

Geochemistry and metallogeny of Neoproterozoic pyrite in oxic and anoxic sediments

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Supplementary Information

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Supplementary Tables

Table S-1 Whole rock compositions for Dalradian shales and diamictites.

Lithology	Locality	Ag (ppm)	Bi (ppm)	Co (ppm)	Cu (ppm)	Mo (ppm)	Ni (ppm)	Pb (ppm)	Re (ppm)	Se (ppm)	Te (ppm)	U (ppm)	V (ppm)	Zn (ppm)	S (%)	TOC (%)	Te/Se	Re/Mo	Se/S	Te/S
Easdale Slate	Cullion	0.13	0.34	13.6	35.4	0.4	27.0	18.0	0.001	2.3	0.06	3.04	26	59	2.46	0.80	0.026	0.003	0.935	0.024
Easdale Slate	Cullion	0.07	0.03	19.6	8.6	0.3	9.2	6.0	<0.001	0.5	0.02	0.40	1	17	0.29	1.57	0.040	0.004	1.724	0.069
Easdale Slate	Cullion	0.06	0.03	18.8	10.5	0.2	8.7	6.5	<0.001	0.5	<0.01	0.33	1	14	0.27	1.52	0.020	0.005	1.852	0.037
Easdale Slate	Cullion	0.10	0.40	41.8	37.5	0.6	37.2	12.1	0.001	1.1	0.04	3.61	26	160	1.07	1.05	0.036	0.002	1.028	0.037
Easdale Slate	Easdale	0.05	0.11	7.7	20.8	0.6	15.9	7.3	<0.001	0.4	0.02	0.41	11	112	0.76	0.24	0.050	0.002	0.526	0.026
Easdale Slate	Easdale	0.09	0.20	22.0	50.1	0.4	55.6	16.8	<0.001	0.5	0.03	0.36	11	101	0.65	0.40	0.060	0.003	0.769	0.046
Easdale Slate	Easdale	0.07	0.10	15.2	28.3	0.3	27.7	11.2	<0.001	0.7	0.02	0.38	12	83	1.37	0.34	0.029	0.003	0.511	0.015
Easdale Slate	Easdale	0.17	0.40	25.2	65.6	0.5	53.5	27.5	0.001	1.0	0.08	0.66	14	103	1.55	0.22	0.080	0.002	0.645	0.052
Easdale Slate	Easdale	0.07	0.18	19.0	29.2	0.3	35.1	16.1	0.003	<1.0	<0.05	2.50	79	118	1.06	0.91	0.050	0.010	0.943	0.047
Easdale Slate	Easdale	0.08	0.24	23.0	36.7	0.2	44.3	20.8	0.002	1.0	<0.05	3.20	96	116	1.00	0.46	0.050	0.010	1.000	0.050
Easdale Slate	Easdale	0.13	0.27	23.1	20.1	0.3	22.7	22.4	0.004	2.0	0.06	1.90	69	40	3.80	0.51	0.030	0.016	0.526	0.016
Easdale Slate	Glenshee	0.95	1.04	55.4	88.5	13.6	79.3	544.0	0.004	5.1	0.12	1.46	7	225	3.05	1.94	0.024	0.000	1.672	0.039
Easdale Slate	Glenshee	0.86	1.06	48.6	86.1	12.6	69.1	555.0	0.004	4.6	0.12	1.61	8	214	2.16	1.33	0.026	0.000	2.130	0.056
Easdale Slate	Jura Forest	0.03	0.09	9.3	24.5	2.0	2.7	3.1	0.002	0.6	0.01	0.95	8	58	0.31	1.09	0.017	0.001	1.935	0.032
Easdale Slate	Jura Forest	0.13	0.42	24.8	120.5	0.8	28.4	32.7	<0.001	0.8	0.09	1.36	22	79	0.64	0.37	0.113	0.001	1.250	0.141
Easdale Slate	Muckcross	0.13	0.33	51.4	34.2	0.7	28.4	16.1	0.002	0.8	0.02	3.00	15	81	1.29		0.025	0.003	0.620	0.016
Easdale Slate	Portsoy	0.12	0.20	49.4	40.8	0.9	32.4	16.5	0.001	2.4	0.02	1.07	9	26	1.62	4.14	0.008	0.001	1.481	0.012
Easdale Slate	Portsoy	0.05	0.24	29.1	57.2	2.2	52.2	14.8	0.003	3.7	0.05	3.31	21	41	2.28	2.86	0.014	0.001	1.623	0.022
Easdale Slate	Portsoy	0.05	0.29	36.0	47.9	2.5	59.3	13.3	0.002	1.7	0.04	1.16	28	54	1.48	3.43	0.024	0.001	1.149	0.027
Easdale Slate	Portsoy	0.11	0.26	23.7	42.6	1.1	28.3	12.4	0.002	3.8	0.03	1.22	9	28	1.19	3.22	0.008	0.002	3.193	0.025
Easdale Slate	Strathorchy	0.50	0.16	76.3	185.5	0.4	145.0	16.7	0.001	5.2	0.13	1.05	5	49	8.53	0.97	0.025	0.002	0.610	0.015
Easdale Slate	Strathorchy	0.17	0.15	46.6	80.7	1.1	51.2	11.7	0.002	3.1	0.04	1.64	2	17	2.52	1.29	0.013	0.002	1.230	0.016
Easdale Slate	Strathorchy	0.07	0.18	14.6	38.3	1.7	34.5	12.9	0.001	2.7	0.04	2.58	3	134	1.46	2.79	0.015	0.001	1.849	0.027
Easdale Slate	Strathorchy	0.22	0.04	34.7	94.1	0.9	135.5	21.4	0.001	4.7	0.03	1.25	3	82	3.65	0.83	0.006	0.001	1.288	0.008
Easdale Slate	Strathorchy	0.12	0.16	25.4	45.6	0.7	48.7	14.7	0.003	2.8	0.04	1.52	4	122	1.94	0.77	0.014	0.005	1.443	0.021
Termon Pelite	Bellanamore	0.54	1.79	32.7	85.8	6.1	7.4	172.0	0.004	2.1	0.25	1.23	4	34	2.04	0.14	0.119	0.001	1.029	0.123
Termon Pelite	Bellanamore	0.27	0.60	26.4	73.1	6.2	23.6	65.8	0.003	2.0	0.09	1.87	7	45	2.76	0.12	0.045	0.000	0.725	0.033
Termon Pelite	Bellanamore	0.04	0.11	24.4	28.0	3.7	26.0	8.4	0.002	0.9	0.03	1.96	16	126	0.98	0.27	0.033	0.001	0.918	0.031



