

*Journal of Geophysical Research: Solid Earth*

Supporting Information for

Remagnetization of red beds on the Tibetan Plateau:

mechanism and diagnosis

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**Text S1. Methods**

Rock magnetic experiments were conducted at the Institute for Rock Magnetism at the University of Minnesota (Minneapolis, USA). We use a KLY-2 KappaBridge AC susceptibility meter (AC field of 300 A/m, frequency of 920 Hz) for the high-temperature, low-field magnetic susceptibility measurements. We use the following heating and cooling cycles during the measurement: 300°C - 20°C - 500°C - 20°C - 600°C - 20°C - 700°C.

A Princeton Measurements MicroMag vibrating-sample magnetometer (VSM, nominal sensitivity of 5 x 10-9 Am2, maximum applied field of 1.4 T, averaging time of 300 ms, pause after sweep increment of 300 ms) was used for hysteresis measurements and isothermal remanent magnetization (IRM) acquisition. We use MAX UnMix (Maxbauer et al., 2016) for the IRM component analyses of 45 samples (thirteen from the Gongjue basin, three from the Nangqian basin, 12 from the Shanglaxiu basin, and 17 from the Jinggu basin, Table S2), to supplement our previous analysis of 31 samples from the Nangqian basin (Huang et al., 2019). The coercivity spectra, the derivatives of the isothermal remanent magnetization (IRM) curves with respect to field, are fitted with coercivity components.

We use a Quantum Design Magnetic Properties Measurement System (MPMS) for the low-temperature remanence experiments. Samples for the room temperature saturation remanent magnetization (RTSIRM) cycling measurements were given a room-temperature IRM in a 2.5 T field first, and then measured in zero field when cooling to 20 K and on rewarming back to room temperature. For the measurement of the field cooled (FC) curves, samples were cooled to 20 K in a 2.5 T field; the FC remanence was measured subsequently in zero field on rewarming to room temperature. For the measurement of the zero-field cooled (ZFC) curves, samples were first cooled to 20 K, then given a low-temperature SIRM in 2.5 T at 20 K. ZFC remanence was measured in zero field during warming to room temperature. We also applied a series of low-temperature remanence measurements to detect goethite. Following the room-temperature SIRM cooling-warming cycles, samples were taken out of the MOMS and demagnetized using an alternating field (AF) demagnetizer with a peak field of 200 mT. The purpose is to remove the signal carried by ferromagnetic minerals with coercivities <200 mT (i.e. magnetite, and fine-grained hematite), and therefore to enhance the contribution of goethite. The samples were then put back in the MPMS and the remanence was measured from 300 K to 20 K. Finally, the remanence was measured when samples were warmed up to 400 K, the Néel temperature of goethite, and then cooled again to 20 K.

Mössbauer spectra were measured with a conventional constant-acceleration spectrometer in transmission geometry with a source of 57Co in a Rh matrix, with an activity of about 50 mCi. Hyperfine parameters such as the magnetic hyperfine field (BHF), isomer shift (IS) and quadrupole splitting (QS) have been determined with in-house software of the Institute for Rock Magnetism. -Fe was used to calibrate isomer shifts and velocity scale at room temperature.

SEM observation and EDS analysis were acquired on a Field Electron and Ion GEG650 SEM, operating at 15 kV and 40–60 nA at the SEM laboratory at the Key Laboratory of Orogenic Belts and Crustal Evolution, School of Earth and Space Sciences, Peking University (Beijing, China).

