Dear Editorial Office of HESS and Dai Editor-in-Chief,

We sincerely appreciate your handling of our manuscript and the Dai Editor-in-Chief's dedicated efforts. In response to the insightful comments from two reviewers and two domain experts, we have thoroughly revised the manuscript. Key improvements are summarized below:

**1. Enhanced Data Completeness**

Historical Data Integration: We systematically compiled published data (2013-2025), revealing spatial hydrogeochemical zonation in the East Anatolian Fault Zone (EAFZ):

Northern Segments: Mixed shallow/deep circulation with igneous rock-dominated water-rock interactions.

Central-Southern Segments: Shallow circulation dominated by sedimentary mineral dissolution (e.g., gypsum, carbonates), with localized seawater influence.

Causal Linkage Clarification: PHREEQC simulations (Appendix B) quantify gypsum's contribution to $SO_4^{2-}$ anomalies (30-100%), minimizing misinterpretation from other minerals (e.g., calcite, dolomite).

**2. Refined Gypsum-Tectonic Linkage**

Terminological Precision: Removed all "seismic precursor" claims, replacing with "indicator of water-rock interaction intensity".

Mechanistic: Combined pre-earthquake macroscopic anomalies. The analysis of post-earthquake data and historical data proves that gypsum may be one of the causes of groundwater macroscopic anomaly

Explicit caveat: "Causal links between gypsum dynamics and tectonics require long-term validation"

**3. Revised Conclusions**

Restructured Key Findings:

"Gypsum abundance serves as a sensitive indicator of water-rock interaction intensity, potentially modulated by tectonic activity. Establishing fault-zone hydrogeochemical baselines is prerequisite for deciphering tectonic-hydrologic coupling."

**4. Future Work Commitment:**

Although the discussion of groundwater principal and trace data has confirmed that gypsum may be a sensitive indicator of water-rock reaction intensity, to further reinforce the conclusion, we plan to conduct additional experiments on the samples, including analysis and determination of Sr, Na, S and B isotopes. In addition, some gas samples were also collected in this study and are currently being analyzed and determined. All additional experiments are expected to be completed by the end of April 2025.

In short, after fully and effectively communicating with the reviewers, we modified the possible problems in our manuscript according to the suggestions of the reviewers, so that the analysis of data in the manuscript is more rigorous and the extension is appropriate

We sincerely wish the current version meets your standards and welcome further guidance.

Finally, I would like to thank HESS editorial Department and Dai Editor-in-Chief for their hard work

Sincerely

Zebin Luo

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## Accessory list

Part 1. PHREEQC simulation

Part 2. Review RC 1

Part 3. Review RC 2

Part 4. Review RC 3

Part 5. Review CC 1

Part 6. Review CC 2

Part 7. Annex I

**Part 1:**

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

**Mineral data preparation**

The proportion of minerals in water-rock reaction was calculated by CIPW (Cross, Iddings, Pirsson, Washington) (Table 1). The calculated data were from Karaoğlu et al. (2020).

Table 1 Results of CIPW calculation

| Mineral | Quartz | Plagioclase | Orthoclase | clinopyroxene | orthopyroxene | Ilmenite | Hematite | Apatite | Sphene |
|---|---|---|---|---|---|---|---|---|---|
| content wt% | 6.1 | 58 | 13.12 | 3.59 | 6.28 | 0.28 | 8.36 | 0.86 | 3.42 |

Table 2 Results of standardization of minerals associated with water-rock reaction

| Mineral | Plagioclase | Orthoclase | pyroxene |
|---|---|---|---|
| content wt% | 58 | 13.12 | 9.87 |
| standardization %wt | 0.72 | 0.16 | 0.12 |

Note: The minerals involved in the water-rock reaction are mainly plagioclase, potassium feldspar and pyroxene, and the three minerals are re-standardized according to 100%. Pyroxene is the sum of two kinds of pyroxene.

**PHREEQC simulation step (Table 3)**

**Choose Databases: llnl_dat**

**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 53°C, which is the thermal reservoir temperature of the river water estimated by $SiO_2$.

**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 $CO_2$ percentage is set as 88.4%, and the logarithm is 1.95.

**REACTION** setup: We set up 6 groups of reactants mixed in different proportions respectively, as shown in Table 4:

Table 3 PHREEQC code and description

| Steps | Instructions |
|---|---|
| SOLUTION_SPREAD<br>-units mg/l<br>Temperature pH Si Li Na K Mg Ca F Cl Br N(5) S(6)<br>HCO3 B Al Mn Fe Sr Ba Zn<br>as SiO2 as NO3 as SO4<br>53 8.43 15.15 1.00E-06 1.13 1.00E-06 4.47 55.34 0.4411<br>1.06 1.00E-06 3.83 5.69 165.72358 0.00477 0.01227<br>0.00105 0.01252 0.05578 0.00189 0.01899 | Initial reactant input (HS08) |
| EQUILIBRIUM_PHASES 1<br>CO2(g) 0 1.95 | Equilibrium phases setting |
| Reaction 1<br>NaCl 1<br>0.07 moles | Deep fluid mixing ratio setting |
| save solution 1<br>end<br>use solution 1 | Store the mixed solution |
| REACTION 2<br>Calcite 1<br>Gypsum 0.3<br>albite 0.4<br>Anorthite 0.4<br>Ca-Al_Pyroxene 0.1<br>K-feldspar 0.16<br>Dolomite 1 | Water rock reaction mineral Settings |
| 1 moles in 20 steps | Reaction steps and total amount of reaction |

Table 4 The proportion of minerals added

| | Mineral | content | Albite | Anorthite | Calcite | Dolomite | Gypsum | Orthoclase | pyroxene |
|---|---|---|---|---|---|---|---|---|---|
| R1 | deep fluid (NaCl) | 0% | 0.7 | 0.02 | 0.4 | 0.4 | 0 | 0.16 | 0.12 |
| R2 | | 2% | | 0.02 | 0.4 | 0.4 | 0 | 0.16 | 0.12 |
| R3 | | 5% | | 0.02 | 0.4 | 0.4 | 0 | 0.16 | 0.12 |
| R4 | | 7% | | 0.02 | 0.4 | 0.4 | 0 | 0.16 | 0.12 |
| R5 | Water-rock reaction (Gypsum) | 30% | 0.4 | 0.4 | 1 | 1 | 0.3 | 0 | 0 |
| R6 | | 100% | 0 | 0 | 0 | 0 | 1 | 0 | 0 |

The total amount of reaction was set to 1mol, and the reaction was carried out in 20 steps. The simulation results are shown in Table 5.

Table 5 Simulation results of water-rock interaction in the EAFZ by PHREEQC.

| step | 2%NaCl | | | | | | 5%NaCl | | | | | | 7%NaCl | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $Ca^{2+}$ | $SO_4^{2+}$ | $HCO_3^-$ | $Cl^-$ | $HCO_3^-+Cl^-$ | $Na^+$ | $Ca^{2+}$ | $SO_4^{2+}$ | $HCO_3^-$ | $Cl^-$ | $HCO_3^-+Cl^-$ | $Na^+$ | $Ca^{2+}$ | $SO_4^{2+}$ | $HCO_3^-$ | $Cl^-$ | $HCO_3^-+Cl^-$ | $Na^+$ |
| | mol/L | | | | | | mol/L | | | | | | mol/L | | | | | |
| Mix | 1.37 | 0.05 | 0.00 | 0.03 | 0.03 | 0.05 | 1.37 | 0.05 | 0.00 | 0.03 | 0.03 | 0.05 | 1.37 | 0.05 | 0.00 | 0.03 | 0.03 | 0.05 |
| 0 | 1.37 | 0.05 | 0.14 | 19.96 | 20.10 | 19.98 | 1.37 | 0.05 | 0.14 | 49.67 | 49.81 | 49.69 | 1.37 | 0.05 | 0.14 | 69.38 | 69.52 | 69.40 |
| 1 | 32.88 | 0.03 | 54.65 | 19.83 | 74.48 | 51.82 | 33.34 | 0.03 | 54.56 | 49.41 | 103.97 | 79.96 | 33.61 | 0.03 | 54.47 | 69.04 | 123.51 | 98.67 |
| 2 | 58.52 | 0.02 | 82.68 | 19.81 | 102.49 | 83.42 | 58.91 | 0.02 | 82.37 | 49.36 | 131.73 | 111.03 | 59.16 | 0.02 | 82.15 | 68.99 | 151.14 | 129.39 |
| 3 | 79.54 | 0.02 | 103.91 | 19.81 | 123.72 | 114.52 | 79.93 | 0.02 | 103.48 | 49.37 | 152.85 | 141.75 | 80.17 | 0.02 | 103.19 | 69.01 | 172.19 | 159.85 |
| 4 | 97.70 | 0.02 | 120.72 | 19.82 | 140.54 | 145.23 | 98.08 | 0.02 | 120.20 | 49.40 | 169.60 | 172.14 | 98.32 | 0.02 | 119.85 | 69.04 | 188.89 | 190.03 |
| 5 | 113.76 | 0.02 | 134.27 | 19.83 | 154.10 | 175.59 | 114.13 | 0.02 | 133.68 | 49.43 | 183.11 | 202.23 | 114.38 | 0.02 | 133.28 | 69.09 | 202.37 | 219.93 |
| 6 | 128.21 | 0.02 | 145.28 | 19.85 | 165.12 | 205.64 | 128.58 | 0.02 | 144.63 | 49.47 | 194.09 | 232.01 | 128.81 | 0.02 | 144.19 | 69.14 | 213.33 | 249.54 |
| 7 | 141.37 | 0.02 | 154.23 | 19.86 | 174.09 | 235.38 | 141.73 | 0.02 | 153.53 | 49.50 | 203.03 | 261.51 | 141.96 | 0.02 | 153.07 | 69.19 | 222.26 | 278.87 |
| 8 | 153.46 | 0.02 | 161.47 | 19.88 | 181.35 | 264.83 | 153.81 | 0.02 | 160.74 | 49.54 | 210.27 | 290.72 | 154.04 | 0.02 | 160.26 | 69.23 | 229.49 | 307.92 |
| 9 | 164.65 | 0.02 | 167.27 | 19.89 | 187.16 | 293.98 | 165.00 | 0.02 | 166.51 | 49.57 | 216.08 | 319.64 | 165.23 | 0.02 | 166.01 | 69.27 | 235.28 | 336.68 |
| 10 | 175.09 | 0.02 | 171.83 | 19.90 | 191.73 | 322.83 | 175.43 | 0.02 | 171.05 | 49.59 | 220.65 | 348.26 | 175.66 | 0.02 | 170.54 | 69.31 | 239.85 | 365.15 |
| 11 | 184.86 | 0.02 | 175.31 | 19.91 | 195.22 | 351.38 | 185.21 | 0.02 | 174.52 | 49.62 | 224.14 | 376.58 | 185.43 | 0.02 | 174.00 | 69.34 | 243.33 | 393.31 |
| 12 | 194.07 | 0.02 | 177.85 | 19.92 | 197.77 | 379.62 | 194.41 | 0.02 | 177.05 | 49.63 | 226.68 | 404.59 | 194.64 | 0.02 | 176.52 | 69.36 | 245.88 | 421.17 |
| 13 | 202.77 | 0.02 | 179.55 | 19.92 | 199.48 | 407.54 | 203.12 | 0.02 | 178.75 | 49.64 | 228.39 | 432.28 | 203.34 | 0.02 | 178.22 | 69.36 | 247.58 | 448.70 |
| 14 | 211.04 | 0.02 | 180.51 | 19.92 | 200.44 | 435.13 | 211.38 | 0.02 | 179.71 | 49.64 | 229.35 | 459.63 | 211.60 | 0.02 | 179.18 | 69.36 | 248.54 | 475.89 |
| 15 | 218.91 | 0.02 | 180.81 | 19.92 | 200.73 | 462.37 | 219.25 | 0.02 | 180.01 | 49.63 | 229.64 | 486.63 | 219.48 | 0.02 | 179.49 | 69.34 | 248.83 | 502.74 |
| 16 | 226.43 | 0.01 | 180.52 | 19.91 | 200.43 | 489.26 | 226.78 | 0.01 | 179.73 | 49.61 | 229.34 | 513.27 | 227.00 | 0.01 | 179.21 | 69.31 | 248.52 | 529.21 |
| 17 | 233.65 | 0.01 | 179.69 | 19.90 | 199.60 | 515.77 | 233.99 | 0.01 | 178.92 | 49.57 | 228.49 | 539.53 | 234.22 | 0.01 | 178.41 | 69.26 | 247.67 | 555.31 |
| 18 | 240.59 | 0.01 | 178.39 | 19.89 | 198.28 | 541.88 | 240.94 | 0.01 | 177.63 | 49.53 | 227.16 | 565.40 | 241.16 | 0.01 | 177.13 | 69.20 | 246.33 | 581.00 |
| 19 | 247.29 | 0.01 | 176.66 | 19.87 | 196.52 | 567.59 | 247.64 | 0.01 | 175.92 | 49.47 | 225.39 | 590.84 | 247.86 | 0.01 | 175.43 | 69.11 | 244.55 | 606.27 |
| 20 | 253.77 | 0.01 | 174.54 | 19.84 | 194.38 | 592.87 | 254.12 | 0.01 | 173.82 | 49.40 | 223.23 | 615.86 | 254.35 | 0.01 | 173.35 | 69.01 | 242.36 | 631.11 |

