

**Seawater-Fluid Composition Records from Molybdenum Isotopes of Sequentially  
Extracted Phases of Seep Carbonate Rocks**

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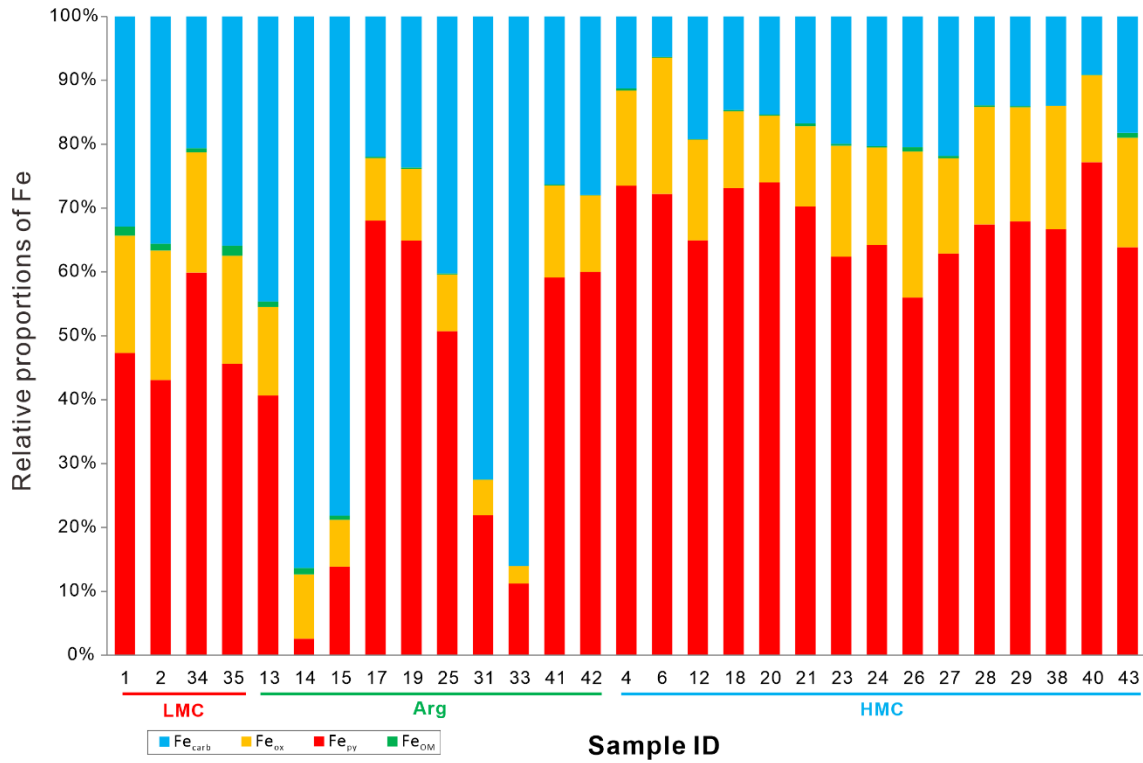
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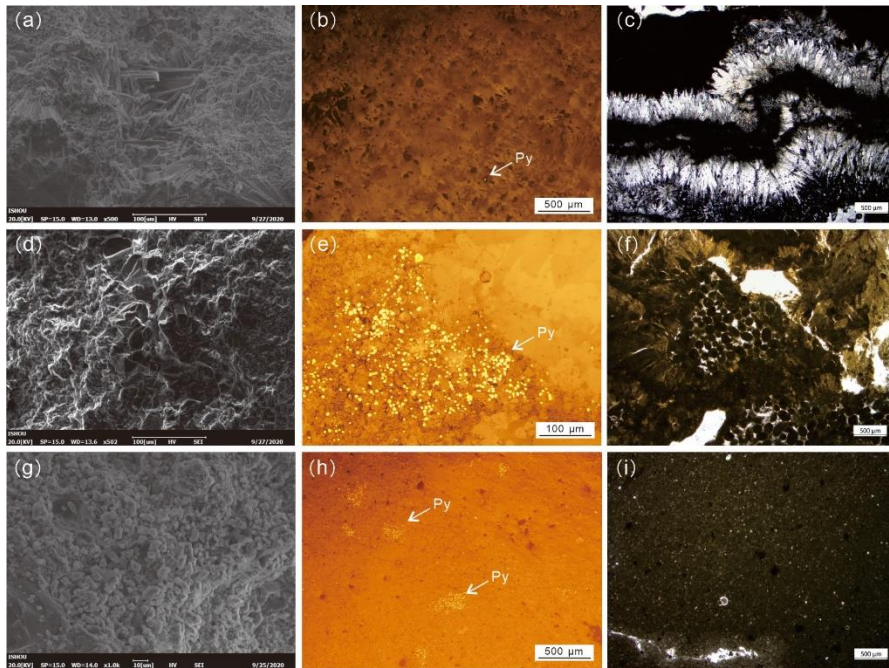
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**Introduction**