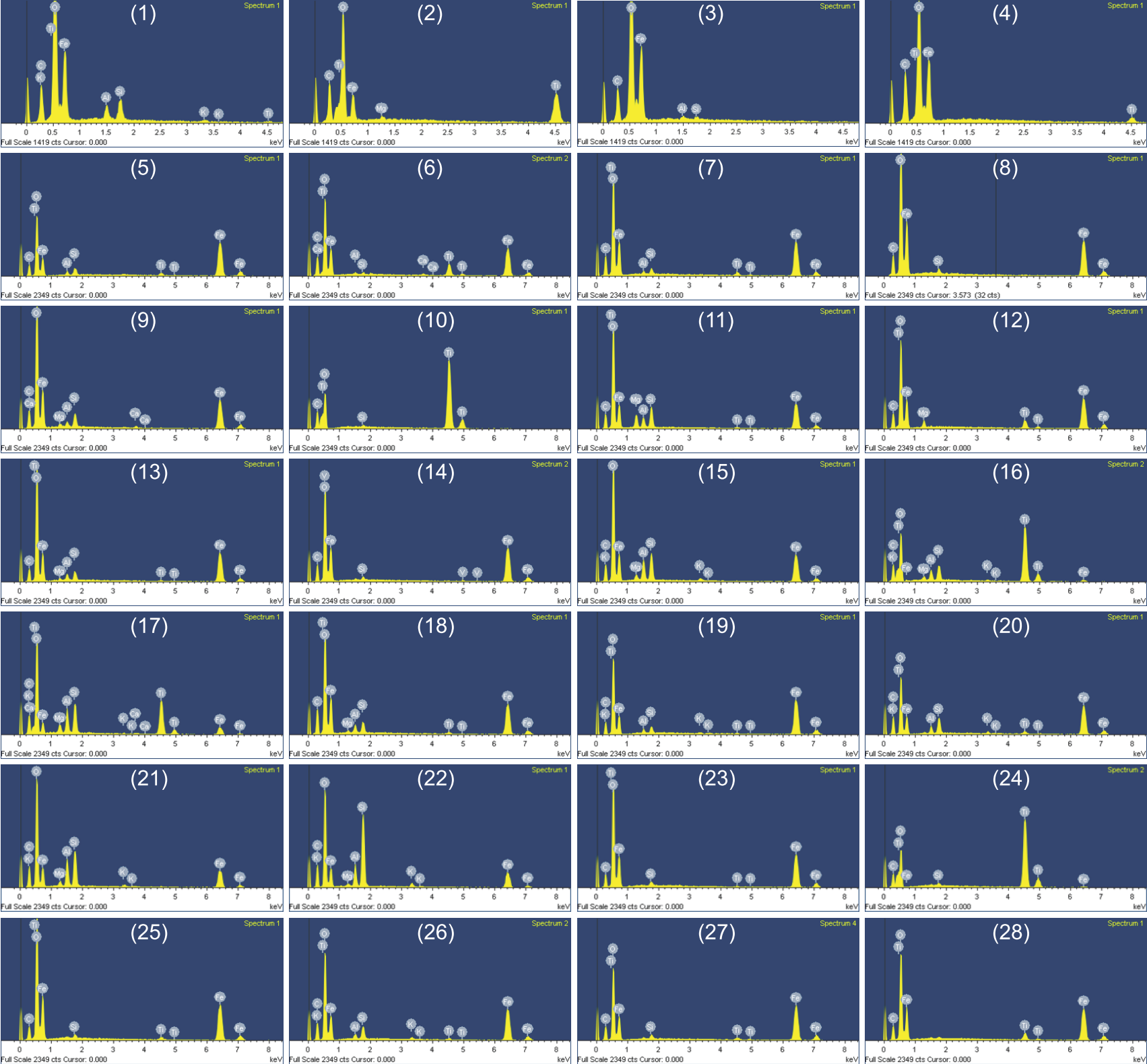


Figure S1. EDS analysis results of dots presented in Figure 10.