Continued

| step | 0NaCl | | | | | | 100%Gypsum | | | | | | 30%Gypsum | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $Ca^{2+}$ | $SO_4^{2+}$ | $HCO_3^-$ | $Cl^-$ | $HCO_3^-+Cl^-$ | $Na^+$ | $Ca^{2+}$ | $SO_4^{2+}$ | $HCO_3^-$ | $Cl^-$ | $HCO_3^-+Cl^-$ | $Na^+$ | $Ca^{2+}$ | $SO_4^{2+}$ | $HCO_3^-$ | $Cl^-$ | $HCO_3^-+Cl^-$ | $Na^+$ |
| | mol/L | | | | | | mol/L | | | | | | mol/L | | | | | |
| Mix | 1.37 | 0.05 | 0.00 | 0.03 | 0.03 | 0.05 | 1.37 | 0.05 | 0.00 | 0.03 | 0.03 | 0.05 | 1.37 | 0.05 | 0.00 | 0.03 | 0.03 | 0.05 |
| 0 | 1.37 | 0.05 | 0.13 | 0.03 | 0.16 | 0.05 | 1.37 | 0.05 | 0.13 | 0.03 | 0.16 | 0.05 | 1.37 | 0.05 | 0.13 | 0.03 | 0.16 | 0.05 |
| 1 | 32.54 | 0.03 | 54.66 | 0.03 | 54.69 | 33.02 | 31.54 | 29.98 | 0.23 | 0.03 | 0.26 | 0.05 | 48.90 | 5.80 | 57.42 | 0.03 | 57.45 | 17.96 |
| 2 | 58.24 | 0.02 | 82.88 | 0.03 | 82.91 | 64.96 | 57.35 | 55.74 | 0.27 | 0.03 | 0.30 | 0.04 | 87.36 | 10.35 | 83.94 | 0.03 | 83.97 | 35.12 |
| 3 | 79.27 | 0.02 | 104.19 | 0.03 | 104.22 | 96.31 | 81.44 | 79.81 | 0.29 | 0.03 | 0.32 | 0.04 | 123.16 | 14.32 | 106.78 | 0.03 | 106.81 | 51.90 |
| 4 | 97.43 | 0.02 | 121.06 | 0.03 | 121.09 | 127.23 | 104.25 | 102.60 | 0.31 | 0.03 | 0.34 | 0.04 | 156.98 | 17.86 | 126.90 | 0.03 | 126.93 | 68.34 |
| 5 | 113.51 | 0.02 | 134.66 | 0.03 | 134.69 | 157.78 | 125.98 | 124.32 | 0.32 | 0.03 | 0.35 | 0.04 | 189.21 | 21.03 | 144.87 | 0.03 | 144.90 | 84.44 |
| 6 | 127.96 | 0.02 | 145.71 | 0.03 | 145.74 | 188.00 | 146.77 | 145.10 | 0.33 | 0.03 | 0.36 | 0.04 | 220.13 | 23.88 | 161.05 | 0.03 | 161.08 | 100.20 |
| 7 | 141.12 | 0.02 | 154.69 | 0.03 | 154.72 | 217.91 | 166.72 | 165.03 | 0.34 | 0.03 | 0.37 | 0.04 | 249.91 | 26.45 | 175.67 | 0.03 | 175.70 | 115.62 |
| 8 | 153.22 | 0.02 | 161.96 | 0.03 | 161.99 | 247.51 | 185.90 | 184.21 | 0.35 | 0.03 | 0.38 | 0.04 | 278.19 | 28.79 | 188.27 | 0.03 | 188.30 | 130.71 |
| 9 | 164.42 | 0.02 | 167.78 | 0.03 | 167.81 | 276.82 | 204.38 | 202.68 | 0.35 | 0.03 | 0.38 | 0.04 | 303.36 | 31.01 | 196.77 | 0.03 | 196.80 | 145.49 |
| 10 | 174.85 | 0.02 | 172.35 | 0.03 | 172.38 | 305.82 | 222.22 | 220.51 | 0.36 | 0.03 | 0.39 | 0.04 | 325.51 | 33.13 | 201.38 | 0.03 | 201.41 | 159.99 |
| 11 | 184.63 | 0.02 | 175.84 | 0.03 | 175.87 | 334.52 | 239.45 | 237.75 | 0.36 | 0.03 | 0.39 | 0.04 | 345.87 | 35.10 | 203.73 | 0.03 | 203.75 | 174.23 |
| 12 | 193.84 | 0.02 | 178.39 | 0.03 | 178.42 | 362.92 | 256.13 | 254.42 | 0.37 | 0.03 | 0.40 | 0.04 | 365.03 | 36.91 | 204.61 | 0.03 | 204.64 | 188.20 |
| 13 | 202.54 | 0.02 | 180.09 | 0.03 | 180.12 | 390.99 | 272.29 | 270.58 | 0.37 | 0.03 | 0.40 | 0.04 | 383.29 | 38.57 | 204.42 | 0.03 | 204.45 | 201.90 |
| 14 | 210.80 | 0.02 | 181.05 | 0.03 | 181.08 | 418.73 | 287.97 | 286.25 | 0.38 | 0.03 | 0.40 | 0.04 | 400.83 | 40.06 | 203.39 | 0.03 | 203.42 | 215.34 |
| 15 | 218.68 | 0.02 | 181.35 | 0.03 | 181.38 | 446.13 | 303.18 | 301.47 | 0.38 | 0.03 | 0.41 | 0.04 | 417.75 | 41.40 | 201.66 | 0.03 | 201.69 | 228.50 |
| 16 | 226.20 | 0.02 | 181.05 | 0.03 | 181.08 | 473.18 | 317.97 | 316.25 | 0.38 | 0.03 | 0.41 | 0.04 | 434.15 | 42.59 | 199.35 | 0.03 | 199.38 | 241.38 |
| 17 | 233.41 | 0.01 | 180.21 | 0.03 | 180.24 | 499.85 | 332.34 | 330.63 | 0.38 | 0.03 | 0.41 | 0.04 | 450.09 | 43.63 | 196.56 | 0.03 | 196.59 | 253.97 |
| 18 | 240.35 | 0.01 | 178.90 | 0.03 | 178.93 | 526.14 | 346.34 | 344.62 | 0.39 | 0.03 | 0.42 | 0.04 | 465.62 | 44.53 | 193.35 | 0.03 | 193.38 | 266.26 |
| 19 | 247.05 | 0.01 | 177.15 | 0.03 | 177.18 | 552.02 | 359.96 | 358.25 | 0.39 | 0.03 | 0.42 | 0.04 | 480.80 | 45.30 | 189.78 | 0.03 | 189.81 | 278.25 |
| 20 | 253.53 | 0.01 | 175.02 | 0.03 | 175.05 | 577.47 | 373.25 | 371.53 | 0.39 | 0.03 | 0.42 | 0.04 | 495.66 | 45.93 | 185.91 | 0.03 | 185.94 | 289.93 |

## Reference:

Italiano, F., Sasmaz, A., Yuce, G., and Okan, O. O.: Thermal fluids along the East Anatolian Fault Zone (EAFZ): Geochemical features and relationships with the tectonic setting, Chemical Geology, 339, 103-114, 2013.

Karaoğlu, Ö., Gülmez, F., Göçmengil, G., Lustrino, M., Di Giuseppe, P., Manetti, P., Savaşçın, M. Y., and Agostini, S.: Petrological evolution of Karlıova-Varto volcanism (Eastern Turkey): Magma genesis in a transtensional triple-junction tectonic setting, Lithos, 364-365, 2020.

Parkhurst, D. L. and Appelo, C. A. J.: Description of input and examples for PHREEQC version 3: a computer program for speciation, batch-reaction, one-dimensional transport, and inverse geochemical calculations, U.S. Geological Survey, Reston, VA, 2013.

**Reply on RC1**

Dear Walter D'Alessandro

Thank you for your highly professional and constructive comments and suggestions, which are of great value to us in improving the quality of our manuscript. After carefully reading your comments, we have made a reply to your comments point-by-point under the discussion of all manuscript authors. The main replies are as follows:

**Major revisions include:**

1. Correction of sample collection time: We apologize for marking the wrong sampling time in Table 1 (marked time, March 2024, <u>**the actual sampling time, March 2023**</u>). The wrong timing brings huge ambiguity to the manuscript. After correcting the sampling time, the main line logic of the article is as follows:

These evidences constitute a complete chain of causality from the source (evaporite) to the process (water-rock reaction balance disrupted by the earthquake) to the response (abnormal groundwater ion concentration).

2. Use "**groundwater**" instead of "**geothermal water**" to define the sample in this study.

We collected 16 groundwater samples from SF and EAFZ within a month of the earthquake. The principle of sample collection is to collect if we can. Because the overall temperature is low, we think it is more reasonable to use "groundwater" instead of "geothermal water".

3. We have given **a complete explanation of the pre-earthquake hydrochemical data** in the manuscript.

4. We supplement the analysis method and data quality control description

5. We rearranged the logic of the article to make the expression clearer

6. We have made a full explanation of some misunderstandings

7. We explain the possible “overestimation of the heat storage temperature” and analyze that the heat storage temperature estimate has little effect on the conclusion of our core conclusions.

8. We plan to conduct additional experiments on the samples, including **radioactive Sr isotopes** and **S isotopes**, to support our argument with more evidence.

Since there are diagrams in the complete reply draft, we put the complete reply draft in the form of an attachment on the website system. If you have any questions or suggestions about the manuscript, we sincerely invite you to keep discussing with us. Thank you for constructive review comments.

Thank you and best regards.

**Point-by-point response to comments:**

Note: *Italic blue* is the comment. Black is the reply, and **<u>important sentences are bolded and underlined</u>**.

*The manuscript "Gypsum as a potential tracer of earthquake: a case study of the Mw7.8 earthquake in the East Anatolian Fault Zone, southeastern Turkey" by Luo et al. presents the results of sampling campaign of groundwaters in the area of the two strong earthquakes that hit heavily Turkey in February 2023. Only the analytical results (major ions, trace elements and water isotopes) of samples collected about one year after the quakes are considered, which is a strong limitation of this study. I feel that this study cannot be published in this form.*

Reply: Thanks. First of all, let's correct an error in Table 1 in manuscript. Our sampling time is **<u>March 2023</u>**, which is **<u>one month</u>** after the earthquake, not **<u>one year</u>**. We apologize for the sampling time error in manuscript (Table 1) and thank you for your careful correction. Therefore, combined with the **<u>groundwater characteristics within one month after the earthquake</u>**, **<u>groundwater data before the earthquake</u>** (obtained from literature research), and **<u>macro anomalies before the earthquake</u>** (whitening and turbidity), we believe that the evidence is sufficient to prove our view that the earthquake has broken the water-rock balance between gypsum and groundwater, and gypsum has the potential to act as an earthquake tracer.

In light of your suggestion, however, we are also considering the need to find **<u>more evidence</u>** to support our conclusion. Therefore, we are conducting **<u>Radioactive Sr isotope</u>** and **<u>S isotope</u>** analysis on our samples. 1) Radioactive Sr isotope is a good source indicator.

The radioactive Sr isotope composition of shallow gypsum dissolution and deep fluid is obviously different, so the radioactive Sr isotope may well restrict the source area of groundwater. 2) S isotope is the main constituent element of gypsum, and the S isotope composition of igneous rock ($\delta^{34}S$ = -5~10‰) is lower than that of evaporite ($\delta^{34}S$ > 10‰), so S isotope can better distinguish the S of evaporite and igneous rock.

**Major comments:**

*Lines 33-36 (abstract): This is one of the most critical claims made by the authors. "Specially, significant gypsum dissolution was observed at HS05, HS09 and HS14 before and after the earthquake, suggesting that the earthquake broke the balance of water-rock reaction and promoted the dissolution of gypsum." In the paper only the results of the analyses of the samples taken one year after the earthquakes are discussed. How should it be possible to evidence variations "before and after the earthquake" if only one sample was taken?*

Reply: Thanks. Sorry again for the error in sampling time in manuscript (Table 1). The exact date of our sample is March 2023. Therefore, our data can be representative of groundwater characteristics after the earthquake. Pre-earthquake data mainly come from *Yuce, G., Italiano, F., D'Alessandro, W., Yalcin, T. H., Yasin, D. U., Gulbay, A. H., Ozyurt, N. N., Rojay, B., Karabacak, V., Bellomo, S., Brusca, L., Yang, T., Fu, C. C., Lai, C. W., Ozacar, A., and Walia, V.: Origin and interactions of fluids circulating over the Amik Basin (Hatay, Turkey) and relationships with the hydrologic, geologic and tectonic settings, Chemical Geology, 388, 23-39, 2014.* After carefully checking the GPS coordinates given in the literature, we can confirm that HS14 is **kirikhan well** (A15), HS15 is **Tahtakopru**

(A12/13), and HS16 is **Kuzey Tepe** (A40) (Table 1). Compared with the literature data, the concentration of $SO_4^{2-}$ and $Ca^{2+}$ in sample HS14 increased.

Table 1 Sample points and data for this study and literature

| This study | | | | | Yuce et al., 2014 | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Long(°) | Lat(°) | No. | $SO_4^{2-}$ (mg/L) | $Ca^{2+}$(mg/L) | Long(°) | Lat(°) | No. | $SO_4^{2-}$ (mg/L) | $Ca^{2+}$(mg/L) | Site name |
| 36.3738 | 36.5036 | HS14 | 316.61 | 151.43 | 36.3741 | 36.5034 | A15 | 101 | 87.1 | kirikhan well |
| 36.1637 | 36.3833 | HS15 | 1.21 | 55.55 | 36.1636 | 36.3835 | A12/13 | 0.2 | 44.7 | Tahtakopru |
| 36.1472 | 36.2737 | HS16 | 75.9 | 73.35 | 36.1471 | 36.2738 | A40 | 361 | 41.1 | Kuzey Tepe |

Pre-seismic mean values of $SO_4^{2-}$ and $Ca^{2+}$ are from Baba et al., 2019. But you mentioned that our average is inconsistent with the data in the Baba et al., 2019. We apologize for any confusion caused by not clearly stating how the data was referenced. Our average does refer to Baba et al., 2019, but not entirely. **We only cite data from sample points close to EAFZ**. The reason for this: Baba et al 2019 evaluated geothermal resources throughout southeastern Turkey. If we average all the data, this is obviously not reasonable. Moreover, **it can also be seen from Baba et al., 2019 that there is a big difference between geothermal resources near EAFZ and those far away from EAFZ (Fig. 1).** Geothermal resources near EAFZ are mainly medium and low temperature. Therefore, when considering the EAFZ pre-earthquake $SO_4^{2-}$ and $Ca^{2+}$ concentrations, **we only chose the average values of 1, 2, 3, 4, 7, 9, 26 and 27 in the paper as the pre-earthquake concentrations (Fig. 2 and Table 2)**.

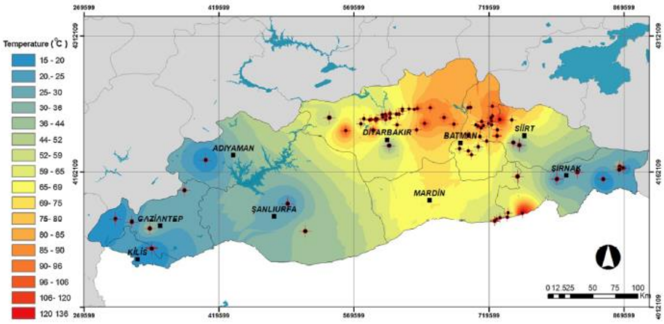


Fig. 1: Temperature distribution map of geothermal resources in southeast Turkey. Screenshot from *Baba, A., Şaroğlu, F., Akkuş, I., Özel, N., Yeşilnacar, M. İ., Nalbantçılar, M. T., Demir, M. M., Gökçen, G., Arslan, Ş., Dursun, N., Uzelli, T., and Yazdani, H.: Geological and hydrogeochemical properties of geothermal systems in the southeastern region of Turkey, Geothermics, 78, 255-271, 2019.*

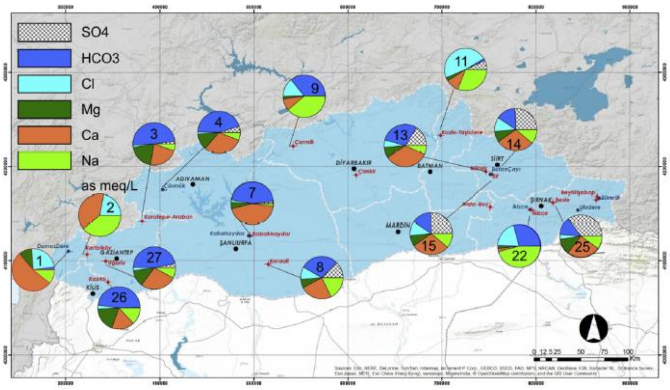


Fig. 2: Baba et al., 2019 sampling point distribution map. Screenshot from *Baba, A., Şaroğlu, F., Akkuş, I., Özel, N., Yeşilnacar, M. İ., Nalbantçılar, M. T., Demir, M. M., Gökçen, G., Arslan, Ş., Dursun, N., Uzelli, T., and Yazdani, H.: Geological and hydrogeochemical properties of geothermal systems in the southeastern region of Turkey, Geothermics, 78, 255-271, 2019.*

Table 2 Ion concentration before earthquake.

| No. | $Ca^{2+}$(mg/L) | $SO_4^{2-}$(mg/L) |
|---|---|---|
| 1 | 14.92 | 0.01 |
| 2 | 66.92 | 0.01 |
| 3 | 45.56 | 9.86 |

| | | |
|---|---|---|
| 4 | 63.84 | 24.79 |
| 7 | 116.03 | 10.22 |
| 9 | 38.65 | 3.34 |
| 26 | 39.85 | 1.83 |
| 27 | 56.03 | 16.41 |
| Average | 55.23 | 8.31 |

Data from: *Baba, A., Şaroğlu, F., Akkuş, I., Özel, N., Yeşilnacar, M. İ., Nalbantçılar, M. T., Demir, M. M., Gökçen, G., Arslan, Ş., Dursun, N., Uzelli, T., and Yazdani, H.: Geological and hydrogeochemical properties of geothermal systems in the southeastern region of Turkey, Geothermics, 78, 255-271, 2019.*

*Line 124: The authors should explain on which basis the 16 sampling sites have been chosen.*

Reply: Thanks. Samples were collected from north to south along the EAFZ. All the places with springs were sampled. Considering the safety considerations after the earthquake, there may be some missing spring points compared with previous studies. But our sampling was done in conjunction with the post-earthquake research in Turkey. In addition to water sampling, Also analyzed the surface rupture and earthquake risk assessment (*Liang, P., Xu, Y., Zhou, X., Li, Y., Tian, Q., Zhang, H., Ren, Z., Yu, J., Li, C., Gong, Z., Wang, S., Dou, A., Ma, Z., and Li, J.: Coseismic surface ruptures of MW7.8 and MW7.5 earthquakes occurred on February 6, 2023, and seismic hazard assessment of the East Anatolian Fault Zone, Southeastern Turkiye, Science China Earth Sciences, doi: 10.1007/s11430-024-1457-7, 2024.*). Therefore, we can guarantee the representativeness and reliability of the samples in this study.

