**Supporting Information for**

**Gypsum as a potential tracer of earthquake: a case study of the *Mw*7.8 earthquake in the East Anatolian Fault Zone, southeastern Turkey**

Zebin Luoa, Xiaocheng Zhoub,c[[1]](#footnote-1)★, Yueren Xub, Peng Liangb, Huiping Zhangd, Jinlong Liange,Zhaojun Zengb, Yucong Yanc, Zheng Gongf, Shiguang Wangf, Chuanyou Lid, Zhikun Rend, Jingxing Yud, Zifa Mad, Junjie Lid

*aSchool of Emergency Management, Xihua University, Chengdu 610039, China*

*bUnited Laboratory of High-Pressure Physics and Earthquake Science, institute of earthquake forecasting, CEA, Beijing 100036, China*

*cSchool of Earth Sciences and Resources, China University of Geosciences, Beijing 100083, China*

*dInstitute of Geology, China Earthquake Administration, Beijing, 100081, China*

*eCollege of Earth Science, Chengdu University of Technology, Chengdu 610059, China*

*fInstitute of Geophysics, China Earthquake Administration, Beijing, 100081, China*

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Video. 01 Seismic precursor anomaly of HS14 geothermal fluid. Shooting time: A month before the earthquake.

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**Part 1:**

Table S1. Temperature results obtained with empirical chemical geothermometers (values in oC)and depths (km) of origin for EAFZ geothermal waters.

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| No | T  (oC) | Na-K | | | K-Mg | Li-Mg | Na-Li | Na-Ca | K-Ca | Na-K-Ca | SiO2 | | | Circulation depth(km) |
| a | b | c | d | e | f | g | k | i | j | k | l |
| HS01 | 15.8 | 280.56 | 263.18 | 255.02 | 53.70 | 1164.31 | 115.33 | 113.53 | 167.74 | 177.81 | 64.74 | 76.87 | 32.72 | 1.8 |
| HS02 | 13.2 | 44.69 | 32.02 | 14.64 | 340.90 | 794.35 | 58.83 | -19.47 | -23.39 | 16.11 | 19.81 | 35.51 | -13.08 | 0.0 |
| HS03 | 13.2 | 97.13 | 83.05 | 65.94 | 110.59 | 329.25 | 256.42 | 136.38 | 80.14 | 78.41 | 74.15 | 85.36 | 42.54 | 2.2 |
| HS04 | 15.0 | 137.35 | 122.34 | 106.10 | 118.49 | 424.51 | 63.34 | 77.09 | 74.70 | 109.03 | 128.09 | 132.88 | 100.43 | 4.4 |
| HS05 | 12.7 | 183.61 | 167.67 | 153.17 | 101.56 | 722.02 | -11.79 | 69.20 | 92.54 | 139.57 | 51.58 | 64.90 | 19.12 | 1.3 |
| HS06 | 15.0 | 211.67 | 195.23 | 182.19 | 117.90 | 1098.86 | -23.85 | 43.82 | 87.06 | 149.16 | 53.76 | 66.89 | 21.36 | 1.4 |
| HS07 | 9.8 | 24.22 | 12.15 | -5.07 | 328.05 | 756.00 | 28.67 | -0.77 | -23.53 | 6.19 | 37.30 | 51.78 | 4.54 | 0.7 |
| HS08 | 8.1 | 16.25 | 4.41 | -12.71 | 326.88 | 752.56 | 17.37 | 8.17 | -23.55 | 2.17 | 53.32 | 66.49 | 20.90 | 1.4 |
| HS09 | 18.0 | 161.91 | 146.39 | 130.98 | 127.21 | 539.15 | 49.11 | 59.01 | 76.01 | 121.33 | 72.83 | 84.17 | 41.15 | 2.1 |
| HS10 | 20.0 | 7.89 | -3.69 | -20.68 | 456.36 | 1200.82 | 5.80 | 38.91 | -15.52 | 1.49 | 81.15 | 91.63 | 49.90 | 2.5 |
| HS11 | 16.3 | 166.55 | 150.93 | 135.70 | 148.33 | 985.95 | -6.80 | 27.09 | 57.05 | 113.61 | 38.24 | 52.65 | 5.49 | 0.8 |
| HS12 | 16.9 | 0.78 | -10.57 | -27.44 | 436.27 | 1120.85 | -3.85 | 56.07 | -13.62 | -1.56 | 98.46 | 107.00 | 68.28 | 3.2 |
| HS13 | 18.2 | 232.80 | 216.03 | 204.29 | 97.49 | 530.50 | 52.80 | 54.40 | 103.32 | 166.87 | 39.42 | 53.74 | 6.69 | 0.8 |
| HS14 | 23.5 | 226.40 | 209.73 | 197.58 | 48.47 | 350.37 | 216.09 | 188.63 | 187.64 | 224.53 | 87.85 | 97.61 | 56.98 | 2.7 |
| HS15 | 32.0 | 150.02 | 134.74 | 118.90 | 26.34 | 286.57 | 170.79 | 210.97 | 148.15 | 176.18 | -39.83 | -21.62 | -71.20 |  |
| HS16 | 24.5 | 299.42 | 281.83 | 275.35 | 25.48 | 540.78 | 122.71 | 258.29 | 274.78 | 375.41 | 82.83 | 93.13 | 51.67 | 2.5 |