Table S1. Hysteresis parameter for individual specimens at room temperature

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **NRM origin** | **Sample** | **Ms** | **Mrs** | **Bc** | **Bcr** | **Mrs/Ms** | **Source** |
|  |  | ***Am2/kg*** | ***Am2/kg*** | ***mT*** | ***mT*** |  |  |
| **Gongjue basin** |  |  |  |  |  |  |  |
| Primary | GJ1.1 | 2.04E-03 | 9.00E-04 | 91.25 | 200.87 | 0.44 | Zhang et al., 2018 |
| Primary | GJ3.2 | 3.55E-03 | 1.59E-03 | 110.94 | 212.23 | 0.45 | Zhang et al., 2018 |
| Primary | GJ7.8 | 3.40E-03 | 1.96E-03 | 238.15 | 268.06 | 0.58 | Zhang et al., 2018 |
| Primary | GJ11.6 | 7.69E-03 | 2.04E-03 | 38.29 | 152.43 | 0.27 | Zhang et al., 2018 |
| Primary | GJ13.5 | 3.09E-03 | 1.47E-03 | 143.87 | 221.76 | 0.48 | Zhang et al., 2018 |
| Primary | GJ16.8 | 5.81E-03 | 2.85E-03 | 147.35 | 242.52 | 0.49 | Zhang et al., 2018 |
| Primary | GJ18.2 | 4.11E-03 | 1.87E-03 | 125.39 | 241.88 | 0.45 | Zhang et al., 2018 |
| Primary | GJ20.9 | 3.97E-03 | 1.64E-03 | 83.04 | 188.39 | 0.41 | Zhang et al., 2018 |
| Primary | GJ23.8 | 1.73E-03 | 8.16E-04 | 108.88 | 165.94 | 0.47 | Zhang et al., 2018 |
| Primary | GJ27.1 | 2.73E-03 | 1.28E-03 | 131.20 | 243.59 | 0.47 | Zhang et al., 2018 |
| Primary | GJ29.3 | 2.21E-03 | 1.04E-03 | 143.06 | 234.06 | 0.47 | Zhang et al., 2018 |
| Primary | JD1.7 | 3.15E-03 | 1.48E-03 | 140.58 | 218.98 | 0.47 | Zhang et al., 2018 |
| Primary | JD3.10 | 3.13E-03 | 1.40E-03 | 99.49 | 191.26 | 0.45 | Zhang et al., 2018 |
| Primary | JD5.6 | 3.56E-03 | 1.89E-03 | 179.19 | 249.50 | 0.53 | Zhang et al., 2018 |
| Primary | JD9.5 | 1.87E-03 | 8.56E-04 | 53.66 | 75.25 | 0.46 | Zhang et al., 2018 |
| Primary | JD11.6 | 1.31E-02 | 2.68E-03 | 26.84 | 97.55 | 0.20 | Zhang et al., 2018 |
| Primary | JD13.4 | 5.39E-03 | 1.86E-03 | 52.11 | 157.58 | 0.34 | Zhang et al., 2018 |
| Primary | JD17.1 | 3.27E-03 | 1.69E-03 | 132.28 | 212.50 | 0.52 | Zhang et al., 2018 |
| Primary | JD19.8 | 2.32E-03 | 1.02E-03 | 86.69 | 160.42 | 0.44 | Zhang et al., 2018 |
| Primary | JD23.8 | 2.05E-03 | 1.08E-03 | 180.17 | 252.20 | 0.53 | Zhang et al., 2018 |
| Primary | JD27.6 | 2.98E-03 | 1.61E-03 | 190.72 | 230.11 | 0.54 | Zhang et al., 2018 |
| Primary | JD31.3 | 3.48E-03 | 1.57E-03 | 95.87 | 212.91 | 0.45 | Zhang et al., 2018 |
| Primary | JD34.9 | 2.08E-03 | 1.10E-03 | 169.57 | 222.40 | 0.53 | Zhang et al., 2018 |
| **Nangqian basin** |  |  |  |  |  |  |  |
| Primary | 15NQ5403 | 6.70E-03 | 4.10E-03 | 291.09 | 483.93 | 0.61 | Huang et al., 2019a |
| Primary | 15NQ5404 | 7.34E-03 | 4.61E-03 | 347.30 | 522.80 | 0.63 | Huang et al., 2019a |
| Primary | 15NQ5405 | 6.27E-03 | 3.90E-03 | 306.77 | 512.04 | 0.62 | Huang et al., 2019a |
| Primary | 15NQ5408 | 9.70E-03 | 7.00E-03 | 399.12 | 462.60 | 0.72 | Huang et al., 2019a |
| Primary | 15NQ5412 | 6.69E-03 | 4.31E-03 | 331.06 | 517.46 | 0.64 | Huang et al., 2019a |
| Primary | 15NQ5417 | 7.83E-03 | 5.09E-03 | 343.61 | 520.18 | 0.65 | Huang et al., 2019a |
| Primary | 15NQ5505 | 5.12E-03 | 3.44E-03 | 260.89 | 487.71 | 0.67 | Huang et al., 2019a |
| Primary | 15NQ5709 | 6.00E-03 | 4.46E-03 | 369.45 | 442.08 | 0.74 | Huang et al., 2019a |
| Primary | 15NQ5721 | 8.15E-03 | 5.04E-03 | 318.01 | 518.48 | 0.62 | Huang et al., 2019a |
| Primary | 15NQ5609 | 1.00E-02 | 7.34E-03 | 383.40 | 522.89 | 0.73 | this study |
| Primary | 15NQ5723 | 1.00E-02 | 7.48E-03 | 407.14 | 465.55 | 0.75 | this study |
| Secondary | 14NQ0703 | 2.93E-03 | 1.58E-03 | 344.90 | 562.41 | 0.54 | Huang et al., 2019a |
| Secondary | 14NQ0712 | 3.07E-03 | 2.19E-03 | 321.30 | 464.38 | 0.71 | Huang et al., 2019a |
| Secondary | 14NQ0719 | 3.46E-03 | 2.60E-03 | 317.16 | 471.74 | 0.75 | Huang et al., 2019a |
| Secondary | 14NQ0910 | 3.25E-03 | 1.82E-03 | 240.34 | 399.73 | 0.56 | Huang et al., 2019a |
| Secondary | 14NQ1504 | 9.59E-03 | 4.53E-03 | 216.04 | 368.43 | 0.47 | Huang et al., 2019a |
| Secondary | 14NQ1509 | 7.66E-03 | 5.16E-03 | 267.30 | 381.57 | 0.67 | Huang et al., 2019a |
| Secondary | 14NQ1510 | 6.21E-03 | 3.33E-03 | 240.96 | 386.18 | 0.54 | Huang et al., 2019a |
| Secondary | 14NQ1513 | 6.28E-03 | 4.26E-03 | 266.69 | 390.42 | 0.68 | Huang et al., 2019a |
| Secondary | 15NQ5315 | 8.84E-03 | 5.70E-03 | 358.50 | 479.07 | 0.65 | Huang et al., 2019a |
| Secondary | 15NQ5318 | 1.27E-03 | 8.31E-04 | 342.09 | 487.55 | 0.65 | Huang et al., 2019a |
| Secondary | 14NQ0409 | 4.07E-03 | 2.44E-03 | 271.90 | 473.70 | 0.60 | Huang et al., 2019a |
| Secondary | 14NQ0411 | 2.90E-03 | 1.73E-03 | 278.41 | 490.57 | 0.60 | Huang et al., 2019a |
| Secondary | 14NQ0602 | 6.19E-03 | 4.35E-03 | 259.84 | 374.40 | 0.70 | Huang et al., 2019a |