We added the description of the sampling point: "**HS01-HS04 was collected from west to east along SF. HS07-HS16 was collected from north to south along EAFZ (Fig. 1)**"

*Line 124: the authors claim to have sampled hot springs but with the exception of the peculiar hyperalkaline spring HS15, which derive its increased temperature from deep circulation, no other sample could be called "hot". Furthermore, I would not define a well with water at 24 °C as geothermal well. Actually, in the results (line 144) the authors affirm that temperatures of the sampled waters are low.*

Reply: Thanks. Indeed, the temperature of all samples in this study is low, indicating that EAFZ is a medium-low temperature hydrothermal system, which is also consistent with the research results of Baba et al., 2019. However, as you said, the temperature of the sample is really low. We also feel that the term "**geothermal water**" is not rigorous enough to describe our samples. Therefore, we considered using the more appropriate term "**groundwater**" to describe our samples. But in fact, whether groundwater or geothermal water, the core point of our manuscript is not contradictory. The use of groundwater chemistry and isotopes to study the water-rock balance before and after earthquakes is considered to be a very effective means (*e.g., Skelton, A., Andren, M., Kristmannsdottir, H., Stockmann, G., Morth, C.-M., Sveinbjoernsdottir, A., Jonsson, S., Sturkell, E., Gudorunardottir, H. R., Hjartarson, H., Siegmund, H., and Kockum, I.: Changes in groundwater chemistry before two consecutive earthquakes in Iceland, Nature Geoscience, 7, 752-756, 2014. and Tsunogai, U. and Wakita, H.: Precursory chemical changes in ground water: kobe earthquake, Japan, Science (New York, N.Y.), 269, 61-63, 1995.*). However, considering the influence of groundwater on many factors (e.g., temperature, pressure, climatic conditions, seasonal changes etc.), we have explained in the abstract and conclusion of the manuscript that gypsum needs to be considered more carefully.

*The methodological section has many limitations:*

*Lines 130-131: it is unclear if filtration has been made in the field and before acidifying the aliquot for cation analysis. Please specify*

Reply: Thanks. Yes, **we confirmed filtering before testing**. The relevant description can be found in lines 130-131 of the original manuscript. We have extensive experience in groundwater and gas extraction. We can guarantee the reliability of sample collection methods and data.

*Line 131: MAT 253 is a model, please specify the used technique*

Reply: Thanks. We have added specific analytical method: "δD and $\delta^{18}O$ were determined by **zinc reducing tube sealing method** combined with MAT 253 (relative to Vienna Standard Mean Ocean Water (V - SMOW)). Precisions on the measured $\delta^{18}O$ and δD value was ±0.2% (2SD) and ±1% (2SD) respectively (Wang et al., 2010)."

*Line 133: please specify the analysed species and the relative reproducibility and detection limits?*

Reply: Thank you for pointing out the problem of the manuscript. We have added the reliability description of hydrochemistry and isotope analysis to the chapter of **Analytical methods**, the details are as follows:

16 samples of water were collected in EAFZ, including hot springs, geothermal wells and river water. HS01-HS04 was collected from west to east along SF. HS07-HS16 was collected from north to south along EAFZ (Fig. 1). Detailed sample collection and testing methods can be found at Luo et al. (2023). In short, the water sample was taken with a 50 mL clean polyethylene bottle and the temperature and pH of the water were measured and

recorded. Two samples are collected at each sampling site, one is added with ultrapure $HNO_3$ to analyse the cation content, and the other is used to analyse the anion content and isotopic composition. **All samples need to be pre-treated with a 0.45 μm filter membrane to remove impurities before being tested.** δD and $\delta^{18}O$ were determined by **zinc reducing tube sealing method** combined with MAT 253 (relative to Vienna Standard Mean Ocean Water (V - SMOW)). **Precisions on the measured $\delta^{18}O$ and δD value was ±0.2% (2SD) and ±1% (2SD) respectively (Wang et al., 2010)**. The cation **($Li^+$, $Na^+$, $K^+$, $Ca^{2+}$and $Mg^{2+}$)** and anion **($F^-$, $Cl^-$, $NO_3^-$ and $SO_4^{2-}$)** were analysed by Dionex ICS-900 ion chromatograph (Thermo Fisher Scientific Inc.) **at the Earthquake Forecasting Key Laboratory of China Earthquake Administration, with the reproducibility within ±2% and detection limits 0.01 mg/L (Chen et al., 2015)**. $HCO_3^-$ and $CO_3^{2-}$ was determined by acid-base titration with a ZDJ-100 potentiometric titrator (reproducibility within ±2%). $SiO_2$ were analysed by inductively coupled plasma emission spectrometer Optima-5300 DV (PerkinElmer Inc.) (Li et al. 2021). Trace elements were analysed by Element XR ICP-MS at the Test Center of the Research Institute of Uranium Geology. Multielement standard solutions (IV-ICPMS 71A, IV-ICP-MS 71B and IV-ICP-MS 71D, iNORGANIC VENTURES) used for quality control. **The analytical error margin of major cations and trace elements were less than 10%)**.

*Line 136: please specify the analysed trace elements and the relative reproducibility and detection limits?*

Reply: Thanks. The specific types of trace elements are shown in Table 2 (manuscript), the detection limit is 0.001μg/L, and the analysis error accuracy is less than 10%

*In the results the authors claim often that some element or ionic species is increased (sometimes adding obviously) but they do not specify with respect to what. Maybe they intend that the concentrations are high.*

Reply: Thanks. In the Results section we are an objective description of the results based on the data. The words "increased" and " obviously " were also relative to other sample results. But, in fact, what we mean is, "relatively high," not " increased." We apologize for any confusion caused by the poor description of the results, and we have re-optimized the presentation and added a quantitative description of the increased concentrations. The revised expression is as follows:

**The concentration of $SO_4^{2-}$ range from 1.21 mg/L to 316.61 mg/L, and the concentration of $SO_4^{2-}$ in some samples is relatively high (e.g. HS01 (287.74 ml/L), HS03 (103.56 ml/L), HS04 (229.75 ml/L), HS14 (316.61 ml/L)).**

*In the same section they speak of geothermal water but they do not present any evidence that these are geothermal waters.*

Reply: Thank you. We have replaced "**groundwater**" with "**geothermal water**" to make the expression more precise.

*The discussion about the geothermal fluids has great limitations.*

*The authors do not present evidences that the sampled waters are, at least partially, fed by hydrothermal systems. The fact that in the area some geothermal system has been discovered and studied, does not mean that all groundwater samples taken in the area are fed by them. The temperatures of the collected samples are low and, as highlighted by the binary diagram of fig. 3 and the ternary diagram of fig. 4, their compositions do not reflect* *high temperature interactions with the rocks. Also the silica geothermometers show low temperatures considering that for such systems equilibrium with chalcedony (or even christobalite or amorphous silica) should be taken into consideration.*

Reply: Thanks. We have already discussed this issue in the previous reply. **Hydrothermal systems** and **groundwater** do not affect our core point. Both geothermal water and groundwater chemical anomalies are considered to be effective means of earthquake early warning. Thanks for your suggestion to us, as mentioned earlier, we have considered using "**groundwater**" instead of "**geothermal water**" to define the samples for this study.

*Especially the use of the mixing models has been made in the wrong way. Mixing models can be applied only to water samples that belong to the same system and not to water samples collected tens of km away from each other and for which no connection has been demonstrated.*

Reply: Thanks. Although the spatial span of the samples in this study is very large (~270 km) (Fig. 1 and Fig. 6 in manuscript), all of them belong to EAFZ. It is difficult to directly conclude that there is no genetic connection between them.

In fact, both the estimation of heat storage temperature and the mixed model only play an auxiliary supporting role in our core view. **Our main concern is the anomaly of ion concentration caused by earthquake breaking the equilibrium of water-rock reaction**. As for whether deep geothermal fluids are involved? What's the mixing ratio? It's all secondary evidence. Deep fluids may bring $SO_4^{2-}$ ($H_2S$ oxidation), but a little $Ca^{2+}$. However, the correlation between $Ca^{2+}$ and $SO_4^{2-}$ was observed in EAFZ, and numerical simulations indicate that gypsum dissolution is indeed present (Fig. 7 in manuscript), coupled with the presence of large evaporite deposits in the ancient lacustrine sedimentary basin of Lake Amik. **These evidences constitute a complete chain of causality from the source (evaporite) to the process (water-rock reaction balance disrupted by the earthquake) to the response (abnormal groundwater ion concentration).**

Based on your comments, the geothermal properties of our samples are not strong and may not belong to hydrothermal systems. Therefore, we consider weakening the sections on heat storage, mixing ratio, and cycle depth. Delete this section or put in supplementary material. As for the problem of using mixed models incorrectly. We don't think it can be completely negative. At least these samples are in EAFZ. The overestimation may be possible at 382℃. But combined with the pre-seismic macroscopic anomaly of HS04, the content of $SiO_2$ (84.64mg/L) and the ion concentration anomalies of $Ca^{2+}$, $SO_4^{2-}$, Sr and Ba. We think it is sufficient to support the argument that the gypsum dissolution equilibrium was disturbed by the earthquake. Thank you.

*The estimation of temperature for the "deep geothermal fluid" (please define) of 382 °C is absolutely unreliable. The sample was taken, as shown in the second video in the supporting information, from an artesian well (although in table 1 it is classified as spring). I think it is impossible that an artesian well, whose upflow is generally rapid, would have only 15 °C temperature if even only a small part of the water would come from a geothermal system with 382 °C.*

Reply: Thanks. Indeed, 382 °C may be overestimated. But as in the previous reply. The heat storage temperature is only secondary evidence for us to determine whether the gypsum was affected by the earthquake. We have considered deleting this part of the discussion or put in supplementary materials. **The estimate of 382℃ is the HS04 sample from the epicenter, and the complex process after the earthquake may be the reason for our excessive estimate**. However, **HS14 shows a lower estimated temperature, with the mixed model estimating only 88 °C (Fig. 5b). We propose that HS14 may be affected by shallow gypsum dissolution, and this lower estimated temperature supports this conjecture**. Therefore, while 382 °C may not be rigorous enough, the estimation of HS14 supports our view.

*The discussion about the sulfate anomalies is highly confusing. Many points are unclear or wrong.*

Reply: Thanks. We adjusted the description of the manuscript to make the logic clearer.

*Why are only samples HS05, HS09 and HS14 considered anomalous? HS01, HS03 and HS04 have also elevated sulfate values.*

Reply: Thanks. This is actually a misunderstanding. The reason for the misunderstanding is that we failed to express it clearly in the manuscript, and there are logical problems. We consider optimizing the manuscript to eliminate misunderstandings. thank you!

We pointed out in the **Fig caption in Fig.6** that **only the spatial distribution characteristics of EAFZ samples**, namely HS07-HS16, were considered in Fig.6. The discussion here does not cover SF samples (HS01-HS04). We considered adding a note to the text of the manuscript to make the logic clear.

In fact, as you commented, HS01, HS03, HS04, HS05, HS09, HS14 all have $SO_4^{2-}$ anomalies. However, the subsequent numerical simulation shows that the influencing factors of $SO_4^{2-}$ concentration increase in **HS01, HS03 and HS04 are more complex and**

**<u>controlled by a variety of minerals (gypsum, calcite, dolomite, anorthite). However, $SO_4^{2-}$ of HS05, HS09, HS14, especially HS14, is almost only controlled by gypsum (Fig. 7 in manuscript)</u>**, and the influencing factors are relatively single. Therefore, HS14 is an important support for our main point, and the other points are ancillary.

*Why should these high sulfate values be considered anomalous and induced by the earthquake? Sulfate dissolution from evaporite deposits within the aquifers is an ubiquitous process independent from seismic activity.*

Reply: Thanks. The reason for your question is that we wrote down the sampling time incorrectly. I'm sorry. Our sampling time was within one month after the earthquake. **we determined that the earthquake was one of the factors affecting the gypsum. But as you commented, there are many factors affecting gypsum, and it can be disturbed without earthquakes. Therefore, we emphasize this concern in both the abstract and the conclusion, showing the limitations of gypsum as an indicator of earthquake warning.**

*Why do the authors use these low averages for Ca (55.23 mg/L) and $SO_4$ (8.31 mg/L) concentrations before earthquake? Baba et al. (2019) in their paper report concentrations up to 773.56 mg/L for Ca and up to 1287.24 mg/L for $SO_4$ much higher than in the samples collected for this study.*

Reply: Thanks. We have already replied to this comment before, and **we use the data near EAFZ**. For this doubt, we consider to explain in the text to eliminate misunderstandings.

*Finally, the authors indicate the whitening and turbidity of the water in a sample as verification for the sulfate anomaly. But without analysis there is no possibility to affirm that such visual anomaly was due to gypsum dissolution.*

Reply: Thanks. The best evidence is our analysis of water samples taken within a month of the earthquake. Your confusion is caused by our marking of the wrong sampling time. Sorry again.

*Furthermore, the authors mistake the samples. The site with the high sulfate concentration is HS14, while the site to which the pictures of figure S1 and of video 01 refer is HS15 which has the lowest sulfate value (1.21 mg/L).*

Reply: Thank you for pointing out this error, we have fixed it.

*Lines 388-389: The authors presenting the data of a single sampling campaign have no evidence to affirm that "the geothermal fluid was diluted due to the infiltration of a large amount of shallow cold water after the double earthquakes in February 2023".*

Reply: Thanks. As discussed earlier, we have considered replacing "geothermal water" with "groundwater", so we will reconsider this conclusion. Thank you for your highly professional and constructive comments. Thanks again.

**Minor comments**

*Line 22: What do the authors mean with "systematic" which do not appear only in the abstract but has been repeated many times in the whole text?*

Reply: Thanks. In your professional comment, we also believe that " systematic " may be a misnomer. We consider deleting the word.

*Lines 24 and 25: The meaning of the sentence is obscure (reconstructed by earthquake?)*

Reply: Thanks. This sentence was not clear enough, so we adjusted the expression: **In order to explore the relationship between groundwater anomaly and earthquake, we performed hydrochemical and isotopic analyses of groundwaters in the East Anatolian Fault Zone (EAFZ). The results show that groundwaters are affected by seismic activity.**

*Line 29: the authors use often the term "abnormal" but they do never define with respect to what.*

Reply: Thanks. "Abnormal" refers to values that deviate from normal values. Divided into **time** and **space** outliers. In the manuscript, "anomaly" refers to spatial outliers. In particular, in Fig. 6, the mean values of $Ca^{2+}$ and $SO_4^{2-}$ (literature research) are compared with the temporal outliers in this study. The literature survey represents the data of the earthquake calm period, and this study represents the data of the earthquake active period.

*Line 38: please define "shallow minerals".*

Reply: Thanks. "Shallow minerals" is a relative term that generally refers to those minerals formed at or near the surface, mainly sedimentary rock related minerals. In this article mainly refers to gypsum. If "shallow mineral" is prone to ambiguity, **we consider directly replacing "shallow mineral" with "gypsum".**

*Line 61: which evidence have the authors of a "geothermal fluids circulation"*

Reply: Thanks. We have replaced "groundwater" with "geothermal water". Therefore, the geothermal water cycle is no longer considered

*Line 69: please define the "geothermal fluid anomaly index"*

Reply: Thanks. The “**geothermal fluid anomaly index**” may be a misnomer, and we consider replacing it with "**groundwater chemical and isotopic anomaly index** ". Refers to changes in the water chemistry and isotopic composition of groundwater caused by changes in the external environment.

*Lines 70-71: the subject is missing in this sentence.*

Reply: Thanks. We deleted that sentence.

*Line 82: please define what a “tectonic collage” is.*

Reply: Thanks. We have adjusted the expression of this sentence: “**Located at the intersection of Eurasia, Africa and Arabia, Turkey has a complex tectonic background**”.

*Fig. 1a: altitude scale is missing.*

Reply: Thanks. We added the  altitude scale (Fig. 3).