Note: Circulation depth(km) =(T-T0)/g+h. “T” is reservoir temperature estimated by SiO2. “T0” is annual average temperature in EAFZ is 20 °C. “g” is geothermal gradient is ~2.50 °C/100 m. “h” is thickness of the constant temperature zone is 30 m.

a Na-K, T = 1390 / [log(Na/K) + 1.75] - 273.15 (Giggenbach, 1988).

b Na-K, T = 933 / [log(Na/K) + 0.993] - 273.15 (Arnórsson, 1983).

c Na-K, T = 1178 / [log(Na/K) + 1.47] - 273.15 (Nieva and Nieva, 1987).

d K-Mg, T = 4410 / [log(K/Mg1/2) + 14.0] - 273.15 (Giggenbach, 1988).

e Li-Mg, T = 2200 / [log(Li/Mg1/2) + 5.47] - 273.15 (Kharaka and Mariner, 1989).

f Na-Li, T = 1000 / [log(Na/Li) + 0.389] - 273.15 (Fouillac and Michard, 1981).

g Na-Ca, T = 1096.7 / [3.08 - log(Na/Ca1/2)] - 273.15 (Tonani, 1980).

h K-Ca, T = 1930 / [3.861 - log(K/Ca1/2)] - 273.15 (Tonani, 1980).

i Na-K-Ca, T = 1647 / [log(Na/K) +1/3log(Ca1/2/Na)+ 2.24] - 273.15 (Fournier and Truesdell, 1973).

j Quartz, no steam loss, T = 1309 / [5.19 - log(SiO2)] - 273.15 (Fournier, 1977).

k Quartz, maximum steam loss, T = 1522/ [5.75 - log(SiO2)] - 273.15 (Fournier, 1977).

l Chalcedony, T = 1032 / [4.78 - log(SiO2)] - 273.15 (Fournier, 1977).

**Part 2:**

PHREEQC is a powerful water chemistry simulation software. In this study, we used its function to simulate “Irreversible Reactions” (Parkhurst and Appelo, 2013).

**SOLUTION\_SPREAD** setup:

HS08 is a river sample, and the initial simulated water sample is defined as the chemical composition of HS08. The initial temperature is 53oC, which is the thermal reservoir temperature of the river water estimated by SiO2.

**EQUILIBRIUM\_PHASES** setup:

Italiano et al. (2013) reported that the carbon dioxide volume fraction of EAFZ ranges from 88.4% to 99.9%. Therefore, the initial CO2 percentage is set as 88.4%, and the logarithm is 1.95. Barite (BaSO4) is also set to allow precipitation.

**REACTION** setup:

We set up 3 groups of reactants mixed in different proportions respectively, as shown in Table S2:

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Table S2. The proportion of minerals added | | | | | | |
| Mineral | Calcite | Gypsum | Anorthite | Dolomite | Barite | Celestite |
| R1 | 0 | 1 | 0 | 0 | 0.005 | 0.01 |
| R2 | 0.2 | 1 | 0.2 | 0.2 | 0.005 | 0.01 |
| R3 | 1 | 1 | 1 | 1 | 0.005 | 0.01 |
| R4 | 1 | 0 | 1 | 1 | 0.005 | 0.01 |

The total amount of reaction was set to 0.006mol, and the reaction was carried out in 20 steps. The simulation results are shown in Table S3.

