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1 **Table S1. Major and trace element concentrations.** Mn concentrations reported in wt% were
 2 determined by XRF, whereas Mn concentrations reported in ppm were determined by ICP-MS.
 3

Name	Height (m)	FeT (wt.%)	Mn (wt.%)	Mn (ppm)	Sr (ppm)	Mn/Sr	Mg (wt.%)	Ca (wt.%)	Mg/Ca	TOC (wt.%)	Al (wt.%)	Ti (ppm)
18JX-82	1540	0.07		22.5	48.6	0.46	12.87	21.16	0.61	2.93	0.12	46.06
18JX-83	1539	0.04		20.8	21.4	0.97	11.49	18.9	0.61	0.03	0.02	7.36
18JX-84	1536	0.06		25	25.4	0.98	12.86	21.1	0.61	0.06	0.04	16.06
18JX-133	1523	0.01		18.1	13.7	1.31	13.18	21.57	0.61	0.04	0.02	5.10
18JX-132	1520	0.04		10	23.9	0.42	12.96	21.45	0.60	0.04	0.08	31.88
18JX-131	1508	0.03		12.1	14	0.86	13.27	21.77	0.61	0.06	0.03	11.18
18JX-130	1505	0.01		8.5	15	0.57	10.21	16.85	0.61	0.04	0.02	7.62
18JX-129	1500	0.02		8	13.3	0.60	12.16	19.9	0.61	0.04	0.03	11.36
18JX-128	1493	0.03		9.2	9.9	0.93	13.01	21.43	0.61	0.07	0.26	14.64
18JX-127	1490	0.04		9	10	0.90	13.12	21.68	0.60	0.04	0.07	24.22
18JX-126	1481	0.02		8.9	11.6	0.77	13.14	21.91	0.60	0.04	0.04	11.69
18JX-125	1480	0.03		7.5	8.1	0.92	13.17	21.76	0.61	0.04	0.04	15.41
18JX-124	1475	0.01		6.8	13.5	0.50	13.08	21.86	0.60	0.06	0.07	18.21
18JX-123	1470	0.01		6.7	11.3	0.59	13.15	21.92	0.60	0.07	0.03	9.65
18JX-122	1450	<0.01		6.7	640.4	0.01	1.01	37.96	0.03	0.05	0.03	13.34
18JX-121	1400	0.04		7.5	61.4	0.12	5.78	31.63	0.18	0.03	0.07	32.82
18JX-120	1390	0.03		6.9	234.1	0.03	1.36	36.77	0.04	0.12	0.12	51.43
18JX-119	1375	<0.01		5.4	105.2	0.05	1.84	37.27	0.05	0.10	0.04	13.52
18JX-118	1370	0.02		7.1	300.5	0.02	3.13	34.91	0.09	0.10	0.12	55.45
18JX-117	1320	0.02		5.2	429.4	0.01	2.28	35.84	0.06	0.09	0.11	52.77
18JX-116	1315	0.01		10.6	256.5	0.04	0.92	38.18	0.02	0.03	0.09	37.30
18JX-115	1314	0.08		17.1	298.5	0.06	1.72	35.82	0.05	0.20	0.12	52.33
18JX-114	1306	0.31		63.9	88.3	0.72	9.47	18.81	0.50	0.19	0.80	365.13
18JX-113	1300	0.14		41.9	271.9	0.15	3.94	31.55	0.13	0.08	0.22	79.91
18JX-112	1285	0.21		50.1	173.1	0.29	4.96	22.73	0.22	0.14	0.46	204.19
18JX-111	1265	0.12		35.2	364.9	0.10	1.64	35.12	0.05	0.13	0.28	139.75
18JX-110	1240	0.29		48.8	171.4	0.28	6.31	23.29	0.27	0.66	0.85	413.66
18JX-109	1235	0.30		65.6	154.3	0.43	7.89	20.2	0.39	0.18	0.70	354.29
18JX-108	1230	0.08		31	391.8	0.08	2.09	34.11	0.06	0.07	0.21	87.10