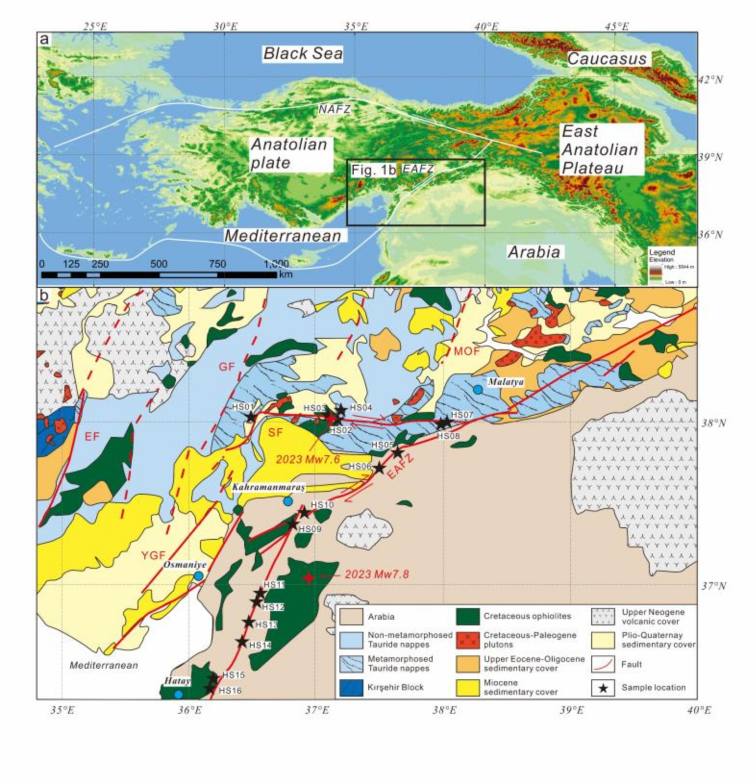


Fig. 3 Geological map after adding altitude scale.

*Line 105: probably crystalline instead of crystallization.*

Reply: Thanks. We changed crystalline instead of crystallization.

*Line 145: in table 1 HS15 is considered a spring, which one is correct?*

Reply: Thanks. We checked the sampling point. HS15 is spring.

*Line 146: the authors claim that "the closer to the epicenter, the higher the $SiO_2$ content", which makes no sense. Firstly because the earthquakes were two and only one sample close to one of the epicenters has a higher $SiO_2$ value. Moreover, other two sampling points with low to very low $SiO_2$ concentrations have the same position as the "anomalous" one.*

Reply: Thanks. We deleted that sentence

*Lines 154-156: the sentence "The δ18O and δD of samples varied from –11.30‰ to –6.55‰ and –65.43‰ to –34.43‰ respectively, which is near to the global meteoric water line (GMWL) (Craig, 1961) (Fig. 3), suggesting their meteoric water origin" has no sense. The regression line obtained plotting both $\delta^{18}O$ and δD values in a graph can be close to GMWL.*

Reply: Thanks. We deleted that sentence.

*Line 159: what type of Statistical analysis?*

Reply: Thanks.  We have changed the word "statistical analysis" to "box-plot analysis" to make the expression more specific.

*Line 160: please define "fluid activity elements".*

Reply: Thanks. We adjusted the expression and used proper nouns: Fluid-mobile element (FME).

*Line 161: I do not understand what the authors mean with "are at historic highs versus". If the authors mean that the concentrations are higher than in the past, then the fig. S2 does* *not prove nothing. Al and Ba are below the median value of the literature data while the remaining are around the median value not showing particularly high values. Furthermore, it is unclear which data are compared in fig. S2 with the present data.*

Reply: Thanks. There is indeed ambiguity in the expression here, so we consider deleting the analysis of the packing diagram to make the manuscript more brief and clear.

*Table 1: please indicate the coordinates with at least 4 digits after the comma, with only two digits it's impossible to obtain a reliable position. Looking at Fig. 1, the indicated coordinates of HS05 are clearly wrong.*

Reply: Thanks. We adjusted the accuracy of the latitude and longitude to keep 4 decimal places.

*Line 190: the highest values do not belong to samples collected closer to the sea.*

Reply: Thanks. It's not rigorous enough. We've improved the sentence: "**The highest value of δD (–34.43‰)and $\delta^{18}$O (–6.55‰) at the southwest of EAFZ, which is close to the Mediterranean Sea, indicating that it originates from the recharge of the evaporation of the Mediterranean Sea (Fig.3)**"

*Line 190: $\delta^{18}$O and δD values are inverted.*

Reply: Thank you. We've corrected it

*Line 212: magma mixing with geothermal fluids generally end in a volcanic explosion which is not the case here.*

Reply: Thanks. It is true that magma usually accompanies volcanic activity. However, there may also be deep partial melting process in the deep fracture zone. For the sake of rigor, we consider using "partial melting" instead of "magma mixing".

*Lines 224-225: the sampling sites are tens of km far from the Mediterranean coastline, how and why should they be "obviously contaminated by Mediterranean Sea water"?*

Reply: Thanks. It is tens of kilometers from the Mediterranean Sea, but from a geological perspective, it is very small. In the manuscript, our conclusions may be too arbitrary. We should consider the contribution of evaporites such as rock and salt. So, based on your comments, we've adjusted the sentence: "**HS16, the sample with the highest concentration, was collected at the southwest of EAFZ, which was obviously contaminated by Mediterranean Sea and/or halite. There is no signal of deep fluid or magma source.**"

*Line 226: which previous study? Please add a reference.*

Reply: Thanks. That sentence doesn't make sense. We deleted it.

*Line 233: pollution is a term connected to an anthropogenic origin, so please use the term contamination instead.*

Reply: Thank you. We changed the word "pollution" to " contamination."

*Lines 233-236: I do not understand the meaning of this sentence.*

Reply: Thanks. We adjusted the expression to make the meaning clearer: "**In addition, water is much less transferable than gas, which makes deep geothermal water may not be able to rise along the fault to the shallow crust or surface like geothermal gas.**"

*Lines 290-292: the two processes are not alternative. Serpentinization includes secondary minerals precipitation.*

Reply: Thanks. We adjusted the expression to make the meaning clearer: "**Compared with other samples, the ion concentration of HS15 is significantly reduced, which may**

**indicate the precipitation of potential secondary minerals (e.g., calcite). Therefore, we conjecture that serpentinization and secondary mineral precipitation such as: calcite or magnesite (Aydin et al., 2020; Cipolli et al., 2004) may be responsible for the increase in pH (Huang; et al., 2023).**”

*Finally, I would signal a possible conflict of interest being the handling editor of the same institution of one the corresponding author.*

Reply: Thanks. China University of Geosciences (Beijing) and China University of Geosciences (Wuhan) are two independent universities with no conflict of interest.

**Reply on RC2**

Dear Walter D'Alessandro

Thanks for your comments again. According to your comments, we added the supplement and analysis of the literature data from 2013 to 2025 to make the data more representative. On this basis, the conclusion of the original manuscript has been revised to weaken the connection between gypsum and seismic activity, and emphasize the sensitive indication of gypsum to the intensity of water-rock interaction. The main replies are as follows. Note: *Italic blue* is the comment. Black is the reply.

*I am sorry to say that reading the reply of the authors my opinion regarding the manuscript did not change. My main criticism relates to the fact that it is not possible to evidence anomalies in groundwater composition related to seismic events having data collected only one time. The authors try to compare their data with other taken from literature but the comparison is not straightforward because no background values have ever been defined. The mean values utilised seem artificially created and, in my opinion, do not represent "normal" values.*

*I am still convinced that the manuscript in this form has to be rejected.*

Reply: Thanks! We sincerely appreciate your critical feedback and fully acknowledge the limitations of single-time sampling in establishing seismic-hydrogeochemical correlations. To address this concern rigorously, we have implemented the following revisions:

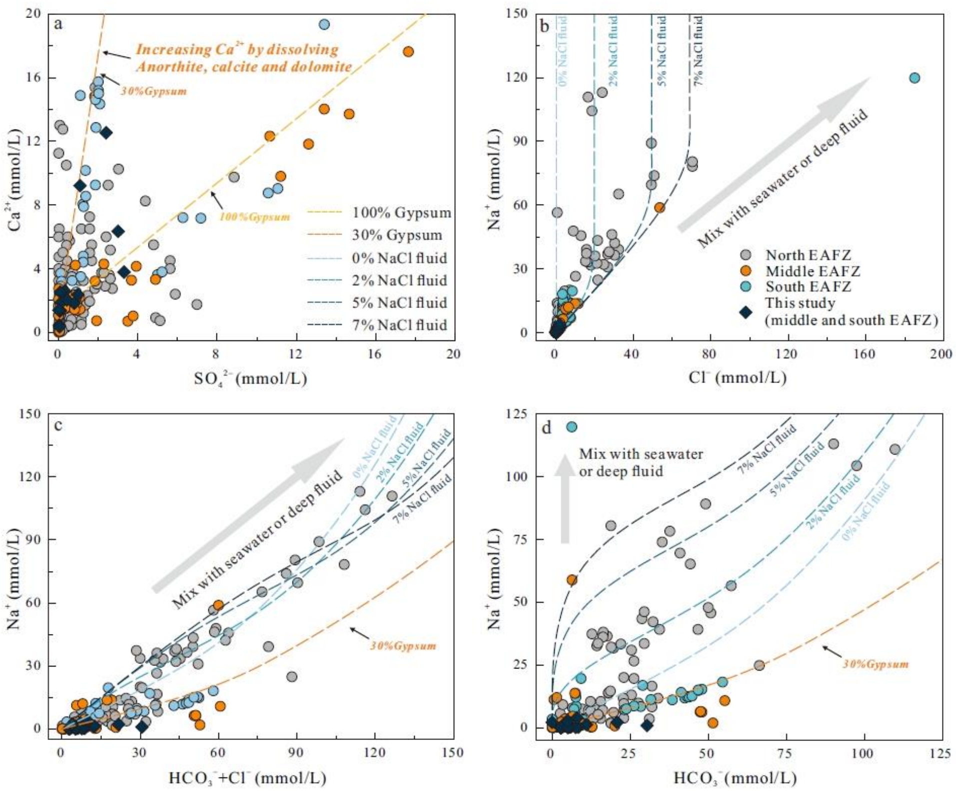


Fig. 1 Characteristics of chemical components of geothermal waters in the EAFZ, during water-rock interaction. The diamond is the measured value of geothermal waters. The dashed line is the numerical simulation result of PHREEQC. a: $Ca^{2+}$ vs $SO_4^{2-}$, b: $Na^+$ vs $Cl^-$, c: $Na^+$ vs $HCO_3^-$+$Cl^-$ and d: $Na^+$ vs $HCO_3^-$. The sources of literature data and the simulation calculations are detailed in Annex I.

1. Investigation and analysis of historical hydrogeochemical data in the study area (Fig. 1): A comprehensive compilation of groundwater chemistry data from the East Anatolian Fault Zone (EAFZ) spanning 2013-2023 has been integrated. This reveals systematic spatial hydrogeochemical patterns:

Northern EAFZ: Mixed shallow/deep circulation with igneous rock-dominated water-rock interactions.

Central-Southern EAFZ: Shallow circulation dominated by sedimentary mineral dissolution (e.g., gypsum, carbonates), with localized seawater influence.

These distinct regimes provide a robust framework for interpreting tectonic-hydrogeochemical linkages, mitigating reliance on isolated measurements.

2. Revised Interpretation of Gypsum Significance:

Following your suggestion, we have reframed the role of gypsum dissolution. Rather than asserting direct seismic causality, we now propose gypsum as a sensitive indicator of water-rock interaction intensity – a process modulated by both climatic (e.g., rainfall) and tectonic drivers. This rephrasing: (1) Removes overinterpretations of single-event correlations, (2) Highlights the need for future systematic monitoring to disentangle tectonic vs. hydrological signals. Preserves gypsum's potential as a tectonic proxy while adhering to evidence-based claims.

These revisions align the manuscript’s conclusions with its evidentiary scope while preserving its novel contribution: establishing a spatially resolved hydrogeochemical baseline to guide future seismotectonic monitoring in the EAFZ. We are grateful for your insightful critique, which has significantly strengthened the study’s rigor and communication of limitations.

*The data could be used to create a simply report without stressing the potential of gypsum as earthquake tracer. The data could be used for future researches in the area. I don’t know if there is a form in which this could be done for this journal. Maybe the editor can suggest solutions.*

Reply: Thanks! We thank you for your constructive suggestion to refocus the manuscript’s scope. In accordance with your guidance, we have rigorously revised the narrative to prioritize hydrogeochemical process characterization over speculative seismological linkages:

Reframed Research Objectives: The study’s primary aim is now explicitly stated as establishing hydrogeochemical signatures across the EAFZ’s tectonic segments. All claims regarding earthquake precursory signals have been removed, with emphasis shifted to documenting spatial patterns in water-rock interaction processes. The term "earthquake tracer" has been systematically replaced with "sensitive indicator of water-rock interaction intensity" throughout the text. A new statement clarifies that gypsum’s tectonic relevance requires validation through future systematic monitoring, aligning with your call for caution in interpretation.

These modifications ensure the manuscript now functions as both a stand-alone hydrogeochemical benchmark study and a catalyst for hypothesis-driven seismic monitoring research. We fully defer to the Editor’s judgment on whether this revised scope aligns with the journal’s aims and welcome further adjustments if needed.

***Comments on authors’ reply***

*Line 13: to affirm that you have measured abnormal groundwater ion concentrations you need to compare them with a series of data before and after the seismic event. Evaporite dissolution happens also in the absence of seismic activity, it is therefore impossible to affirm that high sulfate concentrations in groundwater are related to the earthquakes*

Reply: Thanks! We deeply appreciate your rigorous methodological critique regarding causality attribution. The revisions below directly address this fundamental concern:

After more than a month of research, we have a new understanding of the conclusions in the original draft. Indeed, even with video data of pre-earthquake macroscopic anomalies, it is difficult to form a complete causal chain in the absence of pre-earthquake data. After in-depth discussion by all co-authors, we propose that our data can only account for the dissolution of gypsum during the water-rock reaction. Gypsum may therefore indicate changes in the intensity of the water-rock reaction. As for the controlling factors of the variation of water-rock reaction intensity, we cannot define exactly. Considering that the sampling time was one month after the earthquake and obvious groundwater anomalies were observed before the earthquake, we believe that seismic activity may affect the variation of water-rock response intensity. Therefore, it is necessary to further study the possibility of gypsum as a tracer of tectonic activity.

*Line 44: even if sampled one hour after the earthquake my comment would have been the same. If you don't have data of at least one other sampling, but ideally many samplings covering different seasons both before and after the event, you cannot make inferences on the effects of the earthquake on the water chemistry*

Reply: Thanks! As mentioned earlier, we have revised this understanding to reinterpret the data in a more rigorous way.

*Line 47: your data before the earthquake do not refer to the single sites you sampled, so no comparison can be made*

Reply: Thanks! Through GPS comparison, we confirmed that at least 3 sampling sites had been reported (Table 1 in the first response). However, as you said, the literature data is from 10 years ago, its reference value may be subject to study, and it may not be possible to make valid comparisons. So, we took the last 10 years of data and collected it more likely, and compared all the data we collected with our results (Fig. 1).

*Lines 48-51: no one can deny the existence of a large suite of visible effects of seismic activity on groundwaters but for the advancement of knowledge these have to be described in detail and quantified. You cannot use the simple fact of a water whitening (among other things also confusing the sites) claiming this was due to gypsum dissolution without having the possibility to analyse the water chemistry*

Reply: Thanks! After analyzing 10 years of data in study area, we determined that the main controlling factor of the macro anomaly is gypsum, and there may also be the influence of Calcite, albite, potassium feldspar, etc.

*Lines 52-59: of course I agree that both Sr and S isotopes can be used as good source indicators. But again if you have a single measurement you cannot make any inference about the influence of the earthquake on the groundwaters*

Reply: Thanks! In the revised conclusion, we focus on the relationship between the reaction intensity of gypsum and water-rock. So Sr, S and other isotopes are effective, and we are conducting supplementary experiments, which can be completed in April 2025.

*Lines 75-78: You compared samples from three of your sampling sites with samples taken at the same sampling sites about ten years before. Results: one site registered a strong increase, another remained almost stable and the third one had a sharp decrease. You still cannot be sure that the changes are related to the earthquake, you have to exclude other possible processes. For example, do the composition of the groundwaters* *change seasonally? Has the composition of the water decadal trends related to long periods of drought or water exploitation? Does the well tap aquifers from different levels with different composition and permeability that mixing in the well may change the composition of the water during pumping?*

Reply: Thanks! We think your question about the manuscript is something we must take into account. Therefore, we give up the original conclusion and discuss the relationship between gypsum and water-rock reaction intensity instead.

*Lines 89-91: this seems a forced solution. The selected samples contain all very low sulfate which seems not necessarily being representative of the whole study area. Two out of 8 selected samples are hyperalkaline waters which for their nature contain extremely low sulfate values due to their very negative redox potential. Furthermore, why didn't you include also the data of Yuce et al 2014? The mean sulfate value of that dataset would be 121 mg/L, more than an order of magnitude higher than that obtained with the ad hoc solution from the Baba et al dataset.*

Reply: Thanks! Your advice has been of great help to us. According to your suggestion, we have collected and analyzed the data of the last 10 years. The results confirmed the dissolution of gypsum in the middle and south section.

