Ao Su, Honghan Chen, Yue-xing Feng, and Jian-xin Zhao, 2021, LA-ICP-MS U-Pb dating and geochemical characterization of oil inclusion-bearing calcite cements: Constraints on primary oil migration in lacustrine mudstone source rocks: GSA Bulletin, <https://doi.org/10.1130/B35804.1>.

Supplemental Material

Table S1. LA-ICP-MS U-Pb contents (ppm), and $^{238}\text{U}/^{206}\text{Pb}$ - $^{207}\text{Pb}/^{206}\text{Pb}$ ratios of the microcrystalline-granular calcite (MGC) and blocky calcite (BC) in vein samples FSX1-1 and FSX1-2.

Table S2. LA-ICP-MS rare earth element (REE) data (ppm) for calcite cements in vein samples FSX1-1 and FSX1-2. BC: Block calcite; MGC: microcrystalline-granular calcite; REE concentrations are normalized to PAAS.

Table S1. LA-ICP-MS U-Pb contents (ppm), and $^{238}\text{U}/^{206}\text{Pb}$ - $^{207}\text{Pb}/^{206}\text{Pb}$ ratios of the microcrystalline-granular calcite (MGC) and blocky calcite (BC) in vein samples FSX1-1 and FSX1-2.

Sample Spot No.	$^{238}\text{U}/^{206}\text{Pb}$	2 σ %	$^{207}\text{Pb}/^{206}\text{Pb}$	2 σ %	Approx_U/ppm	Approx_Pb/ppm
FSX1-1-MGC-1	18.874834	2.463180	0.695000	0.022000	0.16	0.04
FSX1-1-MGC-2	9.282473	1.316171	0.775300	0.008600	0.34	0.17
FSX1-1-MGC-3	18.564941	3.602154	0.703000	0.019000	0.34	0.08
FSX1-1-MGC-4	35.845854	4.441994	0.569000	0.025000	0.14	0.01
FSX1-1-MGC-5	27.217755	3.930791	0.637000	0.023000	0.20	0.03
FSX1-1-MGC-6	11.570710	1.044055	0.759700	0.008500	0.39	0.15
FSX1-1-MGC-7	15.150445	1.550106	0.732000	0.010000	0.31	0.09
FSX1-1-MGC-8	34.455713	4.485924	0.582000	0.024000	0.35	0.04
FSX1-1-MGC-9	30.788404	2.895938	0.611000	0.019000	0.17	0.02
FSX1-1-MGC-10	4.160038	0.584353	0.818400	0.004800	0.31	0.35
FSX1-1-MGC-11	38.870353	4.008505	0.557000	0.024000	0.20	0.02
FSX1-1-MGC-12	34.647664	2.798837	0.589000	0.024000	1.13	0.12