Table S3. Simulation results of water-rock interaction in the EAFZ by PHREEQC.

|  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| step | R1 | | | | | | R2 | | | | | |
| Ba2+  (mol/L) | Ca2+  (mol/L) | HCO3-  (mol/L) | Mg2+  (mol/L) | SO42-  (mol/L) | Sr2+  (mol/L) | Ba2+  (mol/L) | Ca2+  (mol/L) | HCO3-  (mol/L) | Mg2+  (mol/L) | SO42-  (mol/L) | Sr2+  (mol/L) |
| 0 | 1.36E-08 | 1.37E-03 | 0.00E+00 | 1.80E-04 | 4.84E-05 | 6.32E-07 | 1.36E-08 | 1.37E-03 | 0.00E+00 | 1.80E-04 | 4.84E-05 | 6.32E-07 |
| 1 | 1.48E-06 | 1.62E-03 | 1.32E-04 | 1.71E-04 | 2.91E-04 | 3.47E-06 | 1.39E-06 | 1.79E-03 | 7.19E-04 | 2.27E-04 | 2.85E-04 | 3.43E-06 |
| 2 | 8.63E-07 | 1.87E-03 | 1.34E-04 | 1.63E-04 | 5.27E-04 | 6.16E-06 | 9.63E-07 | 2.19E-03 | 1.28E-03 | 2.70E-04 | 5.12E-04 | 6.03E-06 |
| 3 | 6.29E-07 | 2.10E-03 | 1.36E-04 | 1.56E-04 | 7.60E-04 | 8.73E-06 | 7.25E-07 | 2.58E-03 | 1.81E-03 | 3.11E-04 | 7.31E-04 | 8.48E-06 |
| 4 | 5.06E-07 | 2.34E-03 | 1.38E-04 | 1.51E-04 | 9.88E-04 | 1.12E-05 | 5.98E-07 | 2.97E-03 | 2.32E-03 | 3.52E-04 | 9.43E-04 | 1.08E-05 |
| 5 | 4.29E-07 | 2.57E-03 | 1.39E-04 | 1.46E-04 | 1.21E-03 | 1.36E-05 | 5.18E-07 | 3.35E-03 | 2.81E-03 | 3.91E-04 | 1.15E-03 | 1.31E-05 |
| 6 | 3.76E-07 | 2.79E-03 | 1.41E-04 | 1.42E-04 | 1.43E-03 | 1.59E-05 | 4.63E-07 | 3.72E-03 | 3.27E-03 | 4.29E-04 | 1.35E-03 | 1.53E-05 |
| 7 | 3.38E-07 | 3.01E-03 | 1.42E-04 | 1.39E-04 | 1.65E-03 | 1.82E-05 | 4.23E-07 | 4.09E-03 | 3.72E-03 | 4.67E-04 | 1.55E-03 | 1.74E-05 |
| 8 | 3.08E-07 | 3.23E-03 | 1.44E-04 | 1.35E-04 | 1.87E-03 | 2.04E-05 | 3.91E-07 | 4.45E-03 | 4.15E-03 | 5.04E-04 | 1.74E-03 | 1.95E-05 |
| 9 | 2.85E-07 | 3.45E-03 | 1.45E-04 | 1.32E-04 | 2.08E-03 | 2.25E-05 | 3.67E-07 | 4.81E-03 | 4.57E-03 | 5.40E-04 | 1.93E-03 | 2.16E-05 |
| 10 | 2.66E-07 | 3.66E-03 | 1.46E-04 | 1.30E-04 | 2.29E-03 | 2.47E-05 | 3.46E-07 | 5.16E-03 | 4.98E-03 | 5.76E-04 | 2.12E-03 | 2.36E-05 |
| 11 | 2.50E-07 | 3.87E-03 | 1.48E-04 | 1.28E-04 | 2.50E-03 | 2.67E-05 | 3.30E-07 | 5.51E-03 | 5.37E-03 | 6.11E-04 | 2.30E-03 | 2.55E-05 |
| 12 | 2.37E-07 | 4.08E-03 | 1.49E-04 | 1.25E-04 | 2.71E-03 | 2.88E-05 | 3.15E-07 | 5.86E-03 | 5.76E-03 | 6.46E-04 | 2.49E-03 | 2.75E-05 |