*Lines 120-121: the reliability of the data has not been questioned but the representativeness still remains doubtful*

Reply: Thanks! In order to make the study more representative, the data of the study area in the past 10 years are used to discuss the water-rock reaction process.

*Line 130: A nearly 1000 km tectonic system cannot be considered a single hydrothermal* *system*

Reply: Thanks! As you said, it is really not a system. The north section is a mixture of shallow groundwater and deep fluids, and igneous rocks participate in water-rock reactions. The central and southern part is the mixing of shallow groundwater and seawater, and sedimentary minerals such as gypsum participate in water-rock reaction.

*Lines 135-142: the cited examples of studies which identified changes in groundwater composition related to earthquake are well known. But differently from your study, the researcher took tens of samples before the seismic events obtaining a clear signal that can be related to the earthquake*

Reply: Thanks! Although we do not have pre-earthquake data, considering that we have observed pre-earthquake macro anomalies, coupled with the analysis of all data from the study area in the past 10 years. We believe that the data are sufficient to support our revised conclusion that gypsum can be used as a tracer of the intensity of water-rock reactions, and it is necessary to further investigate the possibility of gypsum as an indicator of tectonic activity.

*Line 149: You did not answer to my question. Have the samples been filtered in the field and before acidification?*

Reply: Thanks! Yes, we confirm.

*Lines 170-171: if the filtration is not made at the time of sampling you may loose some of the dissolved metals due to precipitation of secondary minerals and/or to adsorption on the walls of the container. Furthermore, if filtration is made after acidification the result may be falsified by acid dissolution of suspended material*

Reply: Thanks! We are responsible for all sample collection, pre-processing and data quality

*Line 172: this method is used only for δD*

Reply: Thanks! The analysis method of $\delta^{18}O$ is supplemented.

*Lines 225-226: You cannot consider a nearly 1000 km long fault system as a single continuous structure. Furthermore, the complex geology of the area changes frequently the rock types present along the fault system. Add also the changing climatic and hydrologic conditions and you cannot consider samples collected many tens of km apart as pertaining to the same system.*

Reply: Thanks! As you said, it is really not a system, we have answered earlier.

*Lines 235-237: to have a chain you need all rings to be connected. You don't have evidence that the water-rock reaction balance has been disrupted by the earthquake. Gypsum or other evaporite rocks are naturally present in many of the lithostratigraphic sequences of the area and when they are part of aquifers, their dissolution contributes naturally to the saline content of the circulating groundwater without the influence of seismic activity. If you consider the data of Yuce et al 2014, you see that in the area many of the collected waters have high sulfate concentrations with values even exceeding your highest value. So there is no evidence of gypsum dissolution as a consequence of the seismic events.*

Reply: Thanks! We have abandoned the conclusion that the gypsum can be inferred from the seismic effects of the data collected. We now propose that gypsum can reflect the intensity of water-rock reaction. Considering that the sample collection time was about one month after the earthquake, it is necessary to further study the possibility of gypsum as an indicator of seismic activity.

*Lines 301-301: I repeat again, even if you analysed a sample taken one hour after the earthquake, this could not confirm that the whitening and turbidity of the water before the seismic event was due to an increased sulfate content*

Reply: Thanks! Although the data in this study maybe limited, we still observed the dissolution of gypsum by analyzing the data of 10 years in the study area together, but we could not determine whether it was caused by seismic activity. Therefore, we have expressed our conclusions more rigorously.

*Line 307: I don't understand how you have fixed it. The video refers to the sampling site HS15 which, as shown in your table, has the lowest sulfate concentration. This video is not a proof of a sulfate anomaly for two reasons: 1) you don't have the concentration of sulfate at the time of the whithening and 2) the concentration you measured one month after was only 1.21 mg/L*

Reply: Thanks! There should be a misunderstanding here. We have stated in the first response that the macroscopic anomaly originates from HS14, which has a $SO_4^{2-}$ concentration of 316.61mg/L.

*Lines 311-312: You are missing the main point: you have no evidence of variations that can be related to the earthquake*

Reply: Thanks! We've revised our conclusions to be more precise.

*Line 327: The problem is that normal values have not been defined. In terms of time you don't have enough samples that you can surely correlate with yours. But the same* *holds true in terms of space, only 16 samples along a structure many hundred km long is not enough*

Reply: Thanks! We have weakened the focus on time and only discussed the water-rock reaction process of gypsum. 10 years of data is sufficient to support spatial representativeness.

**Reply on RC3**

Dear reviewer

Thank you for your comments and suggestions, which are of great value to us in improving the quality of our manuscript. The main replies are as follows. Note: *Italic blue* is the comment. Black is the reply.

*The present work performs a systematic hydrogeochemistry and isotopic analysis of the geothermal fluids in the East Anatolian Fault Zone (EAFZ) to understand any clear relationship between geothermal fluid anomalies and earthquakes existing. I have found the language of the manuscript is fine but must have a proof-editing. I have some of my major comments regarding the work on the other hand.*

*Main motivation behind the work is to elucidate the role of gypsum dissolution as a tracer for earthquake activity in the East Anatolian Fault Zone (EAFZ). The research aims at establishing a link between geothermal fluid anomalies and seismic events, with the claim of using an innovative approach to earthquake forecasting. In this respect, it examines shallow sedimentary minerals, particularly gypsum, as indicators of seismic activity. This concept, while explored in previous research, is further substantiated with empirical data in this study.*

*At this stage my biggest concern stems from the fact that it relies on the data collected post-earthquake but it fails to provide a long-term pre-earthquake dataset for comparative analysis. This appears to undermine claims about gypsum dissolution as a predictive tool rather than a post-seismic indicator. Furthermore we understand that the manuscript never make an in-depth discussion or address other factors such as* *climatic conditions and seasonal variations robustly and only focus is given on the correlation between seismic events and SO42- anomalies is discussed.*

*The authors' uncertainty about the relevance of the results to earthquakes is evident in the final statement of the abstract. As readers, we expect the abstract of this study, which claims to bring innovation to earthquake prediction under normal conditions, to convey a clear take-home message.*

*In this respect I understand that authors are suggesting gypsum dissolution as a universal precursor. But I should remind that a comprehensive considering of regional geological differences or alternative explanations for observed anomalies is of great importance for earthquake hazard studies. Although potential limitations of using gypsum dissolution due to external environmental factors is acknowledge in the manuscript clear strategies for coping with these difficulties in practice.*

*Given its limitations in predictive validation substantial revisions are required for the present work. These revisions should include i) further evidences distinguishing seismic-induced gypsum dissolution from other environmental factors ii) a decent discussion on possible long-term monitoring strategies to make gypsum dissolution as a reliable precursor, iii) quantitative examples that prove the statistical significance of the findings that are critical to improve the robustness of the conclusions.*

*I also suggest adding a discussion that explore practical applications focusing on an integration of their findings into an effective earthquake early warning system.*

*In conclusion I do not think the manuscript is suitable for the publication in its current form and requires a substantial work to address the aforementioned fundamental* *concerns that would significantly advance the understanding of geochemical indicators in seismic studies and warrant publication.*

Reply: Thanks! We sincerely thank you for recognizing the systematic approach of our hydrogeochemical investigation. Please find below our point-by-point responses:

**Data base extension (Annex I)**:

A meta-analysis of 8 published datasets (2013-2023) reveals fundamental differences in water-rock interactions across the EAFZ (Fig. 1):

Northern EAFZ: Mixed shallow/deep circulation with igneous rock-dominated water-rock interactions.

Central-Southern EAFZ: Shallow circulation dominated by sedimentary mineral dissolution (e.g., gypsum, carbonates), with localized seawater influence.

These distinct regimes provide a robust framework for interpreting tectonic-hydrogeochemical linkages, mitigating reliance on isolated measurements.

**Gypsum as Process Indicator:**

While avoiding direct seismic causality claims, three lines of evidence suggest gypsum's tectonic relevance:

The abnormal plasma of $SO_4^{2-}$ and $Ca^{2+}$ was observed one month after the earthquake. Combined with the analysis of 10 years of data in the study area, it was found that gypsum dissolution may be the cause of the abnormal ion concentration.

One month before the earthquake, the macro anomaly of white and cloudy well water was photographed (Video 01)

After analyzing pre-earthquake macro anomaly, post-earthquake data and literature data in the past 10 years, we propose that our data can only account for the dissolution of gypsum during the water-rock reaction. Gypsum may therefore indicate changes in the intensity of the water-rock reaction. As for the controlling factors of the variation of water-rock reaction intensity, we cannot define exactly. Considering that the sampling time was one month after the earthquake and obvious groundwater anomalies were observed before the earthquake, we believe that seismic activity may affect the variation of water-rock response intensity. Therefore, it is necessary to further study the possibility of gypsum as a tracer of tectonic activity.

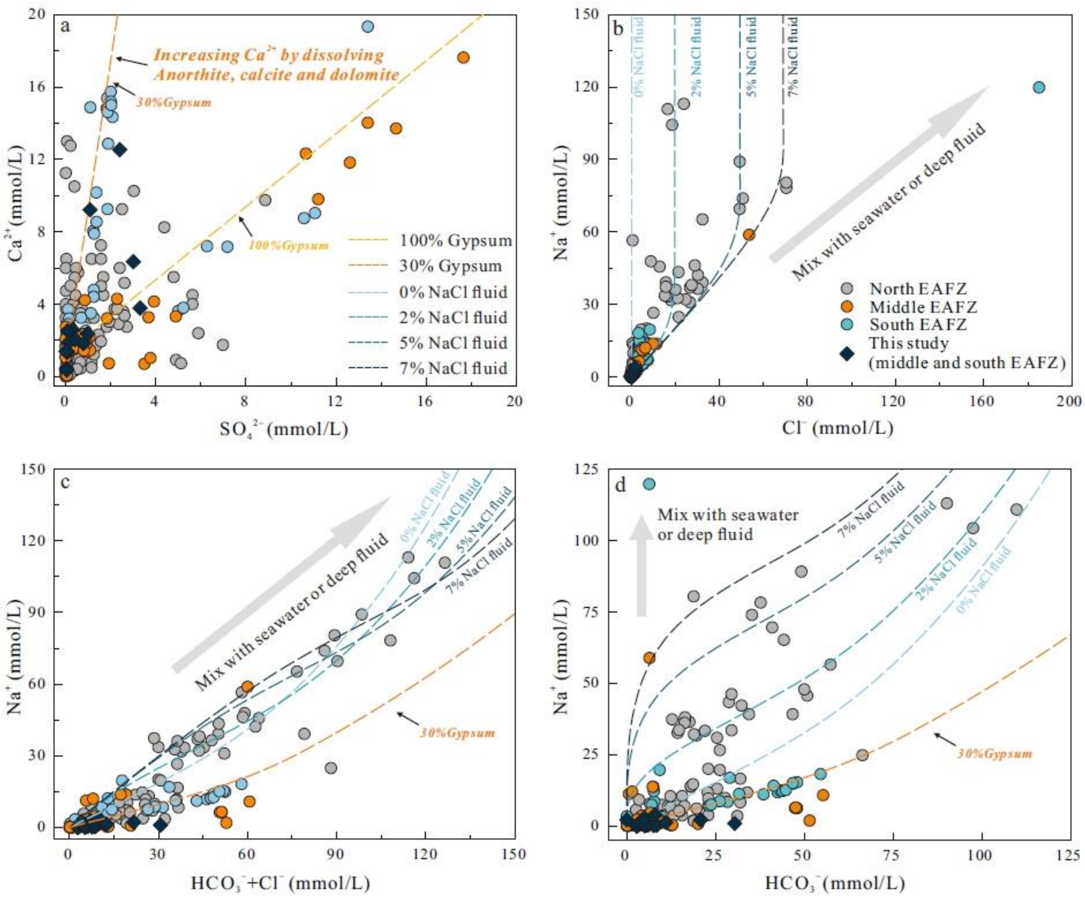


Fig. 2 Characteristics of chemical components of geothermal waters in the EAFZ, during water-rock interaction. The diamond is the measured value of geothermal waters. The dashed line is the

numerical simulation result of PHREEQC. a: $Ca^{2+}$ vs $SO_4^{2-}$, b: $Na^+$ vs $Cl^-$, c: $Na^+$ vs $HCO_3^-$+$Cl^-$ and d: $Na^+$ vs $HCO_3^-$. The sources of literature data and the simulation calculations are detailed in Annex I.

**Clear research orientation:**

Delete all references to "earthquake prediction". This study focuses on the analysis of EAFZ groundwater circulation process and attempts to establish the relationship between water-rock reaction intensity and tectonic activity. This study will provide a new research idea for the subsequent exploration of gypsum as a tracer of tectonic activity.

**Replay on CC1**

Dear Giovanni Martinelli

Thank you for your recognition of our work and valuable suggestions, which are very helpful for us to improve the quality of our manuscripts. Your two comments are exactly where we are lacking. At your suggestion, we plan to add a subsection to the discussion section for assessing the contribution of mantle degassing to EAFZ geothermal fluids. The supplementary content is as follows:

*Contribution of Mantle Degassing to EAFZ Geothermal Fluids*

Mantle degassing occurs extensively along fault zones, and the amount of volatile release can sometimes be comparable to the degassing associated with volcanic activity e.g. (Fischer and Aiuppa, 2020; Zhang et al., 2021). Sulfur-containing volatiles (such as $SO_2$ and $H_2S$) ascend along these fault zones and, upon reaching the shallow subsurface, mix with groundwater, where they are oxidized and migrate in the form of $SO_4^{2-}$ in geothermal fluids. Therefore, the contribution of mantle degassing to the $SO_4^{2-}$ content in geothermal fluids cannot be overlooked. To better assess the contribution of mantle degassing to $SO_4$ in EAFZ geothermal fluids, we need to consider the sources and modifications of geothermal fluids.

The deep-origin geothermal fluids in EAFZ are significantly diluted by shallow groundwater, masking the chemical signature of deeper fluid components. This dilution process introduces a large amount of dissolved oxygen, which facilitates the oxidation of $H_2S$ to $SO_4^{2-}$. Lacking $O_2$ was detected in EAFZ geothermal gases suggested that the dissolved oxygen may have been consumed (Italiano et al., 2013; Yuce et al., 2014).

However, it is important to note that $H_2S$, $H_2$, and $CH_4$ can all react with oxygen. Thermodynamic calculations indicate that $CH_4$ is more favorable than $H_2S$ in oxidation reactions ($\Delta G°$ $CH_4$ = -818.1 kJ/mol, $\Delta G°$ $H_2S$ = -494.2 kJ/mol, at 298 K and 1atm). In actual geothermal systems, however, the depletion of $H_2S$ is more commonly observed than the depletion of $CH_4$, suggesting that $H_2S$ may be oxidized before $CH_4$. To resolve this apparent contradiction, we propose the following possible explanations: 1) Oxidation of $H_2S$: While thermodynamic calculations predict $CH_4$ oxidation first, a small amount of $H_2S$ might still be oxidized simultaneously with $CH_4$. Due to the much lower concentration of $H_2S$ in geothermal systems compared to $CH_4$, $H_2S$ is consumed more quickly, leaving $CH_4$ with a higher residual concentration. 2) Exogenous $CH_4$ Supply: In addition to mantle-derived $CH_4$, other sources of $CH_4$, such as biogenic $CH_4$ and thermogenic $CH_4$ (e.g., serpentinization), may contribute to the geothermal system. These external sources could increase the concentration of $CH_4$ in the geothermal fluids.

In the EAFZ, we observed significant contributions of biogenic and serpentinization-derived $CH_4$ but did not detect significant levels of $H_2S$ (Italiano et al., 2013; Yuce et al., 2014). Therefore, we proposed that although $H_2S$ may contribute to the geothermal system, its impact is likely limited due to its relatively low concentration. Inversely, the notable increase in $SO_4^{2-}$ concentrations following seismic events is likely primarily controlled by the dissolution of shallow evaporitic layers (such as gypsum). All in all, while the oxidation of $H_2S$ may contribute to $SO_4^{2-}$ formation, distinguishing between $H_2S$ oxidation and sulfate dissolution requires additional geochemical indicators, such as S isotopes and Ca isotopes, for more accurate assessments.