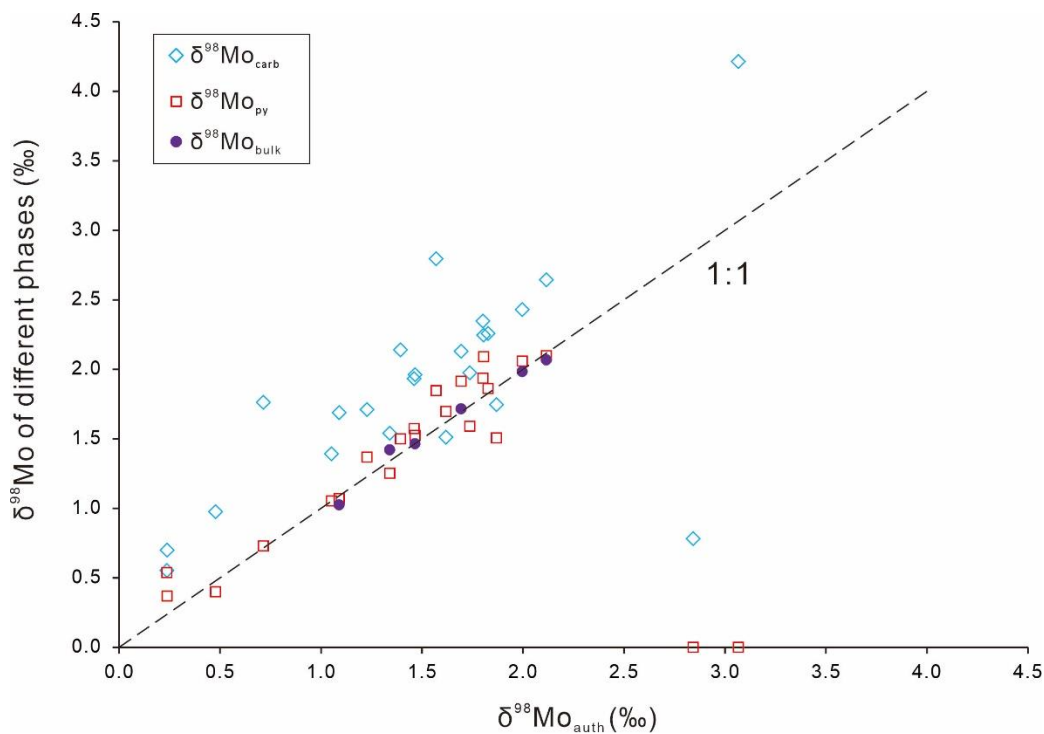
The supporting information includes three figures and three tables.



**Figure S1.** Relative proportions of iron (Fe) species in seep carbonate rocks. Fe<sub>carb</sub>, Fe<sub>ox</sub>, Fe<sub>py</sub>, Fe<sub>OM</sub> correspond to Fe in carbonate, Fe-oxides, pyrite, and organic matter, respectively. The LMC, Arg, and HMC refer to low-magnesium calcite, aragonite, and high-magnesium calcite, respectively.



**Figure S2.** Thin section photomicrographs and SEM photographs of the studied carbonates containing pyrite (Py). (a-c) aragonitic carbonate (ID 25); (d-f) low-Mg calcite carbonate (ID 34); (g-i) high-Mg calcite carbonate (ID 43). Graphs a, d, and g represents SEM photographs, all other images are thin section photomicrographs.



**Figure S3.**  $\delta^{98}\text{Mo}$  values of different phases of samples, including carbonate ( $\delta^{98}\text{Mo}_{\text{carb}}$ ), pyrite ( $\delta^{98}\text{Mo}_{\text{py}}$ ), bulk-rock ( $\delta^{98}\text{Mo}_{\text{bulk}}$ ), and authigenic phase ( $\delta^{98}\text{Mo}_{\text{auth}}$ ).