FSX1-1-MGC-13	23.468887	2.789698	0.675000	0.020000	0.24	0.04
FSX1-1-MGC-14	46.068570	3.753735	0.510000	0.023000	0.66	0.05
FSX1-1-MGC-15	25.967672	3.361160	0.659000	0.021000	0.42	0.06
FSX1-1-MGC-16	41.880510	3.102261	0.546000	0.020000	0.20	0.02
FSX1-1-MGC-17	14.807751	1.939111	0.743000	0.012000	0.15	0.05
FSX1-1-MGC-18	50.769445	4.351666	0.488000	0.024000	0.18	0.01
FSX1-1-MGC-19	27.458092	2.485169	0.655000	0.016000	1.11	0.16
FSX1-1-MGC-20	38.038266	3.024449	0.580000	0.019000	0.27	0.03
FSX1-1-MGC-21	34.841767	2.635091	0.604000	0.019000	0.43	0.05
FSX1-1-MGC-22	30.712380	2.881655	0.634000	0.023000	1.17	0.15
FSX1-1-MGC-23	55.778085	4.002016	0.458000	0.022000	0.19	0.01
FSX1-1-MGC-24	49.953864	4.614213	0.501000	0.024000	0.21	0.01
FSX1-1-MGC-25	48.970525	2.891960	0.509000	0.017000	0.26	0.02
FSX1-1-MGC-26	54.080490	3.056723	0.474000	0.020000	0.25	0.01
FSX1-1-MGC-27	61.273458	4.829435	0.425000	0.024000	0.18	0.01
FSX1-1-MGC-28	51.827141	3.455143	0.495000	0.022000	0.20	0.01
FSX1-1-MGC-29	43.189278	6.598362	0.555000	0.030000	0.26	0.02
FSX1-1-MGC-30	62.192564	4.042517	0.426000	0.020000	0.19	0.01
FSX1-1-MGC-31	38.628921	4.558693	0.589000	0.026000	0.17	0.02
FSX1-1-MGC-32	36.476573	2.995144	0.607000	0.021000	0.24	0.02
FSX1-1-MGC-33	61.152966	2.465361	0.444000	0.015000	0.20	0.01
FSX1-1-MGC-34	50.034241	1.610112	0.521000	0.012000	0.51	0.03
FSX1-1-MGC-35	50.977516	5.432030	0.516000	0.021000	0.32	0.02
FSX1-1-MGC-36	61.062899	1.738659	0.450000	0.012000	0.25	0.01
FSX1-1-MGC-37	58.042529	2.112607	0.473000	0.014000	0.25	0.01
FSX1-1-MGC-38	5.097752	0.752127	0.818000	0.004600	0.23	0.22
FSX1-1-MGC-39	4.916408	0.466379	0.820900	0.003600	0.81	0.79
FSX1-1-MGC-40	3.803827	0.337342	0.830500	0.003500	0.34	0.44
FSX1-1-MGC-41	3.615847	0.252268	0.832900	0.002500	0.65	0.89
FSX1-1-MGC-42	7.448211	1.115002	0.828000	0.015000	0.23	0.15