Termon Pelite	Bellanamore	0.05	0.10	17.8	15.7	4.0	18.6	18.2	0.003	0.9	0.01	1.68	14	110	0.58	0.33	0.011	0.001	1.552	0.017
Termon Pelite	Bellanamore	1.08	2.56	42.1	107.5	4.9	7.6	173.5	0.007	4.0	0.25	3.90	85	59	3.04	0.18	0.063	0.001	1.316	0.082
Termon Pelite	Bellanamore	0.95	2.00	60.4	175.0	6.6	12.5	180.5	0.004	5.0	0.20	2.60	56	56	4.63	0.17	0.040	0.001	1.080	0.043
Termon Pelite	Bellanamore	0.52	1.45	57.9	225.0	1.2	7.9	148.0	0.004	2.0	0.27	3.90	86	37	4.05	0.11	0.135	0.003	0.494	0.067
Craignish Phyllite	Loch Melfort	0.06	0.17	24.6	19.2	2.5	28.5	18.0	0.005	1.8	0.03	1.70	53	80	0.94	0.09	0.017	0.002	1.915	0.032
Craignish Phyllite	Loch Melfort	0.08	0.21	23.1	20.6	1.7	30.1	33.7	0.002	1.8	0.02	2.73	61	106	0.91	0.03	0.011	0.001	1.978	0.022
Craignish Phyllite	Strachur	0.02	0.15	30.5	39.7	0.1	34.2	1.6	0.002	1.0	0.03	1.78	14	93	0.39		0.030	0.025	2.564	0.077
Mean Values		0.23	0.46	31.3	60.5	2.3	38.0	64.8	0.002	2.1	0.07	1.81	25	82	1.91	1.05	0.037	0.003	1.300	0.040
Standard Deviation		0.29	0.60	15.8	50.2	3.2	31.0	129.1	0.001	1.5	0.07	1.03	28	50	1.60	1.08	0.031	0.005	0.619	0.029
Average Shale Value (Hu and Gao, 2008) - n = 21; Se = Stueken <i>et al.</i> (2015); Ag = Turekian and Wedpohl, (1961)		0.07	0.46	15.8	35.3	1.0	38.9	23.3	*	1.3	0.05	3.24	124	83	-	-	-	-	-	-
* Published Values for Re in shale vary widely																				
Lithology	Locality	Ag (ppm)	Bi (ppm)	Co (ppm)	Cu (ppm)	Mo (ppm)	Ni (ppm)	Pb (ppm)	Re (ppm)	Se (ppm)	Te (ppm)	U (ppm)	V (ppm)	Zn (ppm)	S (%)	TOC (%)	Te/Se	Re/Mo	Se/S	Te/S
Diamictite	Balmore	0.06	0.18	37.0	28.1	0.5	20.5	7.1	0.003	1.8	0.16	1.49	52	56	0.20		0.089	0.006	9.000	0.800
Diamictite	Balmore	0.05	0.19	35.3	30.9	0.7	25.1	6.9	0.005	1.1	0.15	1.51	55	56	0.22		0.136	0.007	5.000	0.682
Diamictite	Balmore	0.05	0.18	32.9	31.9	0.7	22.9	7.3	0.009	1.9	0.12	1.98	52	54	0.28	0.02	0.063	0.013	6.786	0.429
Diamictite	Balmore	0.05	0.17	30.4	32.9	0.7	22.3	7.1	0.007	0.9	0.16	1.76	54	55	0.26		0.178	0.010	3.462	0.615
Diamictite	Balmore	0.05	0.15	26.7	28.9	0.7	23.1	6.2	0.007	2.3	0.12	2.19	55	55	0.27	0.02	0.052	0.010	8.519	0.444
Diamictite	Balmore	0.05	0.16	25.6	35.8	0.8	28.3	6.6	0.006	1.2	0.14	2.32	56	57	0.26		0.117	0.007	4.615	0.538
Diamictite	Balmore	0.09	0.19	25.5	37.2	0.9	20.8	8.6	0.005	2.7	0.13	1.80	51	51	0.42	0.01	0.048	0.006	6.429	0.310
Diamictite	Balmore	0.06	0.16	29.8	34.3	0.6	17.5	6.8	0.003	2.1	0.13	1.52	42	42	0.49	0.00	0.062	0.005	4.286	0.265
Diamictite	Balmore	0.04	0.15	23.2	30.2	0.8	20.6	7.6	0.003	2.2	0.10	1.72	45	46	0.34	0.00	0.045	0.004	6.471	0.294