| 13 | 2.26E-07 | 4.29E-03 | 1.50E-04 | 1.23E-04 | 2.91E-03 | 3.08E-05 | 3.03E-07 | 6.20E-03 | 6.14E-03 | 6.80E-04 | 2.67E-03 | 2.94E-05 |
| 14 | 2.16E-07 | 4.49E-03 | 1.51E-04 | 1.21E-04 | 3.12E-03 | 3.28E-05 | 2.92E-07 | 6.55E-03 | 6.51E-03 | 7.14E-04 | 2.84E-03 | 3.13E-05 |
| 15 | 2.07E-07 | 4.70E-03 | 1.52E-04 | 1.20E-04 | 3.32E-03 | 3.48E-05 | 2.83E-07 | 6.89E-03 | 6.87E-03 | 7.48E-04 | 3.02E-03 | 3.32E-05 |
| 16 | 2.00E-07 | 4.90E-03 | 1.53E-04 | 1.18E-04 | 3.52E-03 | 3.68E-05 | 2.74E-07 | 7.22E-03 | 7.23E-03 | 7.81E-04 | 3.19E-03 | 3.50E-05 |
| 17 | 1.93E-07 | 5.10E-03 | 1.54E-04 | 1.17E-04 | 3.72E-03 | 3.87E-05 | 2.67E-07 | 7.56E-03 | 7.58E-03 | 8.14E-04 | 3.37E-03 | 3.68E-05 |
| 18 | 1.87E-07 | 5.30E-03 | 1.55E-04 | 1.15E-04 | 3.92E-03 | 4.06E-05 | 2.60E-07 | 7.89E-03 | 7.93E-03 | 8.47E-04 | 3.54E-03 | 3.86E-05 |
| 19 | 1.81E-07 | 5.49E-03 | 1.56E-04 | 1.14E-04 | 4.11E-03 | 4.25E-05 | 2.54E-07 | 8.22E-03 | 8.28E-03 | 8.79E-04 | 3.71E-03 | 4.04E-05 |
| 20 | 1.76E-07 | 5.69E-03 | 1.57E-04 | 1.13E-04 | 4.31E-03 | 4.44E-05 | 2.48E-07 | 8.55E-03 | 8.62E-03 | 9.11E-04 | 3.88E-03 | 4.22E-05 |
| step | R3 | | | | | | R4 | | | | | |
| Ba2+  (mol/L) | Ca2+  (mol/L) | HCO3-  (mol/L) | Mg2+  (mol/L) | SO42-  (mol/L) | Sr2+  (mol/L) | Ba2+  (mol/L) | Ca2+  (mol/L) | HCO3-  (mol/L) | Mg2+  (mol/L) | SO42-  (mol/L) | Sr2+  (mol/L) |
| 0 | 1.36E-08 | 1.37E-03 | 0.00E+00 | 1.80E-04 | 4.84E-05 | 6.32E-07 | 1.36E-08 | 1.37E-03 | 0.00E+00 | 1.80E-04 | 4.84E-05 | 6.32E-07 |
| 1 | 1.37E-06 | 2.44E-03 | 2.81E-03 | 4.46E-04 | 2.71E-04 | 3.28E-06 | 1.72E-06 | 2.20E-03 | 2.81E-03 | 4.66E-04 | 4.80E-05 | 3.36E-06 |
| 2 | 1.30E-06 | 3.46E-03 | 4.99E-03 | 6.94E-04 | 4.69E-04 | 5.65E-06 | 3.33E-06 | 3.01E-03 | 5.00E-03 | 7.42E-04 | 4.87E-05 | 5.85E-06 |
| 3 | 1.06E-06 | 4.46E-03 | 6.91E-03 | 9.31E-04 | 6.52E-04 | 7.87E-06 | 4.89E-06 | 3.80E-03 | 6.92E-03 | 1.01E-03 | 4.97E-05 | 8.20E-06 |
| 4 | 9.24E-07 | 5.43E-03 | 8.69E-03 | 1.16E-03 | 8.24E-04 | 9.97E-06 | 6.41E-06 | 4.58E-03 | 8.71E-03 | 1.28E-03 | 5.09E-05 | 1.04E-05 |
| 5 | 8.37E-07 | 6.39E-03 | 1.04E-02 | 1.38E-03 | 9.90E-04 | 1.20E-05 | 7.89E-06 | 5.34E-03 | 1.04E-02 | 1.54E-03 | 5.23E-05 | 1.26E-05 |