FSX1-1-BC-1	27.397260	1.801464	0.669000	0.032000	0.50	0.05
FSX1-1-BC-2	50.251260	3.787783	0.520000	0.053000	0.20	0.01
FSX1-1-BC-3	59.171600	4.901789	0.584000	0.075000	0.28	0.01
FSX1-1-BC-4	34.965030	3.667661	0.688000	0.081000	0.21	0.02
FSX1-1-BC-5	32.894740	3.029778	0.654000	0.054000	0.24	0.02
FSX1-1-BC-6	10.638300	1.244907	0.781000	0.022000	0.53	0.17
FSX1-1-BC-7	2.604167	0.325521	0.838000	0.015000	0.44	0.65
FSX1-1-BC-8	4.739336	0.404304	0.835000	0.022000	0.26	0.19
FSX1-1-BC-9	8.000000	0.896000	0.802000	0.031000	0.32	0.14
FSX1-1-BC-10	46.296300	3.858025	0.577000	0.060000	0.23	0.01
FSX1-1-BC-11	38.610040	5.813867	0.648000	0.061000	0.25	0.02
FSX1-1-BC-12	3.717472	0.207294	0.844000	0.016000	0.42	0.45
FSX1-1-BC-13	3.215434	0.279153	0.853000	0.013000	0.66	0.80
FSX1-1-BC-14	2.890173	0.300712	0.867000	0.022000	0.23	0.32
FSX1-1-BC-15	4.132231	0.239055	0.832000	0.013000	0.83	0.74
FSX1-1-BC-16	6.329114	0.400577	0.823000	0.017000	0.88	0.53
FSX1-1-BC-17	1.510574	0.177983	0.859000	0.012000	0.47	1.16
FSX1-1-BC-18	17.271160	0.894879	0.730000	0.021000	0.97	0.20
FSX1-1-BC-19	7.299270	0.532793	0.825000	0.024000	0.32	0.16
FSX1-1-BC-20	46.948360	6.392030	0.599000	0.089000	0.17	0.01
FSX1-1-BC-21	38.167940	4.516054	0.615000	0.050000	0.43	0.03
FSX1-1-BC-22	55.555560	4.320988	0.511000	0.075000	0.20	0.01
FSX1-1-BC-23	43.668120	3.623119	0.574000	0.045000	0.29	0.01
FSX1-1-BC-24	40.160640	4.193481	0.705000	0.085000	0.25	0.02
FSX1-1-BC-25	55.555560	4.938272	0.623000	0.075000	0.19	0.01
FSX1-1-BC-26	37.453180	3.506852	0.581000	0.062000	0.18	0.01
FSX1-1-BC-27	45.662100	3.753049	0.610000	0.053000	0.29	0.01
FSX1-1-BC-28	46.082950	3.822549	0.640000	0.100000	0.17	0.01
FSX1-1-BC-29	35.460990	3.898194	0.614000	0.053000	0.22	0.01
FSX1-1-BC-30	31.152650	3.590804	0.663000	0.052000	0.25	0.02
FSX1-1-BC-31	42.553190	3.802626	0.558000	0.045000	0.29	0.02
FSX1-1-BC-32	54.945050	3.622751	0.551000	0.043000	0.35	0.01
FSX1-1-BC-33	36.101080	3.649207	0.641000	0.051000	0.27	0.02
FSX1-1-BC-34	55.248620	4.883856	0.587000	0.091000	0.19	0.01
FSX1-1-BC-35	34.482760	3.567182	0.671000	0.049000	0.22	0.02
FSX1-1-BC-36	50.761420	4.380427	0.545000	0.063000	0.22	0.01
FSX1-1-BC-37	41.322310	3.415067	0.656000	0.059000	0.18	0.01
FSX1-1-BC-38	27.777780	5.015432	0.727000	0.063000	0.26	0.03
FSX1-1-BC-39	19.920320	1.111093	0.782000	0.048000	0.18	0.03
FSX1-1-BC-40	60.606060	5.509642	0.540000	0.080000	0.18	0.01
FSX1-1-BC-41	9.746589	0.693471	0.787000	0.014000	1.93	0.72
FSX1-1-BC-42	4.694836	0.462871	0.837000	0.025000	0.30	0.24
FSX1-1-BC-43	2.525253	0.178553	0.846000	0.014000	0.57	0.86
FSX1-1-BC-44	3.412969	0.442638	0.848000	0.020000	0.34	0.35
FSX1-1-BC-45	4.149378	0.413216	0.834000	0.029000	0.20	0.19
FSX1-1-BC-46	10.298660	0.784862	0.798000	0.041000	0.20	0.07
FSX1-1-BC-47	1.814882	0.184453	0.848000	0.019000	0.23	0.50
FSX1-1-BC-48	6.802721	1.203202	0.816000	0.031000	0.27	0.15
FSX1-1-BC-49	3.322259	0.242823	0.842000	0.020000	0.25	0.29