**References**

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Yuce, G., Italiano, F., D'Alessandro, W., Yalcin, T. H., Yasin, D. U., Gulbay, A. H., Ozyurt, N. N., Rojay, B., Karabacak, V., Bellomo, S., Brusca, L., Yang, T., Fu, C. C., Lai, C. W., Ozacar, A., and Walia, V.: Origin and interactions of fluids circulating over the Amik Basin (Hatay, Turkey) and relationships with the hydrologic, geologic and tectonic settings, Chemical Geology, 388, 23-39, 2014.

Zhang, M., Xu, S., Zhou, X., Caracausi, A., Sano, Y., Guo, Z., Zheng, G., Lang, Y.-C., and Liu, C.-Q.: Deciphering a mantle degassing transect related with India-Asia continental convergence from the perspective of volatile origin and outgassing, Geochimica Et Cosmochimica Acta, 310, 61-78, 2021.

**Reply on CC2**

Dear Hafidha Khebizi

Thank you for your recognition of our work and constructive suggestions. This is very helpful for us to improve the quality of the manuscript, and also brings confidence for us to continue to explore. Thank you for sharing the very rewarding work you do. We get a lot of inspiration from your work. We would like to express my heartfelt thanks.

We've responded to each of your comments, as detailed below:

Note: *Italic blue* is the comment. Black is the reply.

*Dear authors and colleagues of the scientific community,*

*I congratulate the authors for their interesting work entitled Gypsum as a potential tracer of Earthquakes: a case study of the Mw7.8 2 earthquake in the East Anatolian Fault Zone, southeastern Turkey, and I hope it will be published soon. To find out the relationship between geothermal fluid anomalies and earthquakes, the authors performed a systematic hydrogeochemistry and isotopic analysis of the geothermal fluids in the East Anatolian Fault Zone (EAFZ). The results show that earthquakes reconstructed these geothermal fluids.*

Reply: Thank you for your recognition of our work. Thank you.

*Considering gypsum as an earthquake tracer is excellent reasoning for analysing the impact of anomalies after the earthquake, and the work could be a great reference for future studies related to the earthquake.*

Reply: Yes, through the analysis of groundwater after the earthquake, we discovered the potential value of gypsum as an earthquake warning. It is hoped that this work will attract the attention of more researchers and colleagues, and incubate more meaningful achievement.

*To enrich this excellent analysis, I have some remarks concerning the implication of* *macroscopic and microscopic aspects of geothermal fluids before and after the earthquake, notably the relation with the structural geology of the region. For this, some questions seem important to be asked.*

*First, from a macroscopic point of view, it is necessary to understand, in the normal case (before the earthquake), from a geological point of view, if the existing deformations (faults) already have effective structures for the infiltration of meteorological waters and the implication of the disposition of the thermal springers according to the faults. After the earthquake, is there any sampling from Miocene groundwater and soil? Is there recent salt precipitation in the Miocene and upper Eocene-Oligocene soil and/or in the soil of the surrounding springer sources? Is there a rise in the ground level due to fault action, and are there marine intrusions that occurred after the strike-slip? Is there significant contamination of the water table (increased electrical conductivity)?*

Reply: Hot springs and fault zones are often associated. Hot springs are considered as one of the potential means of earthquake warning. A large number of research results have been published in Japan, the United States, Iceland, Spain, China, Turkey... ... In EAFZ, many hot springs have been systematically studied, and the results show that these hot springs contain material supply from deep crust and even mantle. Therefore, it is highly possible to obtain valuable information by conducting post-earthquake hydrochemical and isotopic analyses of these hot springs.

Unfortunately, we only collected water samples after the earthquake and did not analyze soil samples. Your comment is a very good suggestion, reminding us that detailed analysis of surrounding rock may be needed in future work. Thank you.

Salt precipitation and electrical conductivity (EC). Before we can answer your question, we need to explain an error in the manuscript. Our sample was taken in March 2023 (within one month after the earthquake). In the video 1 we provided, the macro abnormal changes of HS14 were diluted by the adjacent stream, coupled with the fact that the samples were taken within one month after the earthquake and no soil samples were collected, **we could not accurately determine whether salt precipitation existed**. By comparing the EC of the same hot spring during the seismically quiet period and the seismically active period, we found that the EC of HS14 increased slightly (varying from 990 to 1305). Data of EC pre-earthquake from *Yuce, G., Italiano, F., D'Alessandro, W., Yalcin, T. H., Yasin, D. U., Gulbay, A. H., Ozyurt, N. N., Rojay, B., Karabacak, V., Bellomo, S., Brusca, L., Yang, T., Fu, C. C., Lai, C. W., Ozacar, A., and Walia, V.: Origin and interactions of fluids circulating over the Amik Basin (Hatay, Turkey) and relationships with the hydrologic, geologic and tectonic settings, Chemical Geology, 388, 23-39, 2014.*

Seawater intrusion was evident after the earthquake. $Na^+$ and $Cl^-$ of HS14, HS15 and HS16 increased significantly, indicating the possible existence of seawater intrusion (Fig. 6 manuscript).

Rise in the ground level due to fault action is common. We have made a detailed study on the post-earthquake surface rupture and post-earthquake risk analysis. Article link： *Liang, P., Xu, Y., Zhou, X., Li, Y., Tian, Q., Zhang, H., Ren, Z., Yu, J., Li, C., Gong, Z., Wang, S., Dou, A., Ma, Z., and Li, J.: Coseismic surface ruptures of MW7.8 and MW7.5 earthquakes occurred on February 6, 2023, and seismic hazard assessment of the East Anatolian Fault Zone, Southeastern Turkiye, Science China Earth Sciences, doi: 10.1007/s11430-024-*

*1457-7, 2024.*


Screenshot from Liang et al., 2024 doi: 10.1007/s11430-024-1457-7 (If the picture cannot be displayed, please check it in the attachment, thank you).

*From a microscopic point of view, gypsum is easily and quickly influenced by contact with water, thanks to its physicochemical characteristics, in particular its very high dissolution rate and its solubility in water that make it an excellent tracer of hydrochemical anomaly but also a tracer of lithological instability (Khebizi et al., 2022; Khebizi et al., 2023). For this, I am pleased to invite you to read the part concerning the gypsum implication on the lithological instability in my article published in Larhyss Journal and my oral communications, which expose, for the first time in Algeria, a new concept of the lithological vulnerability of the subsurface. Although the study areas differ, the analysis presented in my work shows the indication of gypsum dissolution at the regional scale as an excellent major risk indicator. The lithological vulnerability of the subsurface concept can be applied to different situations around the world, notably the case of earthquakes. It highlights the hydrodynamic anomalies' relation with the structural and geological context of the area to be studied.*

Thank you very much for your sharing. It's a fantastic set of work. From my personal point of view, I can't agree with you more. Gypsum's very high dissolution rate and solubility in water can be used for risk warning of earthquakes and geological disasters. Thank you again for your information. Your work gives us great encouragement and confidence.

*Second, if there is a remarkable increase in calcium concentration in water after the earthquake, how do you explain the reaction of carbonate dissolution and the origin of CO2? Is it linked to magmatic activity? In this case, is there a signature of other gases on other cations? Or is it only related to carbonate since the calcite dissolution is linked to the mineral's surface to be in direct contact with water?*

In my opinion, Ca may come from carbonate or igneous rocks. In order to accurately restrict the source area of Ca, we are also considering introducing Ca isotopes to distinguish its sources. Ca isotopes in carbonate rocks are lighter than those in igneous rocks and mantle. Ca isotope has a good potential in the source region that restricts Ca.

The index of $CO_2$ source region is very mature. Geothermal gases are well studied at EAFZ. The C isotope study of $CO_2$ shows that $CO_2$ is controlled by deep carbon and inorganic carbonate (−5.6 to −0.2‰) (*Italiano, F., Sasmaz, A., Yuce, G., and Okan, O. O.: Thermal fluids along the East Anatolian Fault Zone (EAFZ): Geochemical features and relationships with the tectonic setting, Chemical Geology, 339, 103-114, 2013.*). He isotope analysis also shows a large proportion of the mantle.

Explanation of the specific process: gypsum dissolution and carbonate dissolution are together. In the manuscript, PHREEQC was used to simulate the water-rock reaction process (Fig. 7). The results show that gypsum dissolution alone is not enough to explain the Ca content in the samples, indicating that calcite and other minerals are involved in the water-rock reaction. Combined with previous studies, we believe that $CO_2$ from deep water is first dissolved in water, and then reacts with gypsum or calcite. $CO_2$ is associated with magma, but does not form volcanic eruptions and may only exist in deep areas of partial melting.

*Allow me to add that the underground water circulation, which is controlled by faults and hydraulic parameters (permeability), determines water-rock equilibrium. In this case, water-rock equilibrium depends on the host rock spatial disposition of rock that guides water mineralization and the different processes. Consequentially, the water-rock equilibrium changes from one area to another due to changes in water mineralization according to the host* *rock lithology. For this, the information that can be taken from the geological map is that springer's water is related to ophiolite rocks. So, I think water geochemistry indicates similar water-rock interactions for all sources. However, a mineral's enrichment zoning can occur due to (i) the meteorological conditions, (ii) the proximity of the springer water from seawater, and/or (iii) the distance from the upstream. The earthquake reconstructed these geothermal fluids depending on the energy released which controls hydrothermal circulation and amplifies interactions with the surrounding environment whether at depth or on the surface. For this, vulnerability zoning in a horizontal and vertical direction can be done according to chemical variation, notably gypsum and probably halite enrichment. It can be indicated as shown in Fig. 8.*

I can't agree with you more. Water-rock reaction is affected by meteorology, rock properties, permeability, porosity, temperature, pressure... Multiple factors control. At present, our work is limited to the analysis of water chemistry and isotopes, and there is a lot of work to be done in the future. These works involve not only geochemistry, but also rock mechanics, numerical simulation and other interdisciplinary fields, and we hope to have more like-minded colleagues to explore together.

Earthquake warning is the most difficult problem faced by mankind. Groundwater is considered as one of the means to explore earthquake early warning. However, groundwater in its natural environment is very complex. There is still a long way to go to explore the relationship between groundwater and earthquakes.

*Finally, the discussion on this topic is very significant, and the structural and lithological vulnerability and their tracers after the earthquake using vulnerability mapping of the Turkey* *earthquake seems very interesting for future work.*

Thank you for your recognition of our work, your recognition is our driving force forward.

Sincere thanks and best wishes.