18JX-107	1220	0.28		57.9	193.8	0.30	7.1	22.02	0.32	0.27	0.62	286.23
18JX-106	1212	0.20		42.1	309.4	0.14	3.16	31.41	0.10	0.21	0.47	244.62
19JX-23	580	0.26	0.03		39.8	7.55	1.81	28.82	0.06	0.02	0.52	171.74
19JX-22	575	0.88	0.05		46.4	10.77	8.20	17.07	0.48	0.16	1.25	510.42
19JX-21	570	0.26	0.02		40.9	4.89	0.33	32.72	0.01	0.07	1.14	400.43
19JX-19	565	0.28	0.04		41.6	9.62	1.25	30.80	0.04	0.01	1.53	537.47
19JX-18	560	0.09	0.05		34.9	14.35	0.27	33.94	0.01	0.02	0.84	302.85
19JX-17	555	0.18	0.05		30	16.68	0.59	32.01	0.02	0.02	1.33	557.69
19JX-16	550	0.17	0.04		36.3	11.02	1.68	30.13	0.06	0.02	1.11	378.73
19JX-15	545	0.27	0.05		38.5	12.99	1.75	26.27	0.07	0.01	1.37	430.26
19JX-14	543	0.49	0.08		38.9	20.58	3.12	28.56	0.11	1.43	1.17	477.18
19JX-13	541	0.77	0.08		33.2	24.08	8.19	15.78	0.52	0.01	0.78	330.89
19JX-12	539	0.82	0.1		32.9	30.41	8.31	15.84	0.52	0.02	1.72	405.66
19JX-11	537	0.38	0.1		60.5	16.53	10.13	20.97	0.48	0.01	0.80	388.16
19JX-10	536	0.54	0.1		35.7	28.03	9.73	18.84	0.52	0.01	0.95	427.98
19JX-09	533	0.57	0.1		41.7	24	9.58	18.41	0.52	0.01	0.95	408.03
19JX-08	531	0.48	0.11		33.6	32.72	9.05	18.30	0.49	0.01	0.93	415.23
19JX-07	527	0.46	0.12		40.5	29.65	9.70	18.82	0.52	0.01	1.02	434.71
19JX-06	525	0.50	0.36		23.3	154.6 4	10.80	18.29	0.59	0.01	1.12	362.22
19JX-05	523	0.59	0.31		26.1	119	10.83	18.02	0.60	0.01	0.99	421.25
19JX-04	522	0.41	0.37		24.6	150.6 5	10.95	19.05	0.57	0.01	0.75	320.22
19JX-03	520	0.79	0.06		26.8	22.37	0.42	31.40	0.01	0.01	1.47	588.11
19JX-02	517	0.39	0.32		24.7	129.7 6	10.33	17.31	0.60	0.85	1.49	346.54
19JX-01	515	0.43	0.34		26.1	130.2 2	10.78	18.31	0.59	0.8	0.93	402.14
19JX-25	351	1.33	1.68		27.8	604.3 2	5.34	9.58	0.56	0.04	4.11	1637.0 4
19JX-26	350	1.00	2.35		28.8	817.3 9	7.76	15.05	0.52	0.02	1.93	782.08
19JX-27	349	1.00	2.42		26.1	928.6 3	7.18	13.85	0.52	0.06	2.13	930.00
19JX-28	348	1.20	1.87		21.4	873.4 2	11.28	21.05	0.54	0.03	0.09	52.36
19JX-29	346	0.60	1.09		12.1	903.0 7	5.40	10.31	0.52	2.46	0.06	33.01
19JX-30	345	1.04	1.76		19.8	887.1	11.45	21.23	0.54	2.53	0.07	38.72
19JX-31	344	1.17	1.77		19.8	893.9 4	11.33	20.78	0.55	0.04	0.08	44.29
19JX-32	343	0.48	1.28		26	492.3 1	11.65	20.20	0.58	0.03	0.03	35.02
19JX-33	342	0.44	0.39		7.1	553.1 9	2.90	5.16	0.56	0.02	0.05	41.20
19JX-35	219	0.47	0.41		36.9	111.0 8	11.58	19.47	0.59	1.47	0.21	73.48
19JX-34	218	0.34	0.29		22.2	130.6 3	9.92	16.71	0.59	0.01	0.11	86.19