| Secondary | 14NQ0611 | 4.19E-03 | 2.86E-03 | 278.73 | 408.90 | 0.68 | Huang et al., 2019a |
| Secondary | 14NQ0915 | 4.15E-03 | 2.36E-03 | 243.19 | 401.54 | 0.57 | Huang et al., 2019a |
| Secondary | 14NQ1308 | 2.69E-03 | 1.95E-03 | 306.65 | 472.92 | 0.73 | Huang et al., 2019a |
| Secondary | 14NQ1309 | 4.03E-03 | 2.65E-03 | 250.97 | 419.68 | 0.66 | Huang et al., 2019a |
| Secondary | 15NQ5307 | 7.96E-03 | 5.47E-03 | 367.68 | 520.88 | 0.69 | Huang et al., 2019a |
| Secondary | 15NQ5308 | 5.49E-03 | 3.85E-03 | 322.48 | 459.83 | 0.70 | Huang et al., 2019a |
| Secondary | 15NQ5313 | 6.23E-03 | 4.01E-03 | 318.73 | 474.75 | 0.64 | Huang et al., 2019a |
| Secondary | 15NQ5314 | 7.73E-03 | 5.85E-03 | 378.14 | 487.94 | 0.76 | Huang et al., 2019a |
| Secondary | 15NQ5321 | 5.93E-03 | 3.31E-03 | 262.52 | 410.43 | 0.56 | Huang et al., 2019a |
| Secondary | 15NQ5610 | 9.21E-03 | 5.31E-03 | 311.24 | 520.62 | 0.58 | Huang et al., 2019a |
| Secondary | 15NQ5611 | 8.24E-03 | 5.41E-03 | 347.50 | 519.62 | 0.66 | Huang et al., 2019a |
| Secondary | 15NQ5708 | 6.45E-03 | 4.06E-03 | 315.61 | 497.09 | 0.63 | Huang et al., 2019a |
| Secondary | 15NQ5716 | 9.05E-03 | 5.40E-03 | 313.63 | 508.48 | 0.60 | Huang et al., 2019a |
| Secondary | 14NQ0315 | 5.52E-03 | 3.15E-03 | 212.99 | 372.50 | 0.57 | this study |
| Secondary | 14NQ0905 | 5.16E-03 | 2.99E-03 | 240.33 | 416.08 | 0.58 | this study |
| **Shanglaxiu basin** |  |  |  |  |  |  |  |
| Secondary | 14XL1109 | 2.82E-03 | 1.10E-03 | 74.90 | 444.59 | 0.39 | this study |
| Secondary | 14XL1505 | 3.06E-03 | 1.18E-03 | 112.61 | 365.21 | 0.39 | this study |
| Secondary | 14XL1506 | 1.84E-03 | 1.01E-03 | 183.13 | 385.34 | 0.55 | this study |
| Secondary | 14XL1601 | 3.16E-03 | 1.33E-03 | 103.99 | 457.36 | 0.42 | this study |
| Secondary | 14XL1605 | 4.54E-03 | 1.20E-03 | 63.71 | 340.42 | 0.26 | this study |
| Secondary | 14XL1612 | 6.42E-03 | 2.24E-03 | 111.96 | 362.70 | 0.35 | this study |
| Secondary | 14XL1803 | 5.37E-03 | 1.64E-03 | 87.91 | 374.52 | 0.31 | this study |
| Secondary | 14XL1805 | 2.65E-03 | 9.44E-04 | 69.45 | 464.03 | 0.36 | this study |
| Secondary | 14XL1807 | 2.99E-03 | 1.37E-03 | 99.40 | 377.50 | 0.46 | this study |
| Secondary | 14XL1808 | 3.01E-03 | 1.42E-03 | 104.38 | 371.31 | 0.47 | this study |
| Secondary | 15Xl2814 | 2.23E-03 | 9.33E-04 | 109.82 | 465.31 | 0.42 | this study |
| Secondary | 15XL2815 | 3.09E-03 | 1.43E-03 | 121.15 | 467.21 | 0.46 | this study |
| Secondary | 15XL2904 | 2.15E-03 | 8.90E-04 | 91.64 | 412.42 | 0.41 | this study |
| Secondary | 15XL2906 | 1.87E-03 | 5.89E-04 | 51.39 | 346.94 | 0.32 | this study |
| Secondary | 15XL2911 | 1.52E-03 | 7.46E-04 | 135.87 | 435.91 | 0.49 | this study |
| **Jinggu basin** |  |  |  |  |  |  |  |
| Secondary | B61 | 8.28E-03 | 6.42E-03 | 388.81 | 462.98 | 0.78 | this study |
| Secondary | B62 | 6.58E-03 | 4.21E-03 | 288.92 | 434.82 | 0.64 | this study |
| Secondary | B63 | 8.61E-03 | 4.75E-03 | 317.97 | 492.26 | 0.55 | this study |
| Secondary | B64 | 6.56E-03 | 4.37E-03 | 316.23 | 466.99 | 0.67 | this study |
| Secondary | B65 | 8.44E-03 | 5.92E-03 | 371.22 | 533.19 | 0.70 | this study |
| Secondary | B69 | 6.10E-03 | 4.14E-03 | 392.66 | 469.97 | 0.68 | this study |
| Secondary | B70 | 6.92E-03 | 4.58E-03 | 328.30 | 452.78 | 0.66 | this study |
| Secondary | B106 | 7.57E-03 | 5.66E-03 | 388.38 | 519.63 | 0.75 | this study |
| Secondary | B107 | 7.10E-03 | 3.85E-03 | 275.46 | 427.68 | 0.54 | this study |
| Secondary | B115 | 6.10E-03 | 4.05E-03 | 352.39 | 491.95 | 0.66 | this study |
| Secondary | B173 | 6.40E-03 | 4.72E-03 | 353.62 | 494.59 | 0.74 | this study |
| Secondary | B19 | 6.91E-03 | 4.78E-03 | 376.60 | 534.87 | 0.69 | this study |
| Secondary | B261 | 6.22E-03 | 3.35E-03 | 120.54 | 407.23 | 0.54 | this study |
| Secondary | B281 | 6.29E-03 | 4.27E-03 | 367.78 | 466.53 | 0.68 | this study |
| Secondary | B442 | 4.66E-03 | 2.55E-03 | 186.13 | 452.31 | 0.55 | this study |
| Secondary | B456 | 4.20E-03 | 2.38E-03 | 204.18 | 437.72 | 0.57 | this study |
| Secondary | B458 | 7.88E-03 | 5.28E-03 | 413.18 | 599.22 | 0.67 | this study |
| Secondary | B506 | 7.13E-03 | 4.81E-03 | 365.10 | 466.36 | 0.67 | this study |
| Secondary | B552 | 6.40E-03 | 4.39E-03 | 354.91 | 531.56 | 0.69 | this study |
| Secondary | B534 | 7.16E-03 | 4.92E-03 | 378.75 | 517.33 | 0.69 | this study |
| Secondary | B609 | 4.01E-03 | 2.62E-03 | 258.44 | 404.62 | 0.65 | this study |
| Note. Bc- coercive force; Bcr- remanent coercivity; Mrs- remanent saturation; Ms- saturation magnetization. | | | | | | | |