**Annex I**

| T | pH | $Na^+$ | $K^+$ | $Ca^{2+}$ | $Mg^{2+}$ | $HCO_3^-$ | $Cl^-$ | $SO_4^{2-}$ | $SiO_2$ | $\delta^{18}O$ | $\delta D$ | Data source |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| (°C) | | mg/L | mg/L | mg/L | mg/L | mg/L | mg/L | mg/L | mg/L | | | |
| 63.2 | 6.8 | 1050.0 | 140.0 | 410.0 | 82.0 | 3100.0 | 460.0 | 290.0 | 150.0 | -12.5 | -96.0 | |
| 18.7 | 7.8 | 3.3 | 0.8 | 11.0 | 1.3 | 41.0 | 0.7 | 4.8 | 3.5 | -12.7 | -86.0 | |
| 55.1 | 9.7 | 39.0 | 0.9 | 13.0 | 0.4 | 83.0 | 2.8 | 37.0 | 79.0 | -14.2 | -99.0 | |
| 5.5 | 7.4 | 1.3 | 0.3 | 6.2 | 0.5 | 25.0 | 0.4 | 1.1 | 2.7 | -13.9 | -94.0 | |
| 32.5 | 7.2 | 40.0 | 0.7 | 31.0 | 0.1 | 47.0 | 4.9 | 110.0 | 50.0 | -14.0 | -95.0 | |
| 17.5 | 7.9 | 2.6 | 0.4 | 22.0 | 2.1 | 76.0 | 0.4 | 3.4 | 8.2 | -13.1 | -89.0 | |
| 11.7 | 5.3 | 314.0 | 19.0 | 240.0 | 45.0 | 1100.0 | 150.0 | 230.0 | 120.0 | -13.7 | -96.0 | |
| 13.1 | 7.0 | 6.5 | 5.2 | 43.0 | 7.1 | 150.0 | 4.5 | 13.0 | | -13.1 | -93.0 | |
| 36.6 | 5.6 | 2050.0 | 51.0 | 370.0 | 64.0 | 3000.0 | 1750.0 | 240.0 | 120.0 | -13.4 | -104.0 | |
| 6.0 | 7.3 | 4.7 | 0.5 | 9.0 | 2.9 | 47.0 | 0.5 | 2.1 | 6.0 | -12.1 | -82.0 | |
| 15.2 | 6.0 | 48.0 | 8.5 | 33.0 | 33.0 | 370.0 | 9.0 | 6.1 | 68.0 | -13.3 | -93.0 | |
| 17.4 | 6.8 | 46.0 | 8.2 | 36.0 | 33.0 | 350.0 | 9.0 | 8.5 | | -13.1 | -92.0 | |
| 36.1 | 9.4 | 130.0 | 1.4 | 18.0 | 1.6 | 160.0 | 79.0 | 63.0 | 62.0 | -14.5 | -101.0 | |
| 9.2 | 7.4 | 20.0 | 0.6 | 25.0 | 9.0 | 150.0 | 4.8 | 3.3 | | -10.0 | -66.0 | |
| 24.3 | 5.9 | 1600.0 | 20.0 | 260.0 | 170.0 | 2500.0 | 1750.0 | 2.5 | 120.0 | -12.7 | -93.0 | |
| 14.7 | 7.6 | 5.1 | 1.5 | 15.0 | 5.1 | 81.0 | 1.1 | 1.5 | | -11.9 | -80.0 | |
| 11.6 | 5.6 | 160.0 | 13.0 | 260.0 | 150.0 | 1400.0 | 180.0 | 110.0 | 110.0 | -13.6 | -100.0 | |
| 27.0 | 6.1 | 1100.0 | 46.0 | 260.0 | 78.0 | 3050.0 | 320.0 | 150.0 | 100.0 | -10.1 | -84.0 | |
| 11.9 | 8.0 | 42.0 | 3.6 | 41.0 | 21.0 | 290.0 | 6.1 | 21.0 | 6.9 | -12.7 | -92.0 | |
| 36.5 | 6.1 | 2400.0 | 73.0 | 220.0 | 88.0 | 5950.0 | 660.0 | 160.0 | 140.0 | -10.5 | -88.0 | |
| 57.3 | 7.3 | 2550.0 | 82.0 | 290.0 | 130.0 | 6700.0 | 590.0 | 150.0 | 120.0 | -10.7 | -88.0 | |
| 14.5 | 7.2 | 16.0 | 3.2 | 51.0 | 29.0 | 310.0 | 4.1 | 9.6 | 18.0 | -11.2 | -77.0 | |
| 24.9 | 5.7 | 240.0 | 34.0 | 120.0 | 51.0 | 950.0 | 140.0 | 4.7 | 80.0 | -13.8 | -98.0 | |
| 13.1 | 7.5 | 16.0 | 3.8 | 31.0 | 13.0 | 190.0 | 2.5 | 4.0 | 6.1 | -13.1 | -94.0 | |
| 37.7 | 6.3 | 1800.0 | 59.0 | 520.0 | 160.0 | 2300.0 | 2500.0 | 5.2 | 180.0 | -13.2 | -97.0 | |
| 28.6 | 6.3 | 710.0 | 53.0 | 240.0 | 120.0 | 1550.0 | 950.0 | 0.2 | 100.0 | -12.2 | -91.0 | |
| 12.5 | 7.1 | 10.0 | 4.2 | 39.0 | 7.5 | 160.0 | 3.4 | 8.1 | 7.5 | -11.0 | -75.0 | |
| 57.0 | 6.6 | 900.0 | 120.0 | 450.0 | 240.0 | 2850.0 | 1150.0 | 0.3 | 170.0 | -12.5 | -92.0 | |
| 13.6 | 6.1 | 30.0 | 6.5 | 72.0 | 37.0 | 440.0 | 7.3 | 12.0 | 7.5 | -12.8 | -92.0 | |
| 28.5 | 5.9 | 460.0 | 17.0 | 82.0 | 96.0 | 1400.0 | 250.0 | 0.1 | 100.0 | -13.1 | -91.0 | |
| 12.9 | 7.3 | 16.0 | 1.6 | 20.0 | 9.6 | 140.0 | 5.6 | 1.8 | | -12.5 | -84.0 | |
| 33.4 | 6.2 | 450.0 | 21.0 | 93.0 | 100.0 | 1600.0 | 160.0 | 2.3 | 140.0 | -13.0 | -90.0 | Aydin H., Karakuş H. and Mutlu H. (2020) Hydrogeochemistry of geothermal waters in eastern Turkey: Geochemical and isotopic constraints on water-rock interaction. Journal of Volcanology and Geothermal Research 390. |
| 11.6 | 7.2 | 17.0 | 1.2 | 21.0 | 10.0 | 140.0 | 1.1 | 5.3 | | -12.9 | -88.0 | |
| 36.0 | 6.2 | 1700.0 | 42.0 | 150.0 | 81.0 | 2150.0 | 1800.0 | 0.8 | 110.0 | -13.3 | -95.0 | |
| 38.4 | 6.5 | 1500.0 | 40.0 | 160.0 | 100.0 | 2700.0 | 1150.0 | 0.4 | 140.0 | -13.6 | -97.0 | |
| 19.2 | 7.9 | 1300.0 | 17.0 | 61.0 | 15.0 | 3500.0 | 25.0 | 0.0 | 68.0 | -12.5 | -94.0 | |
| 14.5 | 7.4 | 14.0 | 1.1 | 75.0 | 27.0 | 360.0 | 2.7 | 7.0 | 5.3 | -11.0 | -77.0 | |
| 33.4 | 6.5 | 570.0 | 19.0 | 420.0 | 600.0 | 4050.0 | 770.0 | 37.0 | 180.0 | -12.3 | -90.0 | |
| 18.6 | 5.9 | 80.0 | 8.4 | 67.0 | 330.0 | 1900.0 | 36.0 | 60.0 | 110.0 | -12.2 | -84.0 | |
| 13.7 | 7.5 | 2.1 | 0.7 | 2.1 | 43.0 | 210.0 | 2.9 | 12.0 | | -11.7 | -82.0 | |
| 25.3 | 6.5 | 190.0 | 9.9 | 510.0 | 52.0 | 1950.0 | 170.0 | 20.0 | 51.0 | -12.0 | -82.0 | |
| 30.3 | 6.4 | 86.0 | 21.0 | 230.0 | 110.0 | 1400.0 | 65.0 | 53.0 | 80.0 | -12.0 | -78.0 | |
| 46.9 | 6.6 | 84.0 | 14.0 | 160.0 | 60.0 | 950.0 | 64.0 | 32.0 | 95.0 | -12.2 | -79.0 | |
| 41.0 | 6.5 | 46.0 | 10.0 | 240.0 | 70.0 | 1150.0 | 19.0 | 44.0 | 75.0 | -12.0 | -76.0 | |
| 24.6 | 6.4 | 770.0 | 46.0 | 150.0 | 110.0 | 1800.0 | 560.0 | 68.0 | 85.0 | -12.1 | -87.0 | |
| 19.5 | 5.4 | 22.0 | 34.0 | 49.0 | 9.3 | 130.0 | 19.0 | 120.0 | 86.0 | -14.0 | -96.0 | |
| 48.3 | 7.0 | 160.0 | 70.0 | 93.0 | 81.0 | 880.0 | 160.0 | 140.0 | 68.0 | -12.6 | -94.0 | |
| 64.2 | 6.6 | 120.0 | 52.0 | 130.0 | 84.0 | 920.0 | 120.0 | 100.0 | 153.0 | -11.3 | -91.0 | |
| 53.7 | 7.0 | 160.0 | 59.0 | 180.0 | 69.0 | 990.0 | 120.0 | 160.0 | 60.0 | -11.5 | -92.0 | |
| 25.8 | 2.4 | 34.0 | 71.0 | 70.0 | 32.0 | 0.0 | 9.0 | 670.0 | 140.0 | -10.8 | -79.0 | |
| 50.6 | 7.2 | 170.0 | 69.0 | 69.0 | 76.0 | 590.0 | 180.0 | 130.0 | 56.0 | -12.5 | -95.0 | |
| 65.2 | 6.6 | 160.0 | 76.0 | 130.0 | 52.0 | 710.0 | 270.0 | 120.0 | 120.0 | -12.8 | -90.0 | |
| 39.8 | 6.9 | 150.0 | 70.0 | 78.0 | 78.0 | 750.0 | 170.0 | 150.0 | 79.0 | -12.8 | -94.0 | |
| 11.5 | 7.8 | 17.0 | 1.9 | 48.0 | 30.0 | 310.0 | 1.0 | 8.2 | 5.2 | -12.9 | -91.0 | |
| 18.1 | 6.2 | 180.0 | 20.0 | 92.0 | 12.0 | 400.0 | 190.0 | 34.0 | 45.0 | -11.4 | -83.0 | |
| 65.0 | 6.5 | 1850.0 | 190.0 | 330.0 | 64.0 | 1150.0 | 2500.0 | 420.0 | 78.0 | -10.1 | -79.0 | |
| 51.1 | 7.1 | 730.0 | 70.0 | 220.0 | 75.0 | 1200.0 | 640.0 | 460.0 | 57.0 | -11.3 | -82.0 | |
| 37.0 | 7.0 | 610.0 | 170.0 | 200.0 | 30.0 | 1600.0 | 360.0 | 150.0 | 100.0 | -11.4 | -90.0 | |
| 25.8 | 6.1 | 240.0 | 77.0 | 52.0 | 50.0 | 750.0 | 160.0 | 53.0 | 130.0 | -12.2 | -85.0 | |
| 34.3 | 7.6 | 84.0 | 24.0 | 99.0 | 71.0 | 810.0 | 17.0 | 23.0 | 130.0 | -13.5 | -91.0 | |
| 25.1 | 6.7 | 380.0 | 120.0 | 140.0 | 170.0 | 1950.0 | 160.0 | 63.0 | 130.0 | -11.6 | -85.0 | |
| 11.4 | 7.2 | 10.0 | 0.7 | 20.0 | 2.8 | 85.0 | 1.0 | 6.3 | 23.0 | -12.1 | -83.0 | |
| 53.5 | 7.6 | 2600.0 | 170.0 | 180.0 | 69.0 | 5500.0 | 850.0 | 540.0 | 99.0 | -3.4 | -72.0 | |
| 25.4 | 6.7 | 40.0 | 4.3 | 180.0 | 120.0 | 1150.0 | 14.0 | 40.0 | 19.0 | -12.7 | -89.0 | |
| 34.0 | 7.2 | 900.0 | 160.0 | 110.0 | 120.0 | 2100.0 | 560.0 | 260.0 | 31.0 | -10.7 | -82.0 | |
| 46.8 | 9.2 | 210.0 | 4.2 | 20.0 | 1.5 | 210.0 | 140.0 | 110.0 | 31.0 | -10.9 | -72.0 | |
| 16.3 | 6.3 | 140.0 | 26.0 | 390.0 | 190.0 | 1200.0 | 27.0 | 850.0 | 11.0 | -10.7 | -69.0 | |
| 51.6 | 6.9 | 320.0 | 33.0 | 70.0 | 15.0 | 1100.0 | 23.0 | 0.4 | 170.0 | -9.6 | -65.0 | |
| 14.2 | 10.4 | 120.0 | 13.0 | 100.0 | 62.0 | 900.0 | 32.0 | 4.2 | 9.0 | -9.8 | -66.0 | |
| 34.5 | 6.5 | 300.0 | 52.0 | 130.0 | 94.0 | 1550.0 | 47.0 | 0.5 | 120.0 | -10.0 | -69.0 | |

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|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 11.6 | 6.2 | 6.3 | 2.4 | 25.0 | 7.8 | 110.9 | 2.6 | 4.4 | | -10.6 | -65.9 | |
| 29.0 | 6.0 | 970.0 | 77.2 | 218.7 | 177.4 | 1971.7 | 1077.0 | 38.7 | | | | |
| 26.8 | 6.1 | 335.3 | 30.4 | 100.4 | 83.5 | 1139.0 | 208.9 | 15.3 | | -12.5 | -82.5 | |
| 22.5 | 6.2 | 269.1 | 25.8 | 189.5 | 182.7 | 2069.7 | 77.3 | 0.9 | | -12.5 | -78.5 | |
| 28.2 | 5.8 | 269.0 | 31.0 | 115.2 | 118.1 | 1391.9 | 102.9 | 11.9 | | -12.2 | -79.8 | |
| 8.9 | 7.7 | 3.9 | 0.8 | 26.5 | 2.7 | 89.3 | 0.6 | 1.6 | | | | |
| 8.6 | 7.1 | 2.6 | 1.1 | 7.1 | 2.1 | 33.9 | 0.3 | 0.9 | | | | |
| 32.0 | 6.1 | 225.1 | 34.0 | 200.7 | 131.4 | 1688.3 | 37.4 | 20.1 | | -12.5 | -80.4 | Karaoğlu Ö., Bazargan M., Baba A. and Browning J. (2019) Thermal fluid circulation around the Karliova triple junction: Geochemical features and volcano-tectonic implications (Eastern Turkey). Geothermics 81, 168-184. |
| 14.8 | 6.2 | 22.1 | 6.1 | 90.8 | 50.5 | 533.0 | 3.5 | 9.5 | | | | |
| 11.0 | 6.5 | 5.7 | 1.9 | 15.7 | 5.6 | 77.0 | 0.8 | 1.5 | | | | |
| 10.3 | 6.5 | 4.1 | 2.3 | 14.9 | 4.5 | 73.9 | 1.1 | 2.0 | | | | |
| 7.2 | 6.7 | 2.7 | 1.2 | 13.2 | 2.5 | 58.6 | 0.3 | 0.8 | | | | |
| 9.2 | 6.7 | 4.1 | 1.3 | 13.3 | 4.4 | 70.9 | 0.5 | 1.5 | | | | |
| 9.2 | 6.9 | 3.7 | 1.4 | 16.1 | 3.6 | 67.8 | 0.6 | 1.7 | | | | |
| 6.7 | 7.1 | 2.6 | 1.6 | 8.5 | 2.4 | 36.9 | 0.5 | 2.0 | | | | |
| 4.9 | 7.3 | 2.4 | 1.1 | 7.1 | 2.1 | 33.8 | 0.2 | 0.8 | | | | |
| 7.5 | 7.1 | 4.8 | 1.0 | 12.7 | 2.6 | 58.5 | 0.4 | 1.6 | | | | |
| 13.2 | 5.4 | 52.8 | 18.6 | 84.3 | 27.5 | 499.1 | 4.1 | 6.4 | | | | |
| 6.0 | 7.3 | 3.2 | 1.4 | 7.5 | 2.1 | 36.9 | 0.3 | 0.9 | | | | |
| 5.4 | 6.4 | 2.6 | 1.3 | 8.1 | 1.6 | 33.9 | 0.3 | 1.0 | | | | |
| 27.0 | 6.0 | 142.0 | 24.4 | 392.0 | 571.0 | 2928.0 | 117.0 | 1076.0 | 144.0 | -6.1 | -31.6 | |
| 27.2 | 6.3 | 144.0 | 24.2 | 473.0 | 597.0 | 2891.0 | 116.0 | 1211.0 | 135.5 | | | |
| 27.2 | 6.3 | 148.0 | 25.8 | 493.0 | 552.0 | 2902.0 | 131.0 | 1023.0 | 141.0 | -5.7 | -30.0 | |
| 31.5 | 6.4 | 247.0 | 39.9 | 705.0 | 542.0 | 3373.0 | 191.0 | 1695.0 | 152.1 | -6.2 | -33.2 | |
| 22.0 | 6.3 | 42.4 | 7.4 | 172.0 | 573.0 | 3142.0 | 49.1 | 219.0 | 118.4 | -5.7 | -27.4 | YasİN D. and YÜCe G. (2023) Isotope and hydrochemical characteristics of thermal waters along the active fault zone (Erzin-Hatay/Turkey) and their geothermal potential. Turkish Journal of Earth Sciences 32, 721-739. |
| 19.3 | 6.2 | 3.7 | 0.8 | 561.0 | 183.0 | 763.0 | 7.1 | 1287.0 | 40.5 | -6.5 | -32.4 | |
| 19.6 | 6.0 | 7.5 | 1.6 | 548.5 | 167.1 | 781.0 | 12.6 | 1408.0 | 37.7 | -6.2 | -35.0 | |
| 21.3 | 6.2 | 15.6 | 0.6 | 169.0 | 173.0 | 1226.0 | 19.9 | 81.3 | 65.2 | -4.4 | -24.3 | |
| 23.3 | 11.4 | 1353.0 | 69.0 | 57.7 | 0.0 | 390.0 | 1903.0 | 5.8 | 1.9 | -4.3 | -26.0 | |
| | | 12426.0 | 456.0 | 474.0 | 1409.0 | 26.0 | 21576.0 | 3065.0 | | | | |
| 13.0 | 7.1 | 3.2 | 1.2 | 39.3 | 10.6 | 95.0 | 6.3 | 50.0 | 24.0 | -11.7 | -77.0 | |
| 52.0 | 6.3 | 998.0 | 91.2 | 207.0 | 70.5 | 1755.0 | 764.0 | 250.0 | 122.0 | -10.3 | -77.0 | |
| 67.0 | 6.2 | 766.0 | 69.3 | 116.0 | 47.8 | 1342.0 | 593.0 | 225.0 | 120.0 | -11.1 | -80.0 | |
| 64.0 | 6.2 | 1062.0 | 93.6 | 144.0 | 23.7 | 1800.0 | 1026.0 | 245.0 | 79.0 | -10.5 | -79.0 | |
| 59.0 | 6.9 | 220.0 | 105.0 | 110.0 | 53.5 | 1400.0 | 90.0 | 175.0 | 128.0 | -10.2 | -79.0 | |
| 64.0 | 7.0 | 738.0 | 105.0 | 121.0 | 19.0 | 1154.0 | 878.0 | 185.0 | 90.0 | -10.4 | -79.0 | |
| 78.0 | 5.1 | 750.0 | 68.0 | 160.0 | 8.0 | 875.0 | 750.0 | 540.0 | 90.0 | | | Pasvanoglu S. (2020) Geochemistry and conceptual model of thermal waters from Ercis - Zilan Valley, Eastern Turkey. Geothermics 86. |
| 64.0 | 6.3 | 838.0 | 99.0 | 135.0 | 14.0 | 1075.0 | 1075.0 | 250.0 | 90.0 | | | |
| 65.0 | 6.5 | 850.0 | 88.0 | 150.0 | 12.0 | 1000.0 | 950.0 | 208.0 | 80.0 | -10.2 | -80.0 | |
| 65.0 | 6.5 | 875.0 | 86.0 | 150.0 | 12.0 | 1000.0 | 975.0 | 219.0 | 80.0 | | | |
| 20.0 | 6.4 | 71.0 | 8.4 | 32.0 | 12.0 | 252.0 | 15.6 | 62.0 | 27.0 | | | |
| 80.0 | 7.9 | 830.0 | 74.0 | 96.0 | 56.0 | 994.0 | 715.0 | 565.0 | 109.0 | | | |
| 92.0 | 7.5 | 773.0 | 110.0 | 36.9 | 54.6 | 897.0 | 543.0 | 470.0 | 95.0 | | | |
| 98.0 | 7.7 | 858.0 | 108.0 | 29.5 | 47.0 | 779.0 | 560.0 | 491.0 | 118.0 | | | |
| 14.0 | 8.0 | 20.0 | 3.2 | 17.0 | 9.7 | 80.0 | 13.0 | 48.0 | 15.0 | -11.9 | -84.0 | |