| 6 | 7.76E-07 | 7.32E-03 | 1.20E-02 | 1.60E-03 | 1.15E-03 | 1.39E-05 | 9.34E-06 | 6.10E-03 | 1.21E-02 | 1.80E-03 | 5.39E-05 | 1.47E-05 |
| 7 | 7.31E-07 | 8.24E-03 | 1.36E-02 | 1.82E-03 | 1.31E-03 | 1.58E-05 | 1.08E-05 | 6.84E-03 | 1.37E-02 | 2.05E-03 | 5.54E-05 | 1.67E-05 |
| 8 | 6.95E-07 | 9.15E-03 | 1.52E-02 | 2.03E-03 | 1.46E-03 | 1.76E-05 | 1.22E-05 | 7.57E-03 | 1.53E-02 | 2.30E-03 | 5.71E-05 | 1.87E-05 |
| 9 | 6.66E-07 | 1.00E-02 | 1.67E-02 | 2.24E-03 | 1.61E-03 | 1.94E-05 | 1.35E-05 | 8.29E-03 | 1.68E-02 | 2.55E-03 | 5.88E-05 | 2.05E-05 |
| 10 | 6.42E-07 | 1.09E-02 | 1.82E-02 | 2.44E-03 | 1.76E-03 | 2.12E-05 | 1.49E-05 | 9.00E-03 | 1.83E-02 | 2.79E-03 | 6.05E-05 | 2.24E-05 |
| 11 | 6.22E-07 | 1.18E-02 | 1.97E-02 | 2.64E-03 | 1.90E-03 | 2.28E-05 | 1.62E-05 | 9.70E-03 | 1.99E-02 | 3.03E-03 | 6.23E-05 | 2.42E-05 |
| 12 | 6.05E-07 | 1.26E-02 | 2.12E-02 | 2.84E-03 | 2.05E-03 | 2.45E-05 | 1.75E-05 | 1.04E-02 | 2.14E-02 | 3.27E-03 | 6.41E-05 | 2.60E-05 |
| 13 | 5.90E-07 | 1.35E-02 | 2.27E-02 | 3.03E-03 | 2.19E-03 | 2.61E-05 | 1.79E-05 | 1.11E-02 | 2.29E-02 | 3.50E-03 | 6.53E-05 | 2.77E-05 |
| 14 | 5.76E-07 | 1.43E-02 | 2.42E-02 | 3.23E-03 | 2.33E-03 | 2.77E-05 | 1.83E-05 | 1.18E-02 | 2.44E-02 | 3.74E-03 | 6.65E-05 | 2.94E-05 |
| 15 | 5.64E-07 | 1.52E-02 | 2.56E-02 | 3.42E-03 | 2.47E-03 | 2.92E-05 | 1.86E-05 | 1.24E-02 | 2.58E-02 | 3.97E-03 | 6.77E-05 | 3.10E-05 |
| 16 | 5.54E-07 | 1.60E-02 | 2.71E-02 | 3.61E-03 | 2.61E-03 | 3.08E-05 | 1.89E-05 | 1.31E-02 | 2.73E-02 | 4.20E-03 | 6.89E-05 | 3.26E-05 |
| 17 | 5.44E-07 | 1.68E-02 | 2.85E-02 | 3.79E-03 | 2.75E-03 | 3.23E-05 | 1.92E-05 | 1.38E-02 | 2.88E-02 | 4.42E-03 | 7.01E-05 | 3.42E-05 |
| 18 | 5.35E-07 | 1.76E-02 | 2.99E-02 | 3.98E-03 | 2.89E-03 | 3.37E-05 | 1.95E-05 | 1.44E-02 | 3.02E-02 | 4.65E-03 | 7.13E-05 | 3.58E-05 |
| 19 | 5.27E-07 | 1.84E-02 | 3.13E-02 | 4.16E-03 | 3.02E-03 | 3.52E-05 | 1.97E-05 | 1.51E-02 | 3.16E-02 | 4.87E-03 | 7.26E-05 | 3.73E-05 |
| 20 | 5.19E-07 | 1.92E-02 | 3.28E-02 | 4.34E-03 | 3.16E-03 | 3.66E-05 | 2.00E-05 | 1.57E-02 | 3.31E-02 | 5.09E-03 | 7.38E-05 | 3.88E-05 |