Table S2. Results of IRM component analysis.

|  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **NRM origin** | **Sample** | **Component 1** | | | | | **Component 2** | | | | | **Source** |
|  |  | ***Bh*** | ***DP*** | ***S*** | ***OC.mean*** | ***EC.mean*** | ***Bh*** | ***DP*** | ***S*** | ***OC.mean*** | ***EC.mean*** |  |
| **Gongjue Basin** | |  |  |  |  |  |  |  |  |  |  |  |
| Primary | GJ1.1 | 111.71 | 3.44 | 1.04 | 0.48 | 0.48 | 408.13 | 1.54 | 0.99 | 0.52 | 0.52 | this study |
| Primary | GJ9.2 | 64.83 | 2.67 | 1.11 | 0.16 | 0.12 | 674.38 | 2.11 | 0.95 | 0.84 | 0.88 | this study |
| Primary | GJ13.5 | 69.13 | 2.90 | 0.43 | 0.35 | 0.34 | 421.50 | 1.54 | 1.09 | 0.65 | 0.66 | this study |
| Primary | GJ23.8 | 63.44 | 2.49 | 0.78 | 0.35 | 0.34 | 410.24 | 1.68 | 1.02 | 0.65 | 0.66 | this study |
| Primary | GJ27.1 | 93.33 | 3.61 | 0.70 | 0.42 | 0.43 | 410.38 | 1.54 | 1.01 | 0.58 | 0.57 | this study |
| Primary | GJ29.3 | 70.73 | 3.02 | 0.38 | 0.34 | 0.34 | 416.70 | 1.55 | 1.08 | 0.66 | 0.66 | this study |
| Primary | JD1.7 | 69.08 | 2.76 | 0.37 | 0.30 | 0.29 | 486.78 | 1.64 | 1.24 | 0.70 | 0.71 | this study |
| Primary | JD18.1 | 77.06 | 3.11 | 1.09 | 0.18 | 0.12 | 702.51 | 2.01 | 0.86 | 0.82 | 0.88 | this study |
| Primary | JD19.8 | 47.65 | 3.03 | 0.73 | 0.36 | 0.35 | 402.00 | 1.70 | 1.09 | 0.64 | 0.65 | this study |
| Primary | JD23.8 | 93.18 | 3.21 | 0.60 | 0.41 | 0.38 | 451.45 | 1.55 | 1.09 | 0.59 | 0.62 | this study |
| Primary | JD27.6 | 66.10 | 3.03 | 0.30 | 0.33 | 0.32 | 427.64 | 1.54 | 1.11 | 0.67 | 0.68 | this study |
| Primary | JD31.3 | 69.29 | 3.65 | 1.12 | 0.18 | 0.13 | 785.17 | 2.21 | 0.95 | 0.82 | 0.87 | this study |
| Primary | JD34.9 | 63.77 | 2.86 | 0.38 | 0.32 | 0.31 | 429.82 | 1.60 | 1.11 | 0.68 | 0.69 | this study |
| **Nangqian Basin** | |  |  |  |  |  |  |  |  |  |  |  |
| Primary | 15NQ5408 | - | - | - | 0.00 | 0.00 | 659.93 | 2.02 | 0.84 | 1.00 | 1.00 | Huang et al., 2019a |
| Primary | 15NQ5417 | 114.73 | 2.28 | 0.71 | 0.11 | 0.11 | 506.72 | 1.74 | 0.65 | 0.89 | 0.89 | Huang et al., 2019a |
| Primary | 15NQ5505 | 100.95 | 2.72 | 0.68 | 0.14 | 0.11 | 759.88 | 2.03 | 0.94 | 0.86 | 0.89 | Huang et al., 2019a |
| Primary | 15NQ5709 | 100.49 | 2.19 | 0.66 | 0.06 | 0.05 | 635.10 | 1.97 | 0.85 | 0.94 | 0.95 | Huang et al., 2019a |
| Primary | 15NQ5721 | 86.16 | 1.98 | 0.50 | 0.17 | 0.17 | 368.36 | 1.62 | 0.99 | 0.83 | 0.83 | Huang et al., 2019a |
| Primary | 15NQ5405 | 102.91 | 2.35 | 0.77 | 0.12 | 0.12 | 520.73 | 1.77 | 0.71 | 0.88 | 0.88 | Huang et al., 2019a |
| Primary | 15NQ5609 | 98.38 | 2.67 | 0.68 | 0.13 | 0.11 | 761.37 | 2.04 | 0.94 | 0.87 | 0.89 | this study |
| Primary | 15NQ5723 | - | - | - | 0.00 | 0.00 | 684.29 | 2.05 | 0.84 | 1.00 | 1.00 | this study |
| Secondary | 14NQ0703 | 105.80 | 3.34 | 0.77 | 0.15 | 0.14 | 688.58 | 1.76 | 0.73 | 0.85 | 0.86 | Huang et al., 2019a |
| Secondary | 14NQ0712 | 76.63 | 3.99 | 0.85 | 0.12 | 0.14 | 613.93 | 1.91 | 0.90 | 0.88 | 0.86 | Huang et al., 2019a |
| Secondary | 14NQ0719 | 85.63 | 3.63 | 0.72 | 0.13 | 0.13 | 640.25 | 2.03 | 0.97 | 0.87 | 0.87 | Huang et al., 2019a |
| Secondary | 14NQ0910 | 72.40 | 2.25 | 1.05 | 0.09 | 0.09 | 478.00 | 1.99 | 0.98 | 0.91 | 0.91 | Huang et al., 2019a |
| Secondary | 14NQ1504 | 90.99 | 1.96 | 0.64 | 0.06 | 0.05 | 476.32 | 1.91 | 1.13 | 0.94 | 0.95 | Huang et al., 2019a |
| Secondary | 14NQ1509 | 126.04 | 2.44 | 0.79 | 0.09 | 0.08 | 505.59 | 2.02 | 1.06 | 0.91 | 0.92 | Huang et al., 2019a |
| Secondary | 14NQ1510 | 66.72 | 2.36 | 0.99 | 0.07 | 0.06 | 460.28 | 2.09 | 0.99 | 0.93 | 0.94 | Huang et al., 2019a |
| Secondary | 14NQ1513 | 66.20 | 7.72 | 1.00 | 0.07 | 0.06 | 460.64 | 2.09 | 0.99 | 0.93 | 0.94 | Huang et al., 2019a |
| Secondary | 15NQ5315 | - | - | - | 0.00 | 0.00 | 570.17 | 2.00 | 0.82 | 1.00 | 1.00 | Huang et al., 2019a |
| Secondary | 15NQ5318 | 118.60 | 2.27 | 0.93 | 0.07 | 0.07 | 475.42 | 1.81 | 0.69 | 0.93 | 0.93 | Huang et al., 2019a |
| Secondary | 14NQ0409 | 97.31 | 2.73 | 0.89 | 0.07 | 0.07 | 621.82 | 2.09 | 1.00 | 0.93 | 0.93 | Huang et al., 2019a |
| Secondary | 14NQ0602 | 52.63 | 5.56 | 0.83 | 0.11 | 0.11 | 513.87 | 2.09 | 1.09 | 0.89 | 0.89 | Huang et al., 2019a |
| Secondary | 14NQ0611 | 64.12 | 4.69 | 0.91 | 0.09 | 0.08 | 540.91 | 2.09 | 1.01 | 0.91 | 0.92 | Huang et al., 2019a |
| Secondary | 14NQ0915 | 53.07 | 2.51 | 0.67 | 0.09 | 0.06 | 582.11 | 2.37 | 1.06 | 0.91 | 0.94 | Huang et al., 2019a |
| Secondary | 14NQ1308 | 69.35 | 5.07 | 0.87 | 0.11 | 0.12 | 578.15 | 1.94 | 0.90 | 0.89 | 0.88 | Huang et al., 2019a |
| Secondary | 14NQ1309 | 79.77 | 1.82 | 1.11 | 0.05 | 0.04 | 635.38 | 2.30 | 1.13 | 0.95 | 0.96 | Huang et al., 2019a |