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|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 37.1 | 7.1 | 270.6 | 51.4 | 592.9 | 104.0 | 2593.4 | 131.0 | 174.5 | | | | |
| 38.4 | 6.6 | 285.5 | 58.4 | 591.8 | 106.2 | 2635.7 | 155.0 | 178.8 | | | | |
| 37.8 | 6.5 | 280.7 | 52.2 | 615.4 | 103.4 | 2676.8 | 134.0 | 176.8 | | | | |
| 24.5 | 6.2 | 22.0 | 3.6 | 191.7 | 24.7 | 577.6 | 8.0 | 119.3 | | | | |
| 29.4 | 6.3 | 192.8 | 45.6 | 406.7 | 69.4 | 1731.4 | 110.0 | 130.0 | | | | |
| 44.5 | 6.5 | 323.2 | 88.7 | 573.7 | 114.1 | 2523.1 | 260.0 | 199.4 | | | | |
| 44.6 | 6.5 | 340.6 | 69.5 | 629.4 | 114.9 | 2857.9 | 200.0 | 191.8 | | | | |
| 30.7 | 6.3 | 163.8 | 41.3 | 321.9 | 62.1 | 1416.9 | 99.0 | 117.3 | | | | |
| 19.0 | 6.4 | 387.1 | 56.4 | 140.0 | 132.5 | 1769.0 | 166.0 | 107.2 | | | | |
| 13.1 | 5.8 | 13.4 | 1.7 | 99.3 | 8.6 | 345.1 | 8.0 | 8.0 | | | | |
| 14.5 | 5.9 | 21.7 | 3.2 | 90.4 | 15.6 | 369.8 | 12.0 | 11.0 | | | | |
| 13.2 | 6.1 | 19.6 | 3.3 | 106.4 | 10.2 | 392.9 | 10.0 | 8.0 | | | | |
| 12.6 | 6.0 | 20.5 | 2.0 | 57.9 | 11.0 | 240.4 | 18.0 | 7.8 | | | | |
| 12.8 | 6.8 | 52.7 | 4.1 | 106.6 | 21.3 | 512.3 | 15.0 | 23.5 | | | | Öztekin Okan Ö., Kalender L. and Çetindağ B. (2018) Trace-element hydrogeochemistry of thermal waters of Karakoçan (Elazığ) and Mazgirt (Tunceli), Eastern Anatolia, Turkey. Journal of Geochemical Exploration 194, 29-43. |
| 11.3 | 6.0 | 27.0 | 4.2 | 147.5 | 10.0 | 522.7 | 13.0 | 17.5 | | | | |
| 14.3 | 6.1 | 32.1 | 6.3 | 123.0 | 15.3 | 488.7 | 14.0 | 14.1 | | | | |
| 12.0 | 6.4 | 9.9 | 1.9 | 98.6 | 13.6 | 356.3 | 5.0 | 13.8 | | | | |
| 37.7 | 6.2 | 254.2 | 62.6 | 514.5 | 105.1 | 2349.2 | 156.0 | 180.7 | | | | |
| 38.0 | 6.7 | 288.7 | 74.5 | 584.5 | 116.5 | 2731.6 | 136.0 | 178.5 | | | | |
| 38.0 | 6.8 | 257.7 | 62.9 | 370.2 | 107.4 | 1930.0 | 146.0 | 178.0 | | | | |
| 24.7 | 6.8 | 20.1 | 3.3 | 176.3 | 25.1 | 531.5 | 7.0 | 119.0 | | | | |
| 27.9 | 6.2 | 198.4 | 43.2 | 342.0 | 72.5 | 1599.5 | 92.0 | 131.4 | | | | |
| 45.0 | 6.5 | 351.0 | 84.4 | 607.5 | 118.4 | 2925.2 | 141.0 | 192.2 | | | | |
| 44.4 | 6.5 | 344.8 | 81.3 | 600.1 | 117.4 | 2852.5 | 135.0 | 193.7 | | | | |
| 30.0 | 6.4 | 172.2 | 37.4 | 315.7 | 64.7 | 1449.0 | 98.0 | 121.2 | | | | |
| 19.5 | 6.4 | 417.1 | 63.6 | 595.1 | 157.9 | 3329.6 | 121.0 | 105.0 | | | | |
| 14.6 | 6.4 | 10.9 | 1.6 | 97.3 | 8.7 | 338.3 | 7.0 | 8.5 | | | | |
| 15.2 | 6.5 | 20.5 | 3.0 | 92.5 | 16.3 | 378.3 | 11.0 | 11.0 | | | | |
| 13.3 | 6.5 | 12.7 | 3.8 | 103.0 | 9.2 | 375.7 | 6.0 | 4.9 | | | | |
| 13.8 | 5.9 | 21.1 | 1.8 | 56.9 | 11.5 | 240.8 | 15.0 | 12.0 | | | | |
| 18.1 | 6.7 | 45.9 | 2.8 | 104.8 | 21.8 | 481.8 | 13.0 | 19.0 | | | | |
| 15.1 | 6.2 | 21.2 | 5.0 | 148.8 | 9.8 | 522.7 | 9.0 | 10.0 | | | | |
| 16.7 | 7.1 | 71.8 | 7.3 | 128.3 | 14.5 | 609.9 | 11.0 | 14.0 | | | | |
| 12.8 | 6.3 | 16.1 | 1.7 | 103.0 | 14.9 | 402.8 | 8.0 | 6.3 | | | | |
| | | | | | | | | | | | | |
| 14.5 | 10.5 | 3.5 | 0.3 | 14.9 | 1.7 | 1.8 | 12.0 | 0.0 | 1.5 | -6.8 | -48.2 | |
| 22.5 | 11.7 | 77.2 | 2.7 | 66.9 | 0.0 | 0.0 | 66.9 | 0.0 | 0.2 | -7.9 | -45.4 | |
| 27.8 | 8.2 | 12.5 | 3.9 | 45.6 | 24.2 | 303.8 | 5.9 | 9.9 | 15.3 | -9.4 | -57.8 | |
| 15.9 | 7.6 | 14.1 | 2.2 | 63.8 | 15.7 | 285.5 | 5.3 | 24.8 | 8.4 | -7.4 | -42.0 | |
| 29.0 | 7.2 | 87.5 | 8.4 | 81.0 | 18.1 | 336.7 | 126.8 | 54.7 | 11.3 | | | |
| 23.8 | 7.4 | 6.5 | 0.9 | 7.0 | 110.0 | 358.1 | 8.0 | 11.1 | 15.6 | -5.8 | -33.7 | |
| 18.3 | 7.4 | 6.5 | 1.0 | 116.0 | 8.0 | 367.2 | 8.5 | 10.2 | 17.2 | | | |
| 41.0 | 7.4 | 56.2 | 6.3 | 67.7 | 11.3 | 245.8 | 45.2 | 84.1 | 12.9 | -7.4 | -47.9 | Baba A., Şaroğlu F., Akkuş I., Özel N., Yeşilnacar M. İ., Nalbantçılar M. T., Demir M. M., Gökçen G., Arslan Ş., Dursun N., Uzelli T. and Yazdani H. (2019) Geological and hydrogeochemical properties of geothermal systems in the southeastern region of Turkey. Geothermics 78, 255-271. |
| 51.0 | 7.3 | 195.5 | 20.2 | 38.7 | 5.6 | 472.8 | 113.4 | 3.3 | 19.4 | -10.3 | -63.2 | |
| 84.5 | 6.2 | 2756.1 | 81.9 | 773.6 | 124.7 | 384.3 | 6571.5 | 1287.2 | | -9.5 | -59.8 | |
| 33.1 | 6.4 | 120.5 | 13.8 | 286.9 | 46.4 | 446.5 | 196.8 | 689.2 | 12.9 | -7.9 | -48.2 | |
| 15.2 | 7.0 | 17.2 | 2.6 | 73.2 | 10.8 | 196.4 | 21.8 | 83.8 | 5.4 | -9.7 | -59.6 | |
| 33.7 | 6.5 | 124.1 | 14.5 | 288.3 | 49.1 | 452.6 | 188.9 | 602.2 | 13.5 | -7.4 | -50.7 | |
| 56.6 | 6.6 | 67.1 | 18.0 | 350.3 | 48.3 | 241.6 | 71.7 | 1015.4 | | -8.9 | -57.7 | |
| 62.2 | 6.8 | 68.4 | 18.1 | 361.3 | 52.5 | 242.2 | 77.1 | 1062.2 | | -9.1 | -58.0 | |
| 8.6 | 8.1 | 0.6 | 0.2 | 44.3 | 13.5 | 205.6 | 0.6 | 7.1 | 2.1 | -9.0 | -53.0 | |
| 44.0 | 6.8 | 169.7 | 13.1 | 130.0 | 17.1 | 429.4 | 257.8 | 65.3 | 18.0 | -9.5 | -57.9 | |
| 9.0 | 7.9 | 7.1 | 1.0 | 44.2 | 4.6 | 178.7 | 3.7 | 9.3 | 2.6 | | | |
| 21.1 | 7.2 | 26.0 | 2.9 | 101.3 | 24.0 | 342.8 | 32.8 | 85.1 | 8.9 | -9.4 | -56.9 | |
| 20.0 | 9.0 | 450.0 | 16.0 | 4.1 | 0.0 | 565.5 | 301.6 | 17.0 | 7.1 | | | |
| 22.7 | 8.0 | 278.5 | 12.7 | 12.5 | 7.7 | 464.2 | 190.6 | 4.2 | 7.0 | | | |
| 26.5 | 7.2 | 65.9 | 5.6 | 145.0 | 40.2 | 230.0 | 41.9 | 479.2 | 12.4 | | | |
| 27.3 | 7.2 | 68.1 | 5.3 | 151.9 | 43.5 | 249.5 | 39.3 | 501.1 | 12.5 | | | |
| 35.0 | 7.3 | 33.6 | 3.0 | 39.9 | 25.6 | 328.2 | 11.9 | 1.8 | 13.9 | | | |
| 34.8 | 7.0 | 17.4 | 2.6 | 56.0 | 15.2 | 281.9 | 8.9 | 16.4 | 14.2 | | | |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 20.0 | 7.2 | 13.3 | 2.6 | 67.7 | 31.0 | 311.0 | 23.3 | 40.1 | 26.7 | -6.4 | -31.1 | |
| 21.0 | 7.5 | 11.9 | 0.9 | 59.3 | 27.4 | 268.0 | 24.1 | 32.0 | 20.2 | -6.5 | -31.3 | |
| 21.0 | 7.2 | 42.6 | 1.0 | 55.0 | 106.0 | 580.0 | 60.8 | 89.9 | 32.3 | -6.1 | -29.8 | |
| 22.1 | 7.6 | 15.5 | 0.7 | 58.5 | 29.5 | 293.0 | 23.5 | 15.8 | 43.1 | -5.6 | -26.3 | |
| 22.6 | 7.4 | 16.0 | 1.3 | 60.7 | 37.1 | 329.0 | 25.2 | 37.2 | 28.8 | -6.4 | -31.7 | |
| 23.3 | 7.1 | 33.6 | 4.3 | 129.0 | 38.8 | 348.0 | 50.0 | 176.0 | 20.6 | -6.0 | -32.5 | |
| 29.0 | 7.3 | 24.8 | 4.7 | 94.3 | 30.2 | 305.0 | 39.3 | 78.5 | 20.7 | -6.7 | -36.6 | |
| 37.7 | 6.6 | 315.0 | 29.6 | 166.0 | 40.6 | 458.0 | 411.0 | 376.0 | 40.0 | -7.0 | -39.5 | |
| 25.8 | 6.9 | 27.2 | 1.3 | 87.2 | 18.4 | 317.0 | 36.5 | 27.8 | 27.2 | -6.8 | -36.7 | |
| 30.3 | 9.0 | 257.0 | 1.0 | 28.1 | 0.2 | 36.6 | 178.0 | 335.0 | 29.2 | -7.1 | -37.1 | |
| 28.9 | 7.1 | 28.5 | 3.6 | 87.1 | 66.0 | 390.0 | 47.1 | 101.0 | 45.4 | -6.8 | -35.5 | |
| 31.2 | 6.9 | 80.1 | 9.8 | 133.0 | 67.8 | 253.0 | 59.2 | 469.0 | 69.1 | -6.6 | -34.8 | |
| 22.0 | 7.3 | 21.6 | 0.2 | 58.4 | 45.0 | 296.0 | 18.6 | 104.0 | 46.3 | -6.8 | -36.1 | |
| 23.1 | 6.9 | 10.2 | 1.9 | 72.6 | 32.4 | 268.0 | 12.4 | 88.3 | 23.5 | -7.3 | -39.4 | |
| 16.3 | 7.1 | 5.7 | 0.6 | 67.4 | 16.7 | 262.0 | 9.9 | 6.7 | 16.2 | -7.2 | -36.1 | Yuce G., Italiano F., D'Alessandro W., Yalcin T. H., Yasin D. U., Gulbay A. H., Ozyurt N. N., Rojay B., Karabacak V., Bellomo S., Brusca L., Yang T., Fu C. C., Lai C. W., Ozacar A. and Walia V. (2014) Origin and interactions of fluids circulating over the Amik Basin (Hatay, Turkey) and relationships with the hydrologic, geologic and tectonic settings. Chemical Geology 388, 23-39. |
| 19.7 | 7.1 | 28.3 | 0.6 | 77.2 | 47.3 | 400.0 | 43.4 | 33.6 | 54.8 | -6.4 | -31.2 | |
| 22.5 | 7.4 | 105.0 | 2.2 | 29.1 | 86.6 | 403.0 | 73.5 | 184.0 | 9.5 | -4.6 | -23.6 | |
| 20.2 | | 13.8 | 2.2 | 73.9 | 33.1 | 323.0 | 23.1 | 40.3 | 25.6 | -5.9 | -27.8 | |
| 20.4 | | 12.0 | 0.9 | 61.4 | 30.5 | 262.0 | 21.5 | 31.7 | 20.0 | -5.9 | -28.8 | |
| 19.6 | | 41.5 | 0.7 | 57.8 | 105.0 | 555.0 | 53.2 | 77.3 | 31.6 | -5.9 | -29.3 | |
| 38.0 | 6.7 | 315.0 | 28.9 | 131.0 | 48.0 | 445.0 | 354.0 | 353.0 | 39.0 | -6.7 | -38.9 | |
| 22.5 | 7.2 | 11.3 | 1.8 | 87.8 | 34.4 | 323.0 | 11.9 | 86.7 | 24.7 | -6.8 | -37.0 | |
| 21.8 | 6.9 | 21.2 | 1.4 | 94.6 | 31.9 | 348.0 | 40.4 | 38.8 | 32.0 | -6.3 | -33.2 | |
| 22.1 | 7.3 | 9.7 | 1.3 | 80.6 | 31.2 | 323.0 | 9.0 | 64.3 | 21.0 | -7.2 | -38.0 | |
| 37.6 | 7.5 | 276.0 | 5.4 | 41.1 | 10.3 | 91.5 | 231.0 | 361.0 | 29.2 | -7.2 | -36.2 | |
| 42.8 | 7.3 | 10100.0 | 68.2 | 1030.0 | 224.0 | 67.1 | 17600.0 | 18.6 | 18.4 | -1.8 | -8.5 | |
| 32.6 | 8.0 | 2960.0 | 19.2 | 81.7 | 25.2 | 146.0 | 4640.0 | 8.0 | 21.3 | -4.5 | -25.1 | |
| 42.3 | 7.3 | 10100.0 | 50.2 | 1220.0 | 278.0 | 73.2 | 18800.0 | 0.2 | 20.3 | -1.2 | -7.9 | |
| 28.8 | | 2980.0 | 13.0 | 102.0 | 30.6 | 177.0 | 4780.0 | 0.5 | 21.9 | -4.3 | -25.9 | |
| 26.8 | 7.9 | 11000.0 | 57.5 | 1020.0 | 360.0 | 97.6 | 19900.0 | 0.5 | 15.2 | -1.0 | -8.0 | |
| 33.7 | 10.6 | 49.9 | 1.8 | 44.7 | 0.1 | 183.0 | 47.6 | 0.2 | 0.2 | -8.7 | -45.0 | |
| 25.5 | 11.6 | 28.6 | 0.9 | 83.4 | 0.8 | 244.0 | 45.8 | 0.0 | 0.2 | -7.9 | -40.2 | |
| 33.0 | 11.6 | 50.3 | 2.1 | 42.1 | 0.4 | 177.0 | 44.5 | 0.0 | 0.2 | -8.1 | -42.1 | |
| 21.7 | 12.2 | 55.0 | 1.2 | 110.0 | 0.1 | 336.0 | 72.1 | 0.2 | 0.2 | -7.9 | -41.3 | |
| | 6.3 | 0.8 | 0.2 | 3.6 | 0.2 | 13.0 | 1.6 | 4.4 | | -7.4 | -40.0 | |
| | 6.5 | 0.7 | 0.4 | 2.1 | 0.2 | 11.0 | 1.4 | 2.5 | | -7.7 | -42.0 | |
| | 6.7 | 0.7 | 0.3 | 2.3 | 0.2 | 5.0 | 1.4 | 3.8 | | -8.2 | -46.0 | |
| | | 2.3 | 0.3 | 5.1 | 0.5 | 9.0 | 4.5 | 5.9 | | -4.5 | -16.7 | |
| | | 2.2 | 0.4 | 3.9 | 0.4 | 15.0 | 4.2 | 4.1 | | -4.5 | -18.7 | |
| | | 2.4 | 0.3 | 3.3 | 0.4 | 7.0 | 4.3 | 4.8 | | -6.1 | -28.3 | |