Table S1. Trace element concentrations (ppm) of the Niutitang Formation shales.

Lithology	Samples	Li	Be	B	Sc	V	Cr	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Sr	Zr	Nb	Mo	Ag	Cd	In	Sn
Mudstone	KY-1	12.71	1.16	56.01	0.44	1602.12	134.65	0.52	13.52	5.71	32.58	28.30	0.86	7.66	5.97	72.35	274.53	94.69	29.93	5.45	0.28	0.079	10.45
Chert	KY-2.1	3.25	0.12	5.15	0.14	515.74	177.14	0.16	7.99	4.64	22.16	4.36	0.75	7.16	16.21	29.63	20.03	13.05	13.74	2.27	0.03	0.011	0.94
	KY-2.3	2.55	0.12	4.26	0.18	284.30	299.61	0.34	20.06	10.75	39.71	13.59	0.93	14.24	27.32	28.83	11.33	8.11	13.28	3.88	0.09	0.019	0.80
	KY-2.5	0.92	0.06	3.81	0.83	272.26	263.01	0.20	15.89	8.99	21.31	57.32	0.12	4.91	8.76	31.44	22.86	5.47	6.32	1.84	0.04	0.464	0.26
	KY-2.9	3.28	0.11	3.99	0.27	304.76	548.76	0.34	17.53	5.02	30.73	12.22	0.71	10.85	7.44	31.83	11.53	2.29	10.61	3.06	0.06	0.007	0.31
	KY-2.11	2.49	0.13	4.19	0.19	332.55	289.54	0.29	18.31	4.65	45.98	110.00	0.68	26.38	9.18	68.90	9.39	0.74	37.89	2.45	0.28	0.012	0.32
Organic-rich blackshales	KY-2.2	9.13	0.62	21.83	3.13	2682.31	1556.15	0.40	31.63	9.68	30.75	17.68	1.76	11.46	25.18	60.19	97.14	56.92	19.39	9.25	0.11	0.189	4.24
	KY-2.4	8.83	0.68	23.47	3.15	2071.99	1663.77	0.57	38.17	17.23	39.18	15.72	1.72	16.16	24.15	36.61	82.83	47.67	21.66	10.56	0.12	0.145	3.19
	KY-2.6	10.27	0.82	28.16	3.73	2166.38	1780.98	0.43	31.70	8.27	36.30	12.90	1.56	13.67	19.43	15.68	84.64	46.41	16.50	9.99	0.11	0.125	3.08
	KY-2.8	8.86	0.73	22.03	3.67	2188.04	1552.88	0.50	35.68	12.23	62.55	12.15	1.76	19.33	25.82	28.81	87.56	22.44	30.36	11.23	0.15	0.239	2.63
	KY-2.10	7.01	0.60	16.57	2.66	1449.76	1385.28	0.48	31.66	9.16	51.44	12.59	1.07	24.77	20.96	76.41	52.60	0.81	44.39	6.29	0.26	0.079	0.13
Phosphorite	KY-2.7	2.17	0.26	4.83	3.16	340.70	196.16	0.49	27.39	11.79	60.83	21.39	1.11	16.49	22.17	62.12	11.32	5.07	13.24	4.27	0.42	0.015	2.10
Black shale	KY-3	6.38	0.63	24.33	1.46	1561.14	275.37	1.25	26.96	5.34	17.78	17.01	1.18	35.43	27.41	21.82	96.40	10.58	215.01	6.52	0.14	0.034	2.43
	KY-4	8.29	0.59	24.73	2.65	870.43	161.30	3.17	32.17	6.13	29.88	12.62	1.17	29.54	12.57	21.45	102.29	13.24	107.43	3.90	0.14	0.050	2.24
	KY-5	8.11	0.55	20.62	3.01	724.52	259.33	4.17	39.36	10.15	31.54	12.26	1.02	24.35	8.92	30.79	89.33	8.93	101.44	3.32	0.19	1.004	1.92
	KY-6	6.58	0.42	21.37	2.42	310.04	258.12	0.49	9.12	3.43	10.44	13.80	1.17	9.06	13.06	28.50	96.52	11.68	13.95	5.45	0.07	0.079	2.33
	KY-7	7.61	0.56	19.56	2.54	1292.09	179.31	1.57	21.50	11.15	27.19	10.70	1.22	25.51	9.06	17.79	102.62	9.29	50.10	3.72	0.15	0.150	2.08
	KY-34	35.04	1.51	75.87	1.06	1496.46	113.59	1.18	64.28	9.46	22.24	39.56	1.63	9.65	4.00	36.12	125.51	14.91	43.50	1.44	0.31	0.027	2.41