Diamictite	Clegganhead	0.10	0.06	42.6	30.5	0.2	18.0	9.5	0.002	1.1	0.17	0.90	48	38	0.13	0.02	0.155	0.009	8.462	1.308
Diamictite	Croaghan Hill	0.05	0.16	56.5	17.8	0.6	18.9	10.5	0.004	0.8	0.07	1.14	19	42	0.07		0.088	0.007	11.429	1.000
Diamictite	Fordyce	0.09	0.16	60.0	45.2	0.7	26.5	3.5	0.005	2.9	0.21	1.57	77	48	0.42	0.01	0.072	0.007	6.905	0.500
Diamictite	Fordyce	0.06	0.14	55.6	28.1	0.7	26.9	4.6	0.005	2.0	0.17	1.64	76	46	0.27	0.04	0.085	0.007	7.407	0.630
Diamictite	Fordyce	0.09	0.16	79.8	75.1	0.8	24.9	3.0	0.004	3.1	0.15	1.18	74	57	0.51	0.03	0.048	0.005	6.078	0.294
Diamictite	Fordyce	0.07	0.11	34.0	30.0	0.7	26.7	2.6	0.006	1.6	0.11	1.38	84	54	0.19	0.03	0.069	0.009	8.421	0.579
Diamictite	Garvellachs	0.16	0.57	47.8	52.5	0.6	24.7	11.3	0.006	2.3	0.15	0.42	17	36	0.56	0.04	0.065	0.010	4.107	0.268
Diamictite	Garvellachs	0.02	0.38	42.8	44.4	0.7	31.3	8.7	0.005	6.0	0.21	0.72	12	33	1.07	0.05	0.035	0.007	5.607	0.196
Diamictite	Glen Shee	0.25	0.37	163.5	29.4	1.8	17.2	2.8	0.013	3.1	0.16	1.42	52	41	0.18		0.052	0.007	17.222	0.889
Diamictite	Glen Shee	0.03	0.25	160.5	26.4	1.5	17.7	2.5	0.014	1.4	0.13	1.31	55	44	0.15		0.093	0.009	9.333	0.867
Diamictite	Kiltyfannad	0.02	0.12	26.4	14.2	0.3	12.5	4.6	0.001	1.7	0.05	1.04	15	26	0.59	0.02	0.029	0.004	2.881	0.085
Diamictite	Kiltyfannad	0.02	0.09	20.4	12.8	0.3	13.0	3.6	0.001	1.1	0.05	0.97	15	26	0.53	0.01	0.045	0.004	2.075	0.094
Diamictite	Meikle Fergie Burn	0.01	0.13	13.8	26.3	0.3	16.5	2.3	0.001	1.0	0.10	0.86	30	22	0.61	0.01	0.100	0.004	1.639	0.164
Diamictite	Port Askaig	0.29	0.62	33.5	55.2	1.0	23.8	137.5	0.008	4.0	0.25	1.10	17	44	0.60	0.03	0.063	0.008	6.667	0.417
Diamictite	Port Askaig	0.10	0.22	24.2	28.3	0.9	22.5	8.4	0.004	1.5	0.12	1.01	16	46	0.31	0.03	0.080	0.005	4.839	0.387
Diamictite	Port Askaig	0.07	0.16	18.2	21.2	0.5	18.8	7.5	0.004	2.7	0.09	0.96	9	23	1.29	0.11	0.033	0.009	2.093	0.070
Diamictite	Port Askaig	0.33	0.20	20.6	836.0	0.5	16.7	6.5	0.003	1.9	0.11	0.67	10	20	0.58	0.02	0.058	0.006	3.276	0.190
Diamictite	Port Askaig	0.07	0.26	33.0	33.2	0.6	18.0	9.7	0.004	2.3	0.08	1.34	13	24	0.73	0.01	0.035	0.007	3.151	0.110
Mean Values		0.08	0.21	44.1	60.9	0.7	21.3	11.1	0.005	2.6	0.13	1.30	40	41	0.51	0.03	0.072	0.007	6.120	0.445
Standard Deviation		0.08	0.13	36.2	152.2	0.3	4.6	24.9	0.003	1.1	0.05	0.45	23	12	0.28	0.02	0.036	0.002	3.276	0.307
Average Shale Value (Hu and Gao, 2008) - n = 21; Se = Stueken <i>et al.</i> (2015); Ag = Turekian and Wedpohl, (1961)		0.07	0.46	15.8	35.3	1.0	38.9	23.3	*	1.3	0.05	3.24	124	83	-	-	-	-	-	-
* Published Values for Re in shale vary widely																				