19JX-36	216	0.43	0.31	16.3	$\frac{189.7}{2}$	10.04	16.97	0.59	0.01	0.15	75.74
19JX-37	215	0.48	0.32	18.1	176.8	10.24	17.52	0.58	0.01	0.36	143.09
19JX-38	114	0.34	0.08	21.9	36.48	7.51	12.63	0.59	0.04	0.52	241.07
19JX-39	113	0.27	0.05	21.6	23.19	7.30	12.18	0.60	0.04	0.46	247.72
19JX-40	112	0.24	0.05	10.6	47.13	4.26	7.16	0.60	0.04	1.20	281.84
19JX-41	111	0.41	0.13	21.2	61.26	9.28	15.75	0.59	0.01	0.57	243.26
19JX-42	110	0.20	0.07	8.9	78.83	5.99	10.22	0.59	0.03	0.04	53.59

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6 **Table S2. Iron-speciation data.**

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Name	Height (m)	Fe _{carb} (wt. %)	Fe _{ox} (wt. %)	Fe _{mag} (wt. %)	Fe _{py} (wt. %)	Fe _{HR} (wt. %)	Fe _{HR} /Fe _T	Fe _{py} /Fe _{HR}
19JX-22	575	0.64	0.10	0.01	0.00	0.75	0.86	0.00
19JX-14	543	0.17	0.27	0.01	0.00	0.44	0.90	0.00
19JX-13	541	0.62	0.03	0.00	0.00	0.65	0.84	0.00
19JX-12	539	0.60	0.14	0.03	0.00	0.77	0.95	0.00
19JX-10	536	0.36	0.05	0.03	0.00	0.44	0.81	0.00
19JX-09	533	0.46	0.10	0.02	0.00	0.59	1.03	0.00
19JX-06	525	0.41	0.02	0.03	0.00	0.47	0.93	0.00
19JX-05	523	0.39	0.06	0.03	0.00	0.48	0.81	0.00
19JX-04	522	0.04	0.40	0.09	0.00	0.54	0.68	0.00
19JX-25	351	0.42	0.56	0.03	0.00	1.01	0.76	0.00
19JX-26	350	0.78	0.15	0.01	0.01	0.93	0.94	0.01
19JX-27	349	0.75	0.17	0.01	0.01	0.93	0.93	0.01
19JX-28	348	1.07	0.19	0.01	0.00	1.27	1.06	0.00
19JX-29	346	0.44	0.13	0.00	0.00	0.58	0.97	0.00
19JX-30	345	0.94	0.15	0.00	0.00	1.09	1.04	0.00
19JX-31	344	1.05	0.15	0.01	0.00	1.20	1.03	0.00

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10 **Table S3. Isotopic compositions (Mo, C_{carb} and O_{carb}) and Mo concentrations.** Mo data in bold
 11 were obtained by the double-spike method during isotopic analysis, while other Mo data were
 12 obtained by whole-rock trace element analysis.
 13