	KY-37	41.77	1.35	44.19	2.67	238.53	73.37	14.49	137.29	38.80	73.25	23.02	1.24	20.38	2.71	52.96	91.79	8.71	81.75	1.00	1.05	0.039	1.54
	KY-43	41.09	1.65	64.87	3.53	735.69	96.68	15.92	161.99	41.03	100.85	28.08	1.58	26.51	4.94	71.02	110.34	11.06	87.08	1.04	2.11	0.066	2.05
Siliceous	KY-8	9.00	0.59	21.75	4.28	440.75	190.27	6.08	48.70	11.90	20.16	12.25	1.20	31.37	7.10	29.38	96.58	11.56	72.93	2.83	0.17	0.050	2.07
	KY-9	8.11	0.53	18.59	2.78	654.88	118.22	4.62	41.47	11.77	27.73	11.12	0.92	31.82	3.21	26.25	80.86	6.84	69.38	2.44	0.20	0.056	1.43
	KY-10	9.39	0.59	22.13	3.90	1250.57	221.41	4.47	40.55	12.05	44.79	12.90	1.28	61.30	5.19	31.30	96.58	12.00	76.13	2.22	0.32	0.062	2.54

	KY-11	8.23	0.51	15.43	8.02	286.97	151.88	5.16	39.75	12.34	24.98	16.42	1.10	41.71	2.28	40.55	105.65	9.57	38.28	2.47	0.14	0.053	13.23
	KY-12	8.50	0.51	21.73	7.04	252.33	140.37	4.44	42.45	12.63	19.12	12.91	1.15	68.03	4.75	39.92	95.26	11.41	40.14	2.07	0.16	0.046	1.63
	KY-13	8.95	0.55	20.45	1.70	962.36	90.29	4.86	43.36	23.71	29.69	9.21	1.02	22.15	2.24	28.40	78.02	8.96	40.61	1.76	0.18	0.053	1.77
	KY-14	9.66	0.60	20.76	4.09	1015.86	113.22	5.87	48.90	10.97	26.87	10.77	1.31	30.32	2.71	30.40	93.13	12.04	78.85	1.70	0.20	0.056	3.84
	KY-15	8.56	0.50	20.57	4.23	334.40	70.49	4.76	44.87	10.19	28.53	8.99	1.09	24.55	2.92	38.03	80.80	9.92	65.19	1.44	0.22	0.047	1.70
	KY-16	8.77	0.49	18.62	4.97	886.63	78.62	4.75	41.66	10.56	241.04	15.72	1.35	18.56	2.59	49.32	91.27	10.21	101.59	1.39	1.92	0.079	1.82
	KY-17	9.01	0.53	20.73	4.38	720.04	236.04	5.36	44.25	11.27	41.31	19.31	1.29	20.39	1.98	40.31	97.59	11.33	73.70	1.45	0.33	0.054	1.72
	KY-39	41.41	1.56	63.35	5.52	191.48	100.35	14.60	124.92	39.84	53.45	29.72	1.29	23.15	2.10	88.27	101.56	20.54	100.27	0.95	0.63	0.043	1.78
	KY-41	42.91	1.43	60.47	2.76	685.90	111.04	12.75	119.03	36.89	70.82	32.66	1.26	32.43	5.75	68.95	99.58	10.01	71.57	1.06	1.03	0.050	1.91
	KY-42	52.96	1.59	68.03	4.54	693.11	117.03	13.56	120.80	35.39	109.47	34.40	1.29	28.32	4.24	89.29	109.17	11.58	90.48	1.09	1.51	0.060	2.12
Carbonaceous shale	KY-18	28.06	1.47	62.08	3.76	465.10	57.02	14.69	110.30	29.60	79.66	31.68	1.21	44.40	2.05	64.46	94.25	9.11	63.95	0.83	0.77	0.059	1.46
	KY-19	32.19	1.76	68.55	6.09	175.81	81.66	14.70	89.36	36.58	42.73	29.46	1.23	38.05	2.21	85.55	94.12	10.93	58.27	0.83	0.45	0.047	2.07
	KY-20	31.07	1.71	59.26	4.66	208.06	64.42	26.69	175.00	48.21	142.59	39.25	1.01	21.44	3.20	79.43	84.49	8.13	68.58	0.77	2.16	0.056	1.52
	KY-21	7.91	0.50	19.32	4.14	122.54	66.56	4.33	38.01	18.99	26.90	7.54	1.09	100.94	4.59	22.53	75.23	10.04	42.61	1.39	0.21	0.042	1.77
	KY-22	7.42	0.52	17.97	7.25	148.74	66.12	6.65	73.70	11.90	134.11	10.23	1.29	15.92	5.98	47.52	69.17	9.98	708.68	1.13	1.27	0.076	1.96