FSX1-1-BC-50	1.972387	0.178954	0.845000	0.020000	0.22	0.41
FSX1-1-BC-51	2.183406	0.147785	0.853000	0.011000	0.74	1.31
FSX1-1-BC-52	1.414427	0.114034	0.848500	0.008700	0.59	1.57
FSX1-2-BC-1	1.416417	0.238245	0.875191	0.004400	0.63	2.60
FSX1-2-BC-2	1.439727	0.246151	0.870762	0.004200	1.05	4.44
FSX1-2-BC-3	2.103589	0.257490	0.866642	0.005200	0.53	1.53
FSX1-2-BC-4	2.507990	0.366007	0.866333	0.004600	0.56	1.26
FSX1-2-BC-5	3.157617	0.390728	0.874161	0.004800	0.97	1.80
FSX1-2-BC-6	2.559789	0.396845	0.872513	0.005200	0.67	1.57
FSX1-2-BC-7	1.962055	0.406869	0.871586	0.004600	1.04	3.29
FSX1-2-BC-8	2.458245	0.430569	0.864685	0.005600	0.80	2.02
FSX1-2-BC-9	2.216449	0.460877	0.870350	0.004800	0.83	2.30
FSX1-2-BC-10	2.312967	0.527301	0.860771	0.008800	0.37	0.89
FSX1-2-BC-11	3.965967	0.579031	0.857372	0.006400	0.53	0.79
FSX1-2-BC-12	4.030454	0.617305	0.859844	0.005600	0.85	1.27
FSX1-2-BC-13	2.904761	0.701392	0.859741	0.008000	0.69	1.41
FSX1-2-BC-14	2.899099	0.708641	0.851810	0.008800	0.36	0.70
FSX1-2-BC-15	2.478730	0.729626	0.859844	0.008800	0.69	1.58
FSX1-2-BC-16	3.131026	0.745067	0.863552	0.007800	0.50	0.96
FSX1-2-BC-17	2.860072	0.786830	0.864273	0.007200	0.75	1.51
FSX1-2-BC-18	2.360695	0.794151	0.857166	0.010400	0.31	0.79
FSX1-2-BC-19	4.691601	0.862578	0.851398	0.007400	0.79	1.06
FSX1-2-BC-20	4.876189	1.072968	0.852222	0.010000	0.61	0.78
FSX1-2-BC-21	5.164019	1.140041	0.845424	0.010800	0.38	0.43
FSX1-2-BC-22	6.917384	1.306934	0.850059	0.010000	0.55	0.45
FSX1-2-BC-23	5.349775	1.393468	0.841510	0.012400	0.52	0.58
FSX1-2-BC-24	7.549429	1.692039	0.834815	0.010200	1.03	0.78
FSX1-2-BC-25	8.039121	2.148906	0.834300	0.013000	0.74	0.55
FSX1-2-BC-26	24.847740	2.158245	0.731300	0.012000	0.22	0.04
FSX1-2-BC-27	35.574360	2.158245	0.669500	0.010000	0.70	1.38
FSX1-2-BC-28	7.219600	2.413976	0.839141	0.015200	0.47	0.36
FSX1-2-BC-29	27.427560	2.637855	0.710700	0.008000	0.22	1.08
FSX1-2-BC-30	33.401880	2.637855	0.679800	0.006000	0.77	1.19
FSX1-2-BC-31	9.657386	3.101127	0.817820	0.022000	0.47	0.37
FSX1-2-BC-32	41.141340	3.117465	0.638600	0.010000	0.19	0.11
FSX1-2-BC-33	14.300362	3.885582	0.793100	0.022000	0.41	0.16
FSX1-2-BC-34	10.400263	4.110369	0.808550	0.020000	0.28	0.15
FSX1-2-BC-35	19.466467	4.140034	0.766320	0.028000	0.41	0.12
FSX1-2-BC-36	19.936167	4.153438	0.767350	0.024000	0.43	0.12
FSX1-2-BC-37	30.007380	4.316490	0.700400	0.016000	0.37	0.42
FSX1-2-BC-38	47.930340	4.796100	0.592250	0.014000	0.04	0.02