**Table S1.** Exchangeable Mo ( $\text{Mo}_{\text{ex}}$ ) contents and proportion relative to carbonate-bound Mo ( $\text{Mo}_{\text{carb}}$ ). Exchangeable Mo was extracted by washing samples with 1 M  $\text{MgCl}_2$  (pH=8) for 0.5 h.

Sample ID	$\text{Mo}_{\text{ex}}$ ( $\mu\text{g/g}$ )	$\text{Mo}_{\text{carb}}$ ( $\mu\text{g/g}$ )	$\text{Mo}_{\text{ex}}/\text{Mo}_{\text{carb}}$ (%)
1	0.01	0.07	14
15	0.02	0.30	7
17	0.03	0.18	17
19	0.03	0.33	9
21	0.09	0.52	17
27	0.01	0.73	1
31	0.02	0.20	10
35	0.04	0.27	15
41	0.04	0.21	19

**Table S2.** Mineral compositions of seep carbonate rocks in this study.

Sample ID	Qz (%)	Ab (%)	Chl (%)	LMC (%)	Dol (%)	Arg (%)	NaCl (%)	HMC (%)	Carbonate contents (%)
1	2.5	0	0	97.5	0	0	0	0	98
2	2.8	0	0	97.2	0	0	0	0	97
4	15.6	9.6	6.6	0	0	0	0	68.1	68
6	10.2	8.8	0	0	0	0	0	81.0	81
12	9.2	0	0	0	7.5	7.6	0	75.7	91
13	9.9	0	0	3.5	0	83.6	0	3.0	90
14	5.4	0	0	8.2	0	84.8	1.5	0	93
15	0	0	0	9.0	0	90.3	0.8	0	99
16	0	0	0	0	0	98.0	2.0	0	98
17	7.1	0	0	2.0	13.5	76.7	0.7	0	92
18	4.5	0	0	0	0	0	0	95.5	96
19	10.3	0	0	0	0	81.3	0	8.4	90
20	4.7	0	0	0	0	0	0	95.3	95
21	4.9	4.1	0	0	0	0	0	91.1	91
23	4.5	0	0	0	0	0	0	95.5	96
24	5.5	0	0	0	0	33.8	0	60.7	95
25	6.7	0	0	3.4	0	85.9	0	4.0	93
26	3.3	0	0	0	0	0	0	96.7	97
27	4.2	0	0	0	19.1	0	0	76.7	96
28	4.6	0	0	0	18.5	0	0	76.9	95
29	7.4	0	0	0	1.8	0	0	90.8	93
31	0	0	0	4.6	0	95.4	0	0	100
33	0	0	0	0	0	100	0	0	100
34	4.6	0	0	95.4	0	0	0	0	95
35	5.0	0	0	93.5	1.5	0	0	0	95
38	16.2	6.2	7.7	0	0	18.1	0	51.9	70
40	19.0	9.9	7.8	0	0	0	0	63.4	63
41	13.3	2.8	5.2	2.7	0	75.9	0	0	79
42	12.6	10.3	4.6	14.0	0	58.5	0	0	73
43	17.1	9.6	7	0	0	0	0	66.3	66

Notes: Qz, Ab, Chl, LMC, Dol, Arg, and HMC refer to quartz, albite, chlorite, low-magnesium calcite, dolomite, aragonite, and high-magnesium calcite, respectively.

**Table S3.** Total organic carbon (TOC), pyrite sulfur ( $S_{py}$ ), and manganese (Mn) contents of seep carbonate rocks and molybdenum (Mo) and iron (Fe) contents of different phases of seep carbonate rocks.