Table S-2 LA-ICP-MS compositions of pyrite for Dalradian shales and diamictites.

Lithology	Description	Sulphide	Fe (ppm)	As (ppm)	Se (ppm)	Te (ppm)	Au (ppm)	Pb (ppm)	Se/Te
Shale	Bellanamore	Pyrite	312832	159.65	9.05	1.05	0.08		8.63
Shale	Bellanamore	Pyrite	283147	135.63	11.88	0.95	0.10	48.12	12.53
Shale	Bellanamore	Pyrite	306778	86.02	9.80	0.70	0.05		14.01
Shale	Bellanamore	Pyrite	168266	105.12	8.95	1.00	0.08	411.19	8.95
Shale	Bellanamore	Pyrite	177859	160.85	6.75	0.65	0.04	24.59	10.38
Shale	Bellanamore	Pyrite	175666	116.34	5.85	0.73	0.10	39.91	8.05
Shale	Bellanamore	Pyrite	36749	4.06	5.56	0.17	0.38	53.98	33.33
Shale	Bellanamore	Pyrite	343556	83.25	10.73	0.51	0.10	38.83	21.10
Shale	Bellanamore	Pyrite	305996	247.65	7.85	0.75	0.07	36.75	10.46
Shale	Bellanamore	Pyrite	311474	180.91	8.58	0.86	0.04	28.36	9.97
Shale	Bellanamore	Pyrite	289326	44.59	11.55	0.36	0.06	51.71	31.71
Shale	Bellanamore	Pyrite	201903	90.78	5.71	0.68	0.06	19.85	8.38
Shale	Bellanamore	Pyrite	251763	40.54	9.14	0.58	0.04	36.94	15.87
Shale	Cullion	Pyrite	115164	13.20	7.33	0.17	0.02	17.11	44.03
Shale	Cullion	Pyrite	49917	2.11	2.11	0.04	0.04	35.30	59.45
Shale	Easdale	Pyrite	331047	2.49	6.47	0.27	0.04		23.74
Shale	Easdale	Pyrite	269687	318.11	7.10	1.43	0.06	72.82	4.96
Shale	Easdale	Pyrite	141792	1.41	2.78	0.03	0.02	181.64	84.25
Shale	Easdale	Pyrite	244057	221.53	6.89	1.02	0.02	141.17	6.78
Shale	Easdale	Pyrite	181066	1.75	5.73	0.02	0.03	323.19	262.88
Shale	Foss	Pyrite	137224	25.19	0.49	0.08	0.01	1042.20	5.84
Shale	Glen Shee	Pyrite	31343	80.01	10.00	0.12	0.04	204.26	83.40
Shale	Glen Shee	Pyrite	148534	57.45	11.08	0.39	0.04	145.33	28.69
Shale	Glenbuchat	Pyrite	376937	130.21	9.98	0.71	0.01	144.49	14.00
Shale	Jura Forest	Pyrite	48701	101.70	1.89	1.64	0.03	135.22	1.15
Shale	Jura Forest	Pyrite	56307	70.22	2.83	0.92	0.06	106.39	3.07
Shale	Kerrera	Pyrite	264415	1.28	7.60	0.24	0.03	117.66	31.33
Shale	Muckcross	Pyrite	166378	2.42	4.15	0.30	0.02	136.19	13.62
Shale	Strachur	Pyrite	269295	0.76	3.28	0.05	0.01	42.81	59.98
Shale	Strath Orchy	Pyrite	86468	8.26	5.40	0.25	0.03		21.87
Shale	Portsoy	Pyrrhotite	14699	1.01	1.37	0.10	0.01	7.38	13.26