	KY-23	31.31	1.74	57.70	7.06	149.24	64.44	18.79	207.80	39.45	82.17	36.34	1.09	33.95	4.79	90.07	87.26	9.71	245.52	0.90	1.38	0.058	1.58
	KY-24	28.46	1.71	55.65	11.62	139.74	70.58	15.03	152.31	40.51	71.30	34.44	1.07	29.92	5.82	138.15	81.14	10.65	140.17	0.94	0.87	0.056	1.70
	KY-25	29.76	1.69	61.59	9.20	141.12	67.06	15.82	168.40	56.33	73.85	35.66	1.13	34.06	6.87	121.07	87.21	10.71	163.20	0.98	0.82	0.062	1.47
	KY-26	31.57	1.74	61.15	11.04	163.24	88.42	13.96	193.68	45.63	81.58	39.20	1.12	36.93	8.44	126.98	89.76	10.14	172.55	1.22	1.46	0.059	1.89
	KY-27	30.14	1.69	59.43	10.53	223.68	82.09	17.08	259.59	52.07	105.74	41.41	1.16	33.08	7.41	143.74	91.57	9.45	200.57	1.12	1.65	0.054	1.73
	KY-28	31.38	1.58	60.32	3.37	323.33	78.93	15.41	264.84	51.11	64.54	35.66	1.07	42.99	9.36	89.82	87.79	9.21	107.29	1.18	1.05	0.041	1.75
	KY-29	27.81	1.82	58.31	9.60	2150.08	139.13	12.44	245.98	63.14	981.00	37.20	1.21	41.10	14.17	143.99	94.07	10.85	200.56	1.22	11.91	0.125	2.04
	KY-30	31.64	1.69	60.91	4.05	373.82	83.19	14.91	191.27	38.04	53.33	30.83	1.07	26.08	6.82	81.85	92.28	6.47	134.71	1.21	0.99	0.048	1.30
	KY-31	35.55	1.53	61.44	5.18	154.56	78.98	14.81	132.98	37.15	39.16	27.63	1.06	20.06	4.15	73.34	94.07	7.55	65.69	1.21	0.61	0.046	1.13
	KY-32	40.48	1.73	62.97	6.08	375.16	77.32	19.72	194.50	45.43	70.17	27.65	1.18	24.39	4.27	82.28	95.28	15.81	80.85	1.26	1.49	0.058	1.81

	KY-33	44.18	1.56	59.28	6.66	376.88	77.29	17.56	266.58	41.22	79.36	28.96	1.29	27.00	6.00	84.22	106.21	10.21	121.68	1.15	0.97	0.050	1.48
	KY-35	45.21	1.51	62.18	2.38	1873.63	103.15	11.13	182.61	44.37	1227.53	30.39	1.41	26.34	7.58	61.61	108.09	9.28	85.58	1.46	16.44	0.095	1.82
	KY-36	46.39	1.58	65.44	3.01	364.75	101.96	17.32	217.83	39.84	74.30	27.39	1.45	27.12	4.39	63.45	116.49	9.58	99.36	1.22	0.91	0.058	1.72
	KY-38	45.60	1.56	63.87	3.54	238.68	105.54	14.64	137.62	39.71	46.97	30.60	1.35	26.27	2.69	64.75	92.45	8.54	101.76	0.98	0.65	0.064	1.61
	KY-40	31.76	1.50	55.19	11.90	287.23	73.43	12.02	123.89	27.93	47.11	32.89	1.48	22.46	2.26	191.70	101.57	10.93	76.27	0.94	0.66	0.044	1.59
average		20.56	1.00	38.02	4.34	722.08	276.07	8.23	94.51	24.16	95.26	24.83	1.18	27.55	8.59	61.89	87.72	13.87	90.84	2.67	1.13	0.09	2.20
average (Member 1)		5.96	0.45	16.19	1.79	1184.24	820.66	0.39	24.13	9.01	39.46	26.52	1.09	14.42	17.72	45.23	63.81	25.31	21.44	5.88	0.16	0.12	2.37
average (Member 2)		8.34	0.54	20.76	3.83	770.87	169.62	4.07	37.67	10.91	41.40	13.06	1.17	31.61	7.07	31.61	93.53	10.50	76.32	2.84	0.30	0.12	2.85
average (Member 3)		34.35	1.53	58.05	5.81	480.64	86.13	14.24	159.79	38.79	152.08	30.84	1.24	31.27	5.26	87.04	95.40	10.54	131.25	1.10	2.05	0.06	1.74

Table S2. Trace element concentrations (ppm) of the Niutitang Formation shales.