| Secondary | 15NQ5307 | 81.44 | 2.35 | 0.47 | 0.05 | 0.04 | 638.08 | 2.14 | 0.96 | 0.95 | 0.96 | Huang et al., 2019a |
| Secondary | 15NQ5308 | 81.93 | 2.06 | 1.35 | 0.05 | 0.04 | 669.40 | 2.25 | 1.02 | 0.95 | 0.96 | Huang et al., 2019a |
| Secondary | 15NQ5313 | 93.70 | 2.42 | 0.92 | 0.07 | 0.07 | 478.14 | 1.91 | 0.74 | 0.93 | 0.93 | Huang et al., 2019a |
| Secondary | 15NQ5314 | - | - | - | 0.00 | 0.00 | 588.15 | 2.04 | 0.82 | 1.00 | 1.00 | Huang et al., 2019a |
| Secondary | 15NQ5321 | 66.59 | 2.33 | 0.86 | 0.08 | 0.08 | 439.48 | 2.00 | 0.86 | 0.92 | 0.92 | Huang et al., 2019a |
| Secondary | 15NQ5610 | 102.47 | 2.28 | 0.59 | 0.13 | 0.13 | 518.94 | 1.74 | 0.68 | 0.87 | 0.87 | Huang et al., 2019a |
| Secondary | 15NQ5611 | 97.78 | 2.35 | 0.71 | 0.10 | 0.10 | 490.46 | 1.76 | 0.60 | 0.90 | 0.90 | Huang et al., 2019a |
| Secondary | 15NQ5708 | 88.33 | 2.68 | 1.00 | 0.08 | 0.09 | 463.51 | 1.82 | 0.59 | 0.92 | 0.91 | Huang et al., 2019a |
| Secondary | 15NQ5716 | 133.02 | 2.59 | 1.00 | 0.13 | 0.13 | 492.25 | 1.78 | 0.63 | 0.87 | 0.87 | Huang et al., 2019a |
| Secondary | 14NQ0315 | 90.56 | 2.43 | 0.90 | 0.10 | 0.10 | 502.51 | 2.12 | 1.02 | 0.90 | 0.90 | this study |
| **Shanglaxiu Basin** | |  |  |  |  |  |  |  |  |  |  |  |
| Secondary | 14XL1505 | 61.46 | 2.38 | 1.07 | 0.18 | 0.15 | 572.07 | 2.38 | 1.11 | 0.82 | 0.85 | this study |
| Secondary | 14XL1506 | 53.04 | 2.09 | 1.15 | 0.10 | 0.08 | 569.02 | 2.47 | 1.05 | 0.90 | 0.92 | this study |
| Secondary | 14XL1601 | 83.23 | 2.89 | 0.97 | 0.20 | 0.14 | 963.76 | 2.52 | 1.10 | 0.80 | 0.86 | this study |
| Secondary | 14XL1612 | 99.49 | 3.00 | 0.86 | 0.24 | 0.13 | 1673.51 | 3.50 | 1.41 | 0.76 | 0.87 | this study |
| Secondary | 14XL1803 | 69.95 | 2.50 | 1.11 | 0.16 | 0.10 | 1077.55 | 2.73 | 1.13 | 0.84 | 0.90 | this study |
| Secondary | 14XL1805 | 83.90 | 2.71 | 1.02 | 0.22 | 0.14 | 1134.53 | 2.60 | 1.20 | 0.78 | 0.86 | this study |
| Secondary | 14XL1808 | 86.61 | 2.73 | 1.00 | 0.19 | 0.13 | 982.68 | 2.53 | 1.13 | 0.81 | 0.87 | this study |
| Secondary | 15Xl2814 | 109.33 | 3.79 | 0.99 | 0.27 | 0.25 | 647.17 | 1.88 | 0.96 | 0.73 | 0.75 | this study |
| Secondary | 15XL2815 | 96.13 | 4.21 | 1.04 | 0.26 | 0.23 | 656.53 | 1.96 | 0.97 | 0.74 | 0.77 | this study |
| Secondary | 15XL2904 | 86.55 | 2.64 | 1.16 | 0.28 | 0.24 | 673.66 | 2.15 | 1.00 | 0.72 | 0.76 | this study |
| Secondary | 15XL2906 | 69.56 | 2.91 | 1.22 | 0.33 | 0.27 | 761.97 | 2.60 | 1.06 | 0.67 | 0.73 | this study |
| Secondary | 15XL2911 | 92.92 | 4.41 | 1.08 | 0.25 | 0.21 | 706.37 | 2.38 | 1.04 | 0.75 | 0.79 | this study |
| **Jinggu Basin** | |  |  |  |  |  |  |  |  |  |  |  |
| Secondary | B61 | 103.12 | 2.34 | 0.47 | 0.07 | 0.06 | 734.25 | 1.96 | 1.02 | 0.93 | 0.94 | this study |
| Secondary | B65 | 102.38 | 2.51 | 0.46 | 0.09 | 0.07 | 801.46 | 1.98 | 1.04 | 0.91 | 0.93 | this study |
| Secondary | B69 | 109.17 | 2.61 | 0.42 | 0.10 | 0.07 | 874.02 | 2.07 | 1.09 | 0.91 | 0.93 | this study |
| Secondary | B70 | 84.13 | 2.62 | 0.54 | 0.10 | 0.08 | 716.41 | 1.87 | 0.88 | 0.90 | 0.92 | this study |
| Secondary | B106 | 107.96 | 2.46 | 0.73 | 0.07 | 0.06 | 749.36 | 2.01 | 1.04 | 0.93 | 0.94 | this study |
| Secondary | B115 | 88.12 | 3.12 | 0.23 | 0.10 | 0.08 | 709.50 | 1.98 | 1.03 | 0.90 | 0.92 | this study |
| Secondary | B173 | 74.12 | 2.75 | 0.41 | 0.08 | 0.07 | 705.06 | 1.98 | 1.03 | 0.92 | 0.93 | this study |
| Secondary | B19 | 92.63 | 2.52 | 0.47 | 0.08 | 0.06 | 752.15 | 1.92 | 0.97 | 0.92 | 0.94 | this study |
| Secondary | B261 | 80.18 | 4.84 | 1.24 | 0.24 | 0.21 | 780.11 | 2.20 | 1.15 | 0.76 | 0.79 | this study |
| Secondary | B281 | 97.58 | 2.42 | 0.45 | 0.09 | 0.07 | 774.02 | 1.96 | 1.04 | 0.91 | 0.93 | this study |
| Secondary | B442 | 90.10 | 3.32 | 0.63 | 0.19 | 0.14 | 929.91 | 2.37 | 1.26 | 0.81 | 0.86 | this study |
| Secondary | B456 | 82.82 | 3.51 | 0.82 | 0.21 | 0.17 | 787.28 | 2.28 | 1.22 | 0.79 | 0.83 | this study |
| Secondary | B458 | 79.76 | 3.16 | 0.35 | 0.08 | 0.06 | 855.82 | 1.85 | 0.97 | 0.92 | 0.94 | this study |
| Secondary | B506 | 102.44 | 2.52 | 0.43 | 0.09 | 0.07 | 775.39 | 1.94 | 0.99 | 0.91 | 0.93 | this study |
| Secondary | B552 | 99.54 | 3.28 | 0.65 | 0.10 | 0.08 | 822.61 | 2.04 | 1.05 | 0.90 | 0.92 | this study |
| Secondary | B534 | 106.04 | 2.88 | 0.55 | 0.10 | 0.07 | 838.28 | 1.99 | 1.05 | 0.90 | 0.93 | this study |
| Secondary | B609 | 105.40 | 3.22 | 0.98 | 0.13 | 0.11 | 810.98 | 2.28 | 1.17 | 0.87 | 0.89 | this study |
| Note. Bh- mean coercivity of an individual grain population; DP- dispersion parameter; S- skewness parameter; OC.- observed contribution; EC.- extrapolated contribution. | | | | | | | | | | | | |

