 | 22 | 2196 | 11.5052 | 21.89 ± 5.45 | 39 | 2.10 | 108±3.6 | 111±3.3 | 12.6 ± 2.26 | 13.82 ± 1.51 | 139 |
| 3 | G-5 | 26 | 1703 | 10.0655 | 16.43 ± 3.30 | 85 | 2.14 | 126±3.8 | 127±4.4 | 12.98 ± 1.72 | 14.01 ± 1.23 | 118 |
| 4 | G-7 | 25 | 1952 | 10.8023 | 18.24 ± 4.42 | 71 | 2.24 | 123±3.5 | 125±3.9 | 12.05 ± 2.00 | 13.48 ± 1.34 | 106 |
| 5 | G-11 | 24 | 1844 | 10.1140 | 18.55 ± 4.32 | 57 | 2.00 | 114±3.3 | 115±3.5 | 13.32 ± 1.54 | 14.22 ± 1.22 | 126 |
| 6 | G-13 | 25 | 1778 | 9.6064 | 17.85 ± 5.05 | 39 | 1.70 | 115±3.9 | 116±3.6 | 12.22 ± 1.69 | 13.51 ± 1.19 | 124 |
| 7 | R-1 | 25 | 2509 | 14.9686 | 29.13 ± 5.07 | 7 | 1.53 | 106±3.8 | 106±3.6 | 12.35 ± 1.53 | 13.52 ± 1.17 | 124 |
| 8 | R-3 | 21 | 2727 | 17.8731 | 32.9 ± 7.49 | 24 | 1.52 | 116±3.7 | 117±3.6 | 12.55 ± 1.66 | 13.70 ± 1.20 | 155 |
| 9 | R-5 | 23 | 2843 | 13.1788 | 31.57 ± 9.79 | 44 | 1.43 | 88±2.8 | 89±2.6 | 11.82 ± 1.99 | 13.32 ± 1.27 | 117 |
| 10 | R-7 | 24 | 2040 | 9.9168 | 28.41 ± 7.48 | 48 | 1.47 | 74±2.4 | 75±2.4 | 12.36 ± 1.62 | 13.53 ± 1.17 | 114 |
| 11 | R-10 | 22 | 1984 | 14.8425 | 29.83 ± 8.09 | 53 | 1.31 | 105±3.2 | 105±3.3 | 12.31 ± 1.66 | 13.55 ± 1.20 | 137 |
| 12 | RGL-1 | 25 | 3989 | 17.2432 | 48.11 ± 15.13 | 69 | 1.43 | 75±1.8 | 75±1.9 | 12.15 ± 1.67 | 13.44 ± 1.17 | 146 |
| 13 | RGL-2 | 30 | 5617 | 17.5187 | 88.44 ± 73.03 | 0 | 1.65 | 42±9.7 | 55±7.8 | 12.91 ± 1.58 | 13.91 ± 1.15 | 141 |
| 14 | CBG-1 | 21 | 2786 | 11.4079 | 18.82 ± 3.68 | 61 | 1.70 | 126±3.5 | 125±3.5 | 12.82 ± 1.42 | 13.86 ± 1.00 | 141 |
| 15 | CBG-5 | 23 | 3787 | 10.8439 | 22.72 ± 7.93 | 8 | 1.63 | 98±4.2 | 100±4.0 | 12.76 ± 1.67 | 13.88 ± 1.23 | 119 |
| 16 | CBG-9 | 20 | 3244 | 15.1972 | 24.79 ± 12.26 | 50 | 1.54 | 130±3.7 | 132±3.6 | 12.67 ± 1.87 | 13.84 ± 1.28 | 170 |

**Note:** Ns = number of spontaneous tracks counted; ρs = spontaneous track density; Dpar = long axis of track etch pit. P(χ2) = chi-squared probability that all single-crystal ages represent a single population of ages where degrees of freedom =N-1(Galbraith, 1981). Non-projected Track length measured after 252Cf irradiation. c axis projected mean track length after Ketcham et al. (2007). Nlength = number of lengths measured. P(χ2) measured by using the RadialPlotter. (Vermeesch, 2009). Fission track age is pooled age if P(χ2)>5%, is central age if P(χ2) <5% (Galbraith and Green, 1990). The apatite fission track (AFT) ages measured in samples RGL-2 (Table S3) do not pass the standard χ2 criterion (Galbraith, 1981; Green, 1981), suggesting that single-grain AFT ages are not derived from the same population.