**Part 3.**

Figure S1. Macroscopic anomaly of geothermal fluid before and after the *Mw* 7.8 earthquake. Before the earthquake, the water of HS14 appeared white and became cloudy (a). After the earthquake, it returned to clear and transparent (b). Shooting time: a: A month before the earthquake. b: March 26th, 2023. The seismic precursor anomaly of HS14 geothermal fluid is shown in Video 01.



Figure S2. Statistical Figuer of trace elements (B, Al, Ba, Li, Ra and Sr). Literature data from (Aydin et al., 2020; Baba et al., 2019; Okan et al., 2018; Yuce et al., 2014; Pasvanoglu, 2020).

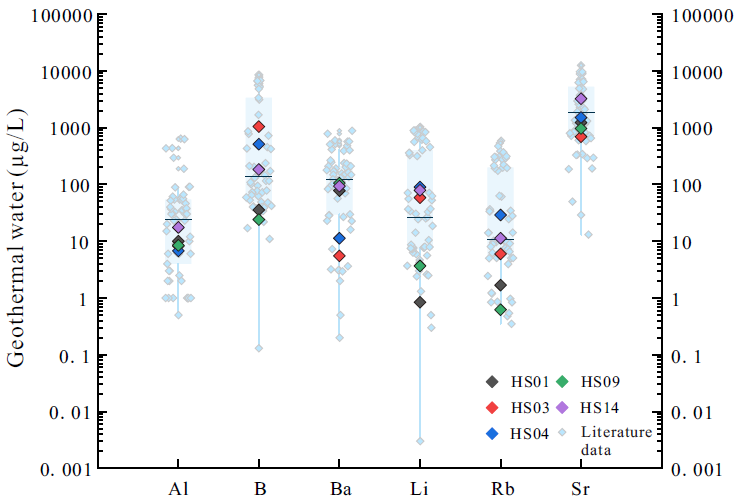
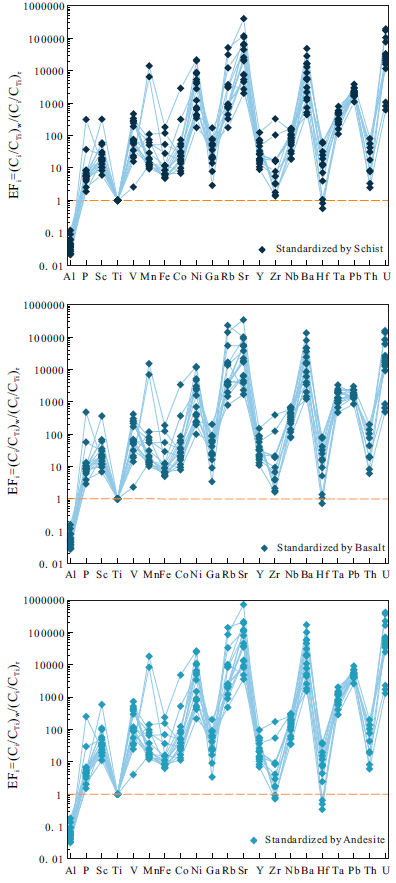


Figure S3. Spider diagram of the water in the EAFZ. Enrichment coefficients (weight ratios) normalized by Ti. EFi=(Ci/CTi)w/(Ci/CTi)r, where i is element, w is water, r is rock Rocks chemistry are taken from (Nurlu, 2020).



**Part4.**

Videos:

Video. 01 Seismic precursor anomaly of HS14 geothermal fluid. See Supporting Information Video. 01.

Video. 02 Post-earthquake anomaly of HS04 geothermal fluid. See Supporting Information Video. 02.

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1. ★ Corresponding author

   E-mail Address: *Xiaocheng Zhou (zhouxiaocheng188@163.com)* [↑](#footnote-ref-1)