Table S3. Remanent magnetization at 20 K after ZFC and FC treatment.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **NRM origin** | **Sample** | **MZFC** | **MFC** | **MFC/MZFC** | **Source** |
|  |  | ***Am2/kg*** | ***Am2/kg*** |  |  |
| **Gongjue basin** |  |  |  |  |  |
| Primary | GJ1.1 | 1.68E-03 | 1.93E-03 | 1.15 | this study |
| Primary | GJ11.6 | 2.44E-03 | 2.62E-03 | 1.08 | this study |
| Primary | GJ25.2 | 2.96E-03 | 3.39E-03 | 1.14 | this study |
| Primary | GJ27.1 | 2.27E-03 | 2.71E-03 | 1.19 | this study |
| Primary | GJ29.3 | 1.86E-03 | 2.23E-03 | 1.20 | this study |
| Primary | JD23.8 | 2.06E-03 | 2.41E-03 | 1.17 | this study |
| Primary | JD27.6 | 2.94E-03 | 3.61E-03 | 1.23 | this study |
| Primary | JD31.1 | 2.13E-03 | 2.30E-03 | 1.08 | this study |
| **Nangqian basin** |  |  |  |  |  |
| Primary | 15NQ5408 | 4.93E-03 | 5.15E-03 | 1.04 | Huang et al., 2019a |
| Primary | 15NQ5412 | 4.98E-03 | 5.22E-03 | 1.05 | Huang et al., 2019a |
| Primary | 15NQ5505 | 3.77E-03 | 4.13E-03 | 1.10 | Huang et al., 2019a |
| Primary | 15NQ5709 | 4.62E-03 | 4.84E-03 | 1.05 | Huang et al., 2019a |
| Primary | 15NQ5721 | 6.07E-03 | 6.36E-03 | 1.05 | Huang et al., 2019a |
| Primary | 15NQ5609 | 5.96E-03 | 6.21E-03 | 1.04 | this study |
| Primary | 15NQ5723 | 5.01E-03 | 5.23E-03 | 1.04 | this study |
| Secondary | 14NQ0703 | 3.87E-03 | 9.70E-03 | 2.51 | Huang et al., 2019a |
| Secondary | 14NQ0712 | 2.19E-03 | 2.70E-03 | 1.23 | Huang et al., 2019a |
| Secondary | 14NQ1504 | 2.79E-03 | 9.48E-03 | 3.40 | Huang et al., 2019a |
| Secondary | 14NQ1509 | 6.10E-03 | 1.86E-02 | 3.05 | Huang et al., 2019a |
| Secondary | 14NQ1513 | 3.74E-03 | 7.63E-03 | 2.04 | Huang et al., 2019a |
| Secondary | 15NQ5318 | 4.83E-03 | 9.29E-03 | 1.92 | Huang et al., 2019a |
| Secondary | 14NQ0409 | 1.90E-03 | 4.58E-03 | 2.42 | Huang et al., 2019a |
| Secondary | 14NQ0411 | 1.76E-03 | 4.95E-03 | 2.81 | Huang et al., 2019a |
| Secondary | 14NQ0602 | 2.83E-03 | 5.05E-03 | 1.79 | Huang et al., 2019a |
| Secondary | 14NQ0611 | 2.44E-03 | 4.26E-03 | 1.75 | Huang et al., 2019a |
| Secondary | 15NQ5308 | 3.64E-03 | 6.74E-03 | 1.85 | Huang et al., 2019a |
| Secondary | 15NQ5314 | 5.17E-03 | 9.30E-03 | 1.80 | Huang et al., 2019a |
| Secondary | 14NQ1309 | 2.79E-03 | 6.16E-03 | 2.21 | Huang et al., 2019a |
| Secondary | 14NQ1308 | 2.02E-03 | 3.01E-03 | 1.49 | Huang et al., 2019a |
| Secondary | 14NQ0315 | 3.05E-03 | 5.87E-03 | 1.93 | this study |
| Secondary | 14NQ0905 | 2.18E-03 | 2.90E-03 | 1.33 | this study |
| **Shanglaxiu basin** |  |  |  |  |  |
| Secondary | 14XL1109 | 2.33E-03 | 3.43E-03 | 1.47 | this study |
| Secondary | 14XL1601 | 4.82E-03 | 7.85E-03 | 1.63 | this study |
| Secondary | 14XL1605 | 1.65E-03 | 4.40E-03 | 2.67 | this study |
| Secondary | 14XL1805 | 1.66E-03 | 2.30E-03 | 1.39 | this study |
| Secondary | 15XL2815 | 3.10E-03 | 4.80E-03 | 1.55 | this study |
| Secondary | 15XL2904 | 3.33E-03 | 4.78E-03 | 1.43 | this study |
| **Jinggu basin** |  |  |  |  |  |
| Secondary | B19 | 4.29E-03 | 5.02E-03 | 1.17 | this study |
| Secondary | B61 | 5.22E-03 | 6.05E-03 | 1.16 | this study |
| Secondary | B106 | 3.98E-03 | 6.00E-03 | 1.51 | this study |
| Secondary | B107 | 4.42E-03 | 6.38E-03 | 1.44 | this study |
| Secondary | B173 | 3.87E-03 | 5.81E-03 | 1.50 | this study |
| Secondary | B261 | 1.93E-03 | 2.63E-03 | 1.37 | this study |
| Secondary | B281 | 3.59E-03 | 3.83E-03 | 1.07 | this study |
| Secondary | B442 | 2.37E-03 | 2.76E-03 | 1.16 | this study |
| Secondary | B458 | 8.22E-03 | 1.20E-02 | 1.47 | this study |
| Secondary | B506 | 4.40E-03 | 6.43E-03 | 1.46 | this study |
| Secondary | B534 | 4.74E-03 | 6.79E-03 | 1.43 | this study |
| Secondary | B609 | 6.94E-03 | 9.86E-03 | 1.42 | this study |