Name	Height(m)	Mo (ppm)	$\delta^{98}\text{Mo}$ (‰)	2se	$\delta^{13}\text{C}_{\text{carb}}$ (‰)	$\delta^{18}\text{O}_{\text{carb}}$ (‰)
18JX-82	1540	0.68	0.47	0.03	-1.27	-5.86
18JX-83	1539	0.99	2.10	0.02	-0.57	-5.96
18JX-84	1536	2.17	2.51	0.04	-0.58	-6.10
18JX-133	1523	0.05				
18JX-132	1520	0.03	1.41	0.07	-0.12	-6.15
18JX-131	1508	0.01	1.22	0.25	-0.31	-6.27
18JX-130	1505	0.06				
18JX-129	1500	0.05				
18JX-128	1493	0.04				
18JX-127	1490	0.02	1.06	0.07	-0.35	-7.23
18JX-126	1481	0.34				
18JX-125	1480	0.03				
18JX-124	1475	0.04				
18JX-123	1470	0.03				
18JX-122	1450	0.03				
18JX-121	1400	0.06				
18JX-120	1390	0.03	0.85	0.06	-0.93	-7.47
18JX-119	1375	0.03				
18JX-118	1370	0.05				
18JX-117	1320	0.04	0.96	0.04	-0.65	-6.86
18JX-116	1315	0.02	0.96	0.13	-0.73	-6.51
18JX-115	1314	0.08	1.53	0.05	-0.48	-5.38
18JX-114	1306	0.68	0.55	0.04	-0.10	-3.47
18JX-113	1300	0.09	1.38	0.07	-0.36	-4.48
18JX-112	1285	0.23	0.71	0.05	-0.67	-4.44
18JX-111	1265	0.43	0.95	0.03	-0.67	-6.11
18JX-110	1240	0.57	0.61	0.05	-0.56	-4.14
18JX-109	1235	0.40	0.79	0.15	0.00	-3.32
18JX-108	1230	0.05	0.76	0.05	-0.70	-4.93
18JX-107	1220	0.13	0.57	0.05	-0.35	-4.47
18JX-106	1212	0.35	0.65	0.05	-0.60	-4.99
19JX-23	580	0.12	0.11	0.04	-1.94	-6.53
19JX-22	575	0.17	0.15	0.04	-0.89	-5.06
19JX-21	570	0.24	-0.18	0.02	-1.65	-7.37
19JX-19	565	0.02	0.54	0.06	-1.41	-7.09
19JX-18	560	0.03	-0.70	0.04	-1.50	-6.93
19JX-17	555	0.04				
19JX-16	550	0.04				
19JX-15	545	0.04	0.00	0.05	-1.35	-6.75
19JX-14	543	0.04				
19JX-13	541	0.08	0.58	0.04	-0.90	-5.66
19JX-12	539	0.05	-1.39	0.05	-0.94	-5.60
19JX-11	537	0.03				
19JX-10	536	0.06	-0.29	0.04	-0.89	-5.36
19JX-09	533	0.06	0.47	0.03	-0.91	-5.71
19JX-08	531	0.05	0.06	0.10	-0.96	-6.04
19JX-07	527	0.06	0.39	0.04	-0.80	-5.80
19JX-06	525	0.02	-2.20	0.12	-0.67	-5.83
19JX-05	523	0.05	-0.41	0.06	-0.60	-5.45
19JX-04	522	0.04	-1.67	0.05	-0.66	-5.57
19JX-03	520	0.28				
19JX-02	517	0.03	-4.00	0.18	-0.70	-5.55
19JX-01	515	0.02	-1.61	0.17	-0.84	-5.86

19JX-25	351	0.19	-0.11	0.05	-2.17	-5.47
19JX-26	350	0.07	-0.66	0.03	-2.61	-5.01
19JX-27	349	0.09		0.04	-2.43	-5.4
19JX-28	348	0.27	1.48	0.02	-1.97	-6.36
19JX-29	346	0.23	0.13	0.03	-1.38	-5.92
19JX-30	345	0.21	0.37	0.03	-1.26	-6.02
19JX-31	344	0.12	0.02	0.09	-0.9	-5.42
19JX-32	343	0.04	-0.01	0.05	-0.51	-4.30
19JX-33	342	0.15	0.77	0.05	-0.66	-6.26
19JX-35	219	0.04				
19JX-34	218	0.02				
19JX-36	216	0.03				
19JX-37	215	0.11	0.28	0.05	0.32	-6.93
19JX-38	114	0.08	0.62	0.04	0.08	-5.91
19JX-39	113	0.05	0.31	0.07	0.25	-5.83
19JX-40	112	0.06	-0.11	0.06	0.18	-7.53
19JX-41	111	0.04	0.69	0.10	0.36	-6.93
19JX-42	110	0.03				

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