Shale	Portsoy	Pyrrhotite	165190	79.48	2.14	0.13	0.04	29.05	16.46
Shale	Portsoy	Pyrrhotite	94569	4.67	3.98	1.88	0.13	303.82	2.12
Shale	Portsoy	Pyrrhotite	88083	2.14	3.50	0.86	0.12	316.73	4.04
Shale	Strachur	Pyrrhotite	143422	0.99	2.77	0.12	0.02		22.20
Shale	Strachur	Pyrrhotite	321538	125.58	5.21	0.28	0.03	30.05	18.33
Mean			191976	75.20	6.26	0.56	0.06	139.45	28.30
Standard Deviation			102720	79.27	3.14	0.47	0.06	194.61	44.66
Lithology	Description	Sulphide	Fe (ppm)	As (ppm)	Se (ppm)	Te (ppm)	Au (ppm)	Pb (ppm)	Se/Te
Diamictite	Balmore	Pyrite	219065	27.53	62.15	20.65	0.59	37.58	3.01
Diamictite	Balmore	Pyrite	206795	28.30	66.01	15.84	1.38		4.17
Diamictite	Balmore	Pyrite	108231	14.80	25.53	13.52	0.09		1.89
Diamictite	Clegganhead	Pyrite	305448	26.49	13.39	1.57	0.03		8.55
Diamictite	Croaghan Hill	Pyrite	352323	269.66	44.39	0.53	0.03	66.94	84.36
Diamictite	Fordyce	Pyrite	127133	4.88	22.77	0.69	0.15	12.78	33.05
Diamictite	Fordyce	Pyrite	137772	0.30	26.80	8.27	0.03	11.53	3.24
Diamictite	Fordyce	Pyrite	306783	9.62	52.56	12.19	0.07	19.39	4.31
Diamictite	Garvellachs	Pyrite	29626	3.83	18.03	0.46	0.09	69.14	38.78
Diamictite	Garvellachs	Pyrite	49797	11.00	46.58	2.14	0.10	54.08	21.75
Diamictite	Garvellachs	Pyrite	315775	10.17	34.05	1.41	0.03	459.22	24.12
Diamictite	Glen Shee	Pyrite	95771	67.15	14.05	0.58	0.00	20.94	24.26
Diamictite	Glen Shee	Pyrite	173033	53.81	30.64	1.72	0.02	25.94	17.79
Diamictite	Glencolumbkille	Pyrite	287994	10.64	39.72	1.72	0.06	10.67	23.04
Diamictite	Glencolumbkille	Pyrite	52837	7.76	41.28	2.11	0.07	12.29	19.52
Diamictite	Meikle Fergie Burn	Pyrite	185226	2.54	17.98	3.85	0.05	30.58	4.67
Diamictite	Mull of Oa	Pyrite	149577	52.96	32.39	3.69	0.45	60.59	8.78
Diamictite	Mull of Oa	Pyrite	219940	75.07	42.62	3.90	0.37	90.48	10.92
Diamictite	Mull of Oa	Pyrite	319039	56.29	64.28	0.45	0.03	10.19	143.69
Diamictite	Port Askaig	Pyrite	93188	7.24	27.52	0.23	0.12	385.58	117.50
Diamictite	Port Askaig	Pyrite	128834	13.15	16.16	1.06	0.05	189.59	15.28
Diamictite	Port Askaig	Pyrite	49137	21.12	32.10	0.56	0.01	127.95	57.68
Mean			177878	35.20	35.05	4.42	0.17	89.23	30.47
Standard Deviation			98976	55.66	15.73	5.70	0.30	123.36	37.25



