

## **Aquatic geochemistry of the rare earth elements and yttrium in the Pioneer River catchment, Australia**

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*Abstract.* The rare earth elements are strong provenance indicators in geological materials, yet the potential for tracing provinciality in surface freshwater samples has not been adequately tested. Rare earth element and yttrium concentrations were measured at 33 locations in the Pioneer River catchment, Mackay, central Queensland, Australia. The rare earth element patterns were compared on the basis of geological, topographical and land-use features in order to investigate the provenancing potential of these elements in a small freshwater system. The rare earth element patterns of streams draining single lithological units with minor land modification show strongly coherent normalised behaviour, with a loss of coherence in agricultural locations. Evidence is reported for an anthropogenic Gd anomaly that may provide a useful hydrological tracer in this region since the introduction of magnetic resonance imaging in 2003. Several samples display a superchondritic Y/Ho mass ratio (up to 44), which is not explainable within the constraints imposed by local geology. Instead, it is suggested that the additional Y is derived from a marine source, specifically marine phosphorites, which are a typical source of fertiliser phosphorus. The data indicate that, under some circumstances, scaled and normalised freshwater rare earth patterns behave conservatively.

**Table 1. Field parameters and trace element content of samples in the Pioneer River catchment**

Trace elements reported in ng g<sup>-1</sup>

Sample number	pH	Conductivity (mS cm <sup>-1</sup> )	Temperature (°C)	P	Mn	Sr	Zr	U
1	7.42	129.8	21.9	13	0.15	55.9	0.0014	0.0077
2	7.04	195	24.4	15	2.53	172.3	0.0006	0.0254
3	6.76	164.5	27.1	5	4.28	107.5	0.0005	0.0130
4	6.84	219.4	29.7	4	31.65	175.7	0.0024	0.0220
5	6.93	201.7	28.1	7	29.12	140.8	0.0016	0.0163
6	7.51	222.2	27.6	4	1.01	159.6	0.0010	0.0146
7	6.97	249.3	27.1	3	2.42	184.4	0.0010	0.0184
8	6.44	97	26.6	5	4.30	55.6	0.0036	0.0101
9	6.05	35.1	22.6	2	1.23	6.9	0.0132	0.0102
10	6.28	45.6	23.0	2	0.75	13.7	0.0102	0.0107
11	6.30	41.5	24.6	2	0.84	10.4	0.0151	0.0103
12	6.03	46.2	26.0	5	1.53	14.9	0.0128	0.0106
13	7.62	52.3	26.0	7	6.51	20.2	0.0125	0.0098
14	5.86	55.5	26.1	7	7.65	23.0	0.0107	0.0105
15	7.65	97.3	26.9	6	8.12	55.5	0.0040	0.0111
16	6.62	76.2	24.7	12	3.15	28.6	0.0091	0.0105
17	6.29	88.8	26.1	10	121.02	39.0	0.0050	0.0151
18	6.29	66.3	27.5	2	17.31	51.7	0.0011	0.0148
19	5.96	136.1	27.9	17	14.85	69.5	0.0015	0.0193
20	6.84	177.7	28.9	3	63.47	116.6	0.0027	0.0234
21	6.75	133.8	27.8	48	9.72	275.8	0.0019	0.0707
22	6.87	156.1	27.9	4	29.91	102.0	0.0020	0.0179
23	6.45	86.1	28.9	4	4.63	82.4	0.0076	0.0136
24	8.99	185.9	28.2	4	2.63	99.9	0.0043	0.0068
25	8.31	187.1	31.4	9	1.26	122.8	0.0029	0.0138
26	8.46	244.7	33.6	11	1.86	126.5	0.0037	0.0152
27	7.50	225	29.2	8	14.98	140.3	0.0029	0.0195
28	8.76	223	32.5	8	9.46	137.8	0.0055	0.0159
29	8.10	250	31.2	4	40.66	148.1	0.0034	0.0240
30	8.65	252	31.3	6	2.59	152.1	0.0045	0.0324
31	7.87	191.7	31.9	12	4.70	107.7	0.0111	0.0237
32	7.96	170.3	29.8	84	15.92	97.0	0.0153	0.0152
33	7.32	182	28.0	7134	54.03	208.1	0.0361	0.0151

**Table 2. Rare earth element (REE) anomalies and Y/Ho mass ratio**

Sample number	Sum REE (pg g <sup>-1</sup> )	La Anomaly	Ce Anomaly	Gd Anomaly	Yb <sub>n</sub> /Sm <sub>n</sub>	Y/Ho
1	43.51	1.32	0.50	1.12	1.16	27.93
2	17.01	1.73	0.64	1.10	1.36	34.36
3	27.05	1.16	0.87	1.20	1.37	31.62
4	40.26	1.22	1.28	1.09	2.00	28.14
5	20.16	1.35	1.13	1.13	1.37	32.70
6	13.58	1.09	0.66	1.02	1.40	35.21
7	14.80	1.38	0.99	1.09	1.47	34.50
8	57.80	1.16	0.99	1.06	1.48	26.50
9	516.18	0.89	0.59	1.00	1.29	27.19
10	267.25	0.91	0.57	0.99	1.34	26.83
11	436.09	0.94	0.66	1.01	1.27	26.96
12	391.68	0.93	0.66	1.00	1.30	27.24
13	314.79	1.04	0.83	1.01	1.36	27.19
14	245.27	1.02	0.92	1.00	1.34	26.46
15	85.20	1.07	1.01	1.05	1.52	26.96
16	205.91	1.09	0.67	1.05	1.24	26.34
17	253.39	1.20	0.97	1.10	1.15	26.90
18	60.65	1.21	0.72	1.10	1.24	26.60
19	76.37	1.20	1.30	1.08	1.57	26.23
20	42.79	1.34	1.01	1.17	1.56	28.47
21	35.92	1.62	0.42	1.07	1.90	35.41
22	46.56	1.14	0.98	1.07	1.38	30.20
23	103.51	1.19	0.74	1.07	1.38	30.66
24	24.79	1.18	0.84	1.05	1.70	30.01
25	27.18	1.58	0.93	0.97	2.16	40.28
26	41.94	1.23	0.77	1.07	1.88	39.90
27	45.89	1.41	0.69	1.10	1.38	34.14
28	25.93	1.36	0.76	0.91	2.04	38.68
29	194.48	1.25	0.70	1.23	0.80	44.53
30	40.31	1.48	0.75	1.03	2.12	36.86
31	69.81	1.30	0.72	1.10	1.90	33.37
32	81.55	1.22	0.70	1.05	1.71	30.24
33	68.66	1.19	0.95	13.70	7.42	26.43