Sample ID	TOC (%)	$S_{py}$ (%)	Mo <sub>auth</sub> (µg/g)	Mo <sub>carb</sub> (µg/g)	Mo <sub>ox</sub> (µg/g)	Mo <sub>py</sub> (µg/g)	Mo <sub>OM</sub> (µg/g)	Mn <sub>auth</sub> (µg/g)	Fe <sub>auth</sub> (µg/g)	Fe <sub>carb</sub> (µg/g)	Fe <sub>ox</sub> (µg/g)	Fe <sub>py</sub> (µg/g)	Fe <sub>OM</sub> (µg/g)
1	2.03	0.14	1.42	0.07	0.03	1.21	0.19	352	9030	1460	816	2100	62.1
2	1.88	0.03	3.50	0.22	0.12	3.16	0.34	231	8410	1520	866	1840	44.8
4	0.40	0.03	1.00	0.05	0.02	0.71	0.04	432	17400	1750	2310	11400	51.6
6	0.35	0.02	2.52	0.07	0.07	1.82	0.10	2060	18400	982	3310	11200	14.6
12	n.d.	n.d.	4.91	0.19	0.06	4.08	0.09	370	10300	1750	1440	5920	8.05
13	1.52	0.09	1.05	0.05	0.02	0.63	0.09	65.5	7860	1470	456	1340	28.9
14	2.61	0.19	0.47	0.22	0.04	0.04	0.04	71.3	3570	1480	173	44.4	17.1

15	5.71	0.28	0.77	0.30	0.05	0.35	0.07	97.4	2780	1470	138	261	12.3
16	n.d.	n.d.	0.18	0.15	0.02	0.04	0.00	9.11	1550	1300	20.7	46.5	n.d.
17	13.30	0.54	0.85	0.18	0.04	0.62	0.03	218	6310	1200	534	3720	11.2
18	1.45	1.82	10.20	0.88	0.52	7.13	0.30	156	9550	1200	987	6000	17.9
19	n.d.	n.d.	1.95	0.33	0.07	1.37	0.05	128	6540	1400	667	3840	10.7
20	3.11	0.56	9.29	0.40	0.26	6.87	0.29	75	8820	1140	776	5500	14.8
21	2.41	0.78	7.75	0.52	0.34	5.19	0.31	68.3	8840	1120	842	4690	26.5
23	1.51	1.64	5.54	0.28	0.20	3.80	0.21	206	8390	1390	1210	4350	22
24	n.d.	n.d.	7.95	0.71	0.52	4.94	0.20	142	9040	1450	1090	4590	17.3
25	1.80	0.15	0.66	0.21	0.05	0.38	0.02	70.6	4150	1380	305	1740	5.35
26	n.d.	n.d.	28.4	1.33	1.45	23.40	1.57	298	11200	1500	1680	4110	52.6
27	0.98	3.04	5.23	0.73	0.34	4.83	0.24	255	12400	1740	1190	5010	29.3
28	0.92	2.18	8.55	0.58	0.57	5.34	0.27	767	13200	1460	1930	7080	25.7
29	0.86	0.07	0.56	0.09	0.02	0.36	0.03	199	11400	1360	1730	6570	13.7
31	n.d.	n.d.	0.54	0.20	0.05	0.19	0.01	10.5	2260	1380	105	418	1.49
33	n.d.	n.d.	0.29	0.15	0.02	0.10	0.00	6.55	1760	1310	41.6	171	0.56
34	2.10	0.88	6.19	0.29	0.33	5.84	0.39	759	11300	1490	1360	4330	47.7
35	5.79	0.10	2.01	0.27	0.12	1.63	0.22	367	7660	1400	660	1780	61.9
38	0.58	0.99	14.10	0.47	0.78	9.77	0.33	225	21100	2720	3750	13000	10.2
40	0.60	1.18	7.22	1.05	0.49	3.89	0.18	285	19200	1540	2290	13000	16.9
41	1.81	0.12	1.14	0.21	0.07	0.68	0.03	88.5	9340	2170	1190	4880	12.1
42	1.30	0.05	0.31	0.07	0.03	0.15	0.01	69.5	6400	1640	702	3520	4.2
43	0.69	1.22	14.20	4.26	1.23	7.00	0.86	303	18700	1850	1740	6490	79.4

Notes:  $Mo_{auth}$ ,  $Mo_{carb}$ ,  $Mo_{ox}$ ,  $Mo_{py}$ , and  $Mo_{OM}$  refer to Mo contents of total authigenic, carbonate, Fe-Mn oxide, pyrite, and organic matter fractions of seep carbonate rocks, respectively.  $Mn_{auth}$  indicates Mn contents of total authigenic fraction of seep carbonate rocks.  $Fe_{auth}$ ,  $Fe_{carb}$ ,  $Fe_{ox}$ ,  $Mo_{py}$ , and  $Mo_{OM}$  refer to Fe contents of total authigenic, carbonate, Fe oxide, pyrite, and organic matter fractions of seep carbonate rocks, respectively. n.d.: no data.