Supplementary Figures

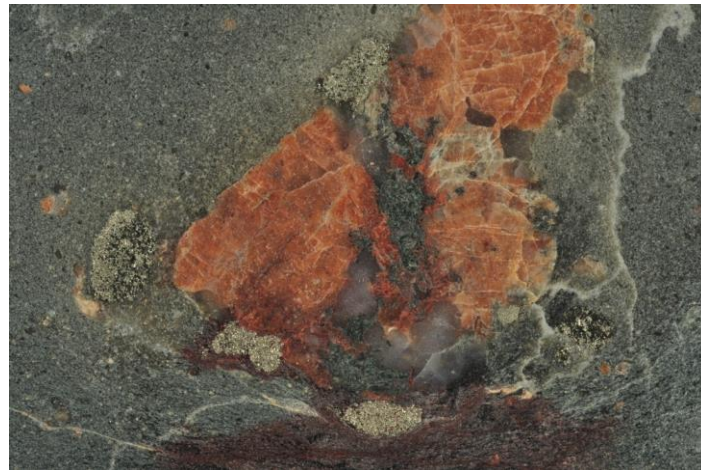


Figure S-1 Clustered microcrystals of pyrite around granite clast, Dalradian diamictite, Port Askaig. Field width 6 cm.

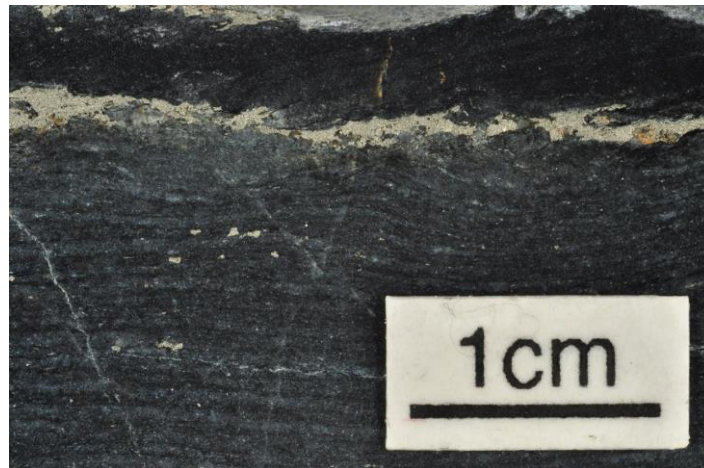


Figure S-2 Clustered microcrystals of pyrite along sedimentary lamination, Dalradian shale, Strath Orchy.

Supplementary Information References

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