**References:**

Dai, J., Wang, C., Hourigan, J., and Santosh, M. (2013). Insights into the early Tibetan Plateau from (U–Th)/He thermochronology. *Journal of the Geological Society* 170, 917-927. doi: https://doi.org/10.1144/jgs2012-076

Farley, K. A., Wolf, R. A., and Silver, L. T. (1996). The effects of long alpha-stopping distances on (U-Th)/He ages. *Geochimica et Cosmochimica Acta* 60(21), 4223-4229. doi: https://doi.org/10.1016/S0016-7037(96)00193-7

Flowers, R.M., Ketcham, R.A., Shuster, D.L., and Farley, K.A. (2009). Apatite (UeTh)/He thermochronometry using a radiation damage accumulation and annealing model. *Geochem. Cosmochim. Acta* 73 (8), 2347-2365. doi: https://doi.org/10.1016/j.gca.2009.01.015

Galbraith R.F. (1981). On statistical models for fission track counts. *Journal of Mathematical Geology*13, 471 -478. doi: https://doi.org/10.1007/BF01034498

Galbraith R.F., and Green P.F. (1990). Estimating the component ages in a finite mixture. *International Journal of Radiation Applications & Instrumentation Part D Nuclear Tracks & Radiation Measurements* 17(3), 197-206. doi: https://doi.org/10.1016/1359-0189(90)90035-V

Galbraith R F. (2005). Statistics for fission track analysis. *Chapman and Hall/CRC*. doi: https://doi.org/10.1201/9781420034929

Green P.F., 1981. A new look at statistics in fission-track dating. *Nuclear Tracks* 5(1-2), 77-86. doi: https://doi.org/10.1016/0191-278X(81)90029-9

Gleadow, A. J. W., Gleadow, S. J., Belton, D. X., Kohn, B. P., Krochmal, M. S., and Brown, R. W. (2009). Coincidence mapping - a key strategy for the automatic counting of fission tracks in natural minerals. *Geological Society, London, Special Publications* 324(1), 25-36. doi: https://doi.org/10.1144/SP324.2

Haider, V.L., Dunkl, I., Eynatten, H.v., Ding, L., Frei, D., and Zhang, L. (2013). Cretaceous to Cenozoic evolution of the northern Lhasa Terrane and the Early Palaeogene development of peneplains at Nam Co, Tibetan Plateau. *Journal of Asian Earth Sciences* 70–71, 79-98. doi: https://doi.org/10.1016/j.jseaes.2013.03.005

Hasebe, N., Barbarand, J., Jarvis, K., Carter, A., and Hurford, A. J. (2004). Apatite fission-track chronometry using laser ablation ICP-MS. *Chemical Geology*, 207(3-4), 135-145. doi:https://doi.org/10.1016/j.chemgeo.2004.01.007

Hetzel, R., Dunkl, I., Haider, V., Strobl, M., von Eynatten, H., Ding, L., and Frei, D. (2011). Peneplain formation in southern Tibet predates the India-Asia collision and plateau uplift. *Geology* 39, 983-986. doi: https://doi.org/10.1130/G32069.1

House, M. A., Kohn, B. P., Farley, K. A., and Raza, A. (2002). Evaluating thermal history models for the Otway Basin, southeastern Australia, using (U-Th)/He and fission-track data from borehole apatites. *Tectonophysics*, 349(1-4), 277-295. doi: https://doi.org/10.1016/S0040-1951(02)00057-4

Jolivet, M., Brunel, M., Seward, D., Xu, Z., Yang, J., Malavieille, J., Roger, F., Leyreloup, A., Arnaud, N., and Wu, C. (2003). Neogene extension and volcanism in the Kunlun Fault Zone, northern Tibet: New constraints on the age of the Kunlun Fault. *Tectonics* 22(5), 1052. doi: <https://doi.org/10.1029/2002TC001428>

Jolivet, M., Brunel, M., Seward, D., Xu, Z., Yang, J., Roger, F., Tapponnier, P., Malavieille, J., Arnaud, N., and Wu, C. (2001). Mesozoic and Cenozoic tectonics of the northern edge of the Tibetan plateau: fission-track constraints. *Tectonophysics* 343(1), 111-134. doi: https://doi.org/10.1016/S0040-1951(01)00196-2

Ketcham, R. A., Carter, A., Donelick, R. A., Barbarand, J., and Hurford, A. J. (2007). Improved modeling of fission-track annealing in apatite. *American Mineralogist* 92(5-6), 799-810. doi: https://doi.org/10.2138/am.2007.2281

Lu, L., Zhen, Z., Zhenhan, W., Cheng, Q., and Peisheng, Y. (2015). Fission Track Thermochronology Evidence for the Cretaceous and Paleogene Tectonic Event of Nyainrong Microcontinent, Tibet. *Acta Geologica Sinica (English Edition)* 89(1), 133-144. doi: https://doi.org/10.1111/1755-6724.12400

McRivette, M.W., Yin, A., Chen, X., and Gehrels, G.E. (2019). Cenozoic basin evolution of the central Tibetan plateau as constrained by U-Pb detrital zircon geochronology, sandstone petrology, and fission-track thermochronology. *Tectonophysics* 751, 150-179. doi: https://doi.org/10.1016/j.tecto.2018.12.015