Supplementary Table.2S LA-ICP-MS rare earth element (REE) data (ppm) for calcite cements in vein samples FSX1-1 and FSX1-2. BC: Block calcite; MGC: microcrystalline-granular calcite; REE concentrations are normalized to PAAS

Sample	Type	La	Ce	Pr	Nd	Sm	Eu	Gd	Tb	Dy	Y	Ho	Er	Tm	Yb	Lu	ΣREE	Y/Ho	δEu
Vein FSX1-1	MGC	5.884	10.39	1.209	4.604	0.871	0.193	0.949	0.156	1.077	8.235	0.24	0.757	0.117	0.776	0.114	35.571	34.38	0.93
	MGC	5.611	9.93	1.176	4.536	0.84	0.187	0.879	0.144	0.951	7.43	0.21	0.657	0.101	0.671	0.099	33.421	35.45	0.95
	MGC	5.947	10.99	1.273	4.901	0.924	0.217	0.98	0.163	1.133	8.269	0.239	0.761	0.112	0.78	0.111	36.801	34.57	1
	MGC	4.317	7.7	0.93	3.682	0.693	0.165	0.774	0.122	0.847	6.587	0.189	0.589	0.089	0.578	0.086	27.348	34.94	0.98
	MGC	3.725	6.733	0.819	3.263	0.631	0.143	0.674	0.107	0.75	5.905	0.162	0.509	0.075	0.503	0.075	24.074	36.56	0.96
	MGC	3.148	5.825	0.707	2.758	0.548	0.122	0.55	0.09	0.598	4.876	0.128	0.405	0.062	0.42	0.061	20.298	38.09	0.98
	MGC	5.09	9.9	1.132	4.27	0.762	0.159	0.734	0.115	0.711	5.395	0.157	0.459	0.069	0.453	0.068	29.474	34.28	0.93
	MGC	6.01	10.24	1.181	4.53	0.883	0.2	0.973	0.164	1.127	9.383	0.262	0.856	0.135	0.943	0.138	37.025	35.77	0.95
	MGC	4.46	7.93	0.914	3.492	0.66	0.139	0.67	0.111	0.747	5.83	0.16	0.504	0.075	0.526	0.078	26.296	36.35	0.92
	MGC	3.942	6.729	0.793	3.188	0.615	0.141	0.68	0.107	0.77	6.177	0.17	0.535	0.081	0.541	0.081	24.55	36.34	0.95
	MGC	6.32	12	1.363	5.41	1.06	0.244	1.135	0.188	1.298	10.45	0.289	0.915	0.135	0.943	0.138	41.887	36.22	0.97
	MGC	7.03	12.85	1.457	5.59	1.093	0.254	1.173	0.193	1.358	10.29	0.294	0.956	0.139	0.947	0.137	43.76	34.95	0.98
	MGC	7.49	13.37	1.521	5.9	1.135	0.254	1.175	0.187	1.312	9.777	0.292	0.883	0.136	0.94	0.134	44.505	33.46	0.96
	MGC	5.047	8.65	0.999	3.958	0.742	0.163	0.773	0.123	0.882	6.958	0.189	0.612	0.096	0.673	0.102	29.966	36.85	0.94
	MGC	6.96	12.22	1.366	5.34	0.994	0.228	1.064	0.167	1.172	8.92	0.254	0.804	0.124	0.842	0.123	40.578	35.12	0.97
	MGC	5.147	9.11	1.042	4.057	0.742	0.177	0.832	0.134	0.953	7.342	0.202	0.65	0.1	0.667	0.099	31.254	36.28	0.98
	MGC	4.54	7.81	0.909	3.7	0.718	0.158	0.746	0.117	0.834	6.73	0.186	0.555	0.082	0.592	0.088	27.765	36.24	0.95
	MGC	6.29	11.17	1.252	4.91	0.918	0.209	0.931	0.145	0.997	8.37	0.224	0.71	0.108	0.728	0.111	37.072	37.43	0.99
	MGC	5.285	9.14	1.024	4.08	0.788	0.181	0.822	0.132	0.93	8.24	0.225	0.704	0.106	0.76	0.119	32.536	36.62	0.99
	MGC	4.135	7.46	0.837	3.318	0.63	0.137	0.634	0.097	0.684	6.151	0.151	0.495	0.076	0.522	0.079	25.406	40.63	0.95
Vein FSX1-1	BC	0.954	2.07	0.269	1.057	0.218	0.08	0.196	0.031	0.166	0.921	0.027	0.054	0.006	0.028	0.003	6.079	34.62	1.69