Table S4. Fitted Mössbauer parameters from three red bed samples.

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **NRM origin** | **Sample** | **Temperature** | **IS(1)** | **QS(1)** | **BHF(1)** | **Width(1)** | **Percentage(1)** | **BHF(1) variation** | **IS(2)** | **QS(2)** | **BHF(2)** | **Width(2)** | **Percentage(2)** | **BHF(2) variation** |
|  |  | ***[K]*** | ***[mm/s]*** | ***[mm/s]*** | ***[T]*** | ***[mm/s]*** | ***[%]*** |  | ***[mm/s]*** | ***[mm/s]*** | ***[T]*** | ***[mm/s]*** | ***[%]*** | ***-*** |
| Secondary | 14NQ0719 | 295 | 0.36 | -0.17 | 49.81 | 0.3 | 8.26 | 11 | 0.35 | -0.21 | 51.12 | 0.35 | 44.26 | - |
| 18 | 0.45 | -0.25 | 50.35 | 0.3 | 22.00 | 3.71 | 0.46 | -0.20 | 53.15 | 0.32 | 52.36 | - |
| Primary | 15NQ5721 | 295 | 0.36 | -0.21 | 50.38 | 0.3 | 11.57 | 4.55 | 0.35 | -0.22 | 51.21 | 0.30 | 45.7 | - |
| 18 | 0.47 | -0.22 | 53.90 | 0.3 | 0.00 | 1.80 | 0.47 | -0.20 | 53.14 | 0.30 | 59.7 | - |
| Primary | JD27.6 | 295 | 0.48 | -0.37 | 46.10 | 0.3 | 0.00 | 11.00 | 0.35 | -0.20 | 51.03 | 0.42 | 47.7 | - |
| 18 | 0.46 | -0.19 | 53.13 | 0.33 | 50.20 | - | - | - | - | - | - | - |
| Note. IS- isomer shift; QS-quadrupole splitting; BHF- magnetic hyperfine field; Numbers 1 and 2 represent sextet 1 and sextet 1, respectively. | | | | | | | | | | | | | | |