Ren, Z., Cui, J., Liu, C., Li, T., Cheng, G., Dou, S., Tian, T., and Luo, Y. (2015). Apatite Fission Track Evidence of Uplift Cooling in the Qiangtang Basin and Constraints on the Tibetan Plateau Uplift. *Acta Geologica Sinica (English Edition)* 89(2), 467-484. doi: https://doi.org/10.1111/1755-6724.12441

Rohrmann, A., Kapp, P., Carrapa, B., Reiners, P.W., Guynn, J., Ding, L., and Heizler, M. (2012). Thermochronologic evidence for plateau formation in central Tibet by 45 Ma. *Geology* 40, 187-190. doi: https://doi.org/10.1130/G32530.1

Song C.Y., Wang J., and Tan F.W. (2014). Cretaceous rapid uplift of the Qiangtang Basin in the central Tibet: Evidence from the zircon fission track dating. *Journal of Mineralogy and Petrology* 2, 77-84. (in Chinese with English abstract)

Song C.Y., Wang J., Fu X.G., Chen W.B., Xie S.K., and He L. (2018). Thermochronological evidence for rapid uplift and denudation since Cretaceous in the Qiangtang Basin. *Journal of Northeast Petroleum University* 42(6), 62-72. (in Chinese with English abstract)

Staisch, L.M., Niemi, N.A., Clark, M.K., and Chang, H. (2016). Eocene to late Oligocene history of crustal shortening within the Hoh Xil Basin and implications for the uplift history of the northern Tibetan Plateau. *Tectonics* 35, 862-895. doi: https://doi.org/10.1002/2015TC003972

Shi, W., Wang, F., Wu, L., Yang, L., Zhang, W., and Wang, Y. (2018). A prolonged Cenozoic erosional period in East Kunlun (Western China): Constraints of detrital apatite (U-Th)/He ages on the onset of mountain building along the northern margin of the Tibetan Plateau. *Journal of Asian Earth Sciences* 151, 54-61. doi: https://doi.org/10.1016/j.jseaes.2017.10.027

Vermeesch, P., Avigad, D., and McWilliams, M. O. (2009). 500 m.y. of thermal history elucidated by multi-method detrital thermochronology of North Gondwana Cambrian sandstone (Eilat area, Israel). *GSA Bulletin* 121(7-8), 1204-1216. doi: https://doi.org/10.1130/B26473.1

Wang, C., Zhao, X., Liu, Z., Lippert, P.C., Graham, S.A., Coe, R.S., Yi, H., Zhu, L., Liu, S., Li, Y., 2008. Constraints on the early uplift history of the Tibetan Plateau. Proceedings of the National Academy of Sciences 105, 4987-4992. doi: https://doi.org/10.1073/pnas.0703595105

Wang, L., and Wei, Y. (2013). Apatite fission track thermochronology evidence for the Mid-Cretaceous tectonic event in the Qiangtang Basin, Tibet. *Acta Pet. Sin.* 29, 1039-1047. (in Chinese with English abstract)

Wang, F., Shi, W., Zhang, W., Wu, L., Yang, L., Wang, Y., and Zhu, R. (2017). Differential growth of the northern Tibetan margin: evidence for oblique stepwise rise of the Tibetan Plateau. *Scientific Reports* 7, 41164. doi: https://doi.org/10.1038/srep41164

Wang, Y., Zhang, X., Sun, L., and Wan, J. (2007). Cooling history and tectonic exhumation stages of the south-central Tibetan Plateau (China): Constrained by 40Ar/39Ar and apatite fission track thermochronology. *Journal of Asian Earth Sciences* 29(2), 266-282. doi: https://doi.org/10.1016/j.jseaes.2005.11.001

Wolf, R.A., Farley, K.A., and Silver, L.T. (1996). Helium diffusion and low-temperature thermochronometry of apatite. *Geochimica et Cosmochimica Acta* 60(21), 4231-4240. doi: https://doi.org/10.1016/S0016-7037(96)00192-5

Zhang, J., Sinclair, H. D., Li, Y., Wang, C., Persano, C., Qian, X., Han, Z., Yao, X., and Duan, Y. (2019). Subsidence and exhumation of the Mesozoic Qiangtang Basin: Implications for the growth of the Tibetan plateau. *Basin Research* 31(4), 754-781. doi: https://doi.org/10.1111/bre.12343

Zhao, Z., Lu, L., and Wu, Z. (2018). Uplifting evolution of the Central Uplift Belt, Qiangtang: tectonothermochronologic constrains. *Earth Sciences Frontiers* 26(2), 249-263. doi: [10.13745/j.esf.sf.2018.9.7](https://doi.org/10.13745/j.esf.sf.2018.9.7)