	BC	0.543	1.429	0.199	0.923	0.237	0.151	0.27	0.045	0.26	1.697	0.041	0.083	0.008	0.042	0.004	5.931	41.59	2.61
	BC	0.531	1.156	0.144	0.656	0.167	0.09	0.161	0.026	0.158	0.971	0.024	0.048	0.005	0.018	0.002	4.158	39.96	2.42
	BC	1.149	2.5	0.304	1.25	0.274	0.168	0.258	0.036	0.203	1.29	0.034	0.066	0.007	0.031	0.004	7.574	38.17	2.77
	BC	0.378	1.04	0.107	0.466	0.126	0.059	0.126	0.021	0.135	0.831	0.021	0.041	0.004	0.023	0.002	3.38	40.34	2.04
	BC	1.02	2.32	0.284	1.215	0.276	0.114	0.236	0.039	0.208	1.233	0.035	0.068	0.008	0.031	0.004	7.09	35.53	1.96
	BC	0.791	1.5	0.176	0.72	0.171	0.123	0.158	0.026	0.148	0.963	0.024	0.05	0.005	0.023	0.003	4.882	39.79	3.28
	BC	0.946	1.748	0.206	0.835	0.178	0.138	0.179	0.026	0.148	1.046	0.024	0.054	0.006	0.024	0.003	5.56	43.58	3.38
	BC	0.773	1.7	0.21	0.854	0.197	0.127	0.174	0.026	0.149	0.95	0.023	0.052	0.005	0.022	0.003	5.264	40.77	3
	BC	0.879	1.73	0.208	0.827	0.196	0.135	0.172	0.027	0.159	1.137	0.025	0.055	0.006	0.03	0.004	5.59	46.03	3.23
	BC	0.943	1.82	0.209	0.876	0.196	0.202	0.187	0.027	0.168	1.192	0.026	0.054	0.005	0.02	0.002	5.927	46.56	4.63
	BC	0.584	1.249	0.151	0.571	0.127	0.096	0.117	0.019	0.098	0.772	0.016	0.034	0.003	0.017	0.002	3.857	47.65	3.47
	BC	0.971	2.276	0.311	1.331	0.342	0.251	0.327	0.051	0.273	1.995	0.042	0.081	0.009	0.039	0.005	8.303	47.5	3.29
	BC	25.188	68.696	7.466	32.390	7.322	3.212	7.626	1.277	7.117	39.979	0.946	1.770	0.169	0.823	0.104	204.087	42.25	2.01
	BC	11.806	33.857	5.343	23.206	5.375	1.938	5.724	0.963	5.326	26.476	0.714	1.308	0.123	0.580	0.073	122.811	37.11	1.63
Vein FSX1-2	BC	20.521	52.340	7.533	31.188	6.650	2.138	6.486	1.106	5.834	31.058	0.790	1.439	0.133	0.514	0.077	167.806	39.34	1.53
	BC	9.015	26.427	3.867	16.447	3.615	1.866	3.607	0.627	3.279	17.280	0.432	0.786	0.071	0.304	0.038	87.662	39.98	2.42
	BC	28.531	80.363	10.305	42.735	9.250	3.185	9.046	1.539	8.376	44.469	1.126	2.058	0.197	1.078	0.115	242.373	39.50	1.63
	BC	26.931	78.292	12.004	52.720	12.083	4.203	11.266	2.012	9.917	54.701	1.257	2.222	0.202	0.936	0.115	268.860	43.53	1.69
	BC	16.414	45.154	6.512	27.500	5.900	2.053	5.817	0.991	5.479	29.273	0.748	1.374	0.132	0.630	0.076	148.053	39.11	1.64
	BC	20.831	63.680	10.384	46.844	10.886	2.987	9.934	1.791	8.553	52.680	1.081	1.489	0.169	0.781	0.096	232.184	48.73	1.35
	BC	13.298	35.155	5.211	22.210	4.805	1.502	4.770	0.808	4.469	24.039	0.621	1.160	0.111	0.614	0.067	118.841	38.72	1.47
	BC	9.013	25.505	3.749	16.097	3.692	1.512	3.766	0.632	3.675	23.492	0.512	0.995	0.098	0.462	0.062	93.262	45.91	1.90
	BC	21.989	60.540	9.020	38.215	8.413	2.778	8.086	1.390	7.528	50.053	1.017	1.863	0.176	0.830	0.101	211.999	49.24	1.58
	BC	16.915	42.537	6.416	29.010	6.494	3.108	5.926	1.103	5.269	34.052	0.660	1.155	0.103	0.460	0.057	153.266	51.57	2.36

Note: $\delta\text{Eu} = \text{Eu}_{\text{SN}} / 0.5(\text{Sm}_{\text{SN}} + \text{Gd}_{\text{SN}})$, where SN—normalized to PAAS