Lithology	Samples	Sb	Cs	Ba	Hf	Ta	W	Re	Au	Tl	Pb	Bi	Th	U	Ni/Co	V/(V+Ni)	V/Cr	Mo/TOC	Ba-bio	Ni+Cu+Zn
Mudstone	KY-1	2.07	18.05	4309.40	32.57	5.82	0.27	0.13	0.08	1.30	12.23	0.28	5.36	26.02	26.24	0.99	11.90	13.11	3385.65	51.81
Chert	KY-2.1	2.42	1.77	768.20	1.41	0.41	0.31	0.03	0.00	0.07	8.19	0.03	1.95	6.07	49.65	0.98	2.91	7.67	697.48	34.79
	KY-2.3	2.13	1.10	2025.30	0.63	0.12	0.48	0.02	0.00	0.04	10.96	0.02	1.38	5.46	58.66	0.93	0.95	3.37	1968.80	70.52
	KY-2.5	0.31	1.01	8846.90	1.23	0.01	0.19	0.02	0.00	0.03	3.06	0.01	1.13	3.36	79.83	0.94	1.04	1.18	8790.76	46.19
	KY-2.9	0.96	1.24	2609.90	6.02	0.10	0.31	0.04	0.01	0.06	1.16	0.05	1.62	5.16	51.51	0.95	0.56	1.54	2549.02	53.29
	KY-2.11	1.08	1.33	17968.30	1.72	0.14	0.22	0.03	0.00	0.09	1.03	0.02	1.93	9.42	64.17	0.95	1.15	6.60	17880.08	68.94
Organic-rich blackshales	KY-2.2	1.82	9.98	2118.20	5.27	0.59	1.12	0.14	0.00	0.31	17.65	0.13	4.99	27.40	79.05	0.99	1.72	1.97	1822.56	72.06
	KY-2.4	1.71	10.78	1790.60	5.74	0.73	1.33	0.14	0.00	0.33	8.48	0.11	4.25	27.44	66.41	0.98	1.25	2.28	1463.97	94.58
	KY-2.6	1.53	12.31	1356.70	5.34	0.77	1.37	0.16	0.00	0.39	4.72	0.11	4.86	28.15	73.25	0.99	1.22	1.60	993.62	76.26
	KY-2.8	2.31	10.63	1336.85	5.04	0.54	1.02	0.16	0.00	0.39	5.96	0.11	5.17	28.61	71.70	0.98	1.41	3.05	1015.14	110.45
	KY-2.10	1.51	7.54	1671.60	3.97	0.09	0.30	0.13	0.00	0.33	3.22	0.09	3.22	43.87	65.66	0.98	1.05	4.62	1381.42	92.26
Phosphorite	KY-2.7	1.92	1.50	5459.60	1.04	0.21	0.79	0.06	0.00	0.05	2.18	0.02	2.84	47.67	55.44	0.93	1.74	2.07	5394.35	100.01
Black shale	KY-3	1.43	11.05	3305.30	6.41	0.43	1.57	0.20	0.00	2.80	6.46	0.11	4.03	35.50	21.51	0.98	5.67	37.48	2794.94	50.08

	KY-4	1.16	9.37	3180.50	6.48	0.95	1.64	0.09	0.00	1.93	5.83	0.10	3.95	35.82	10.14	0.96	5.40	18.52	2696.39	68.18
	KY-5	0.94	8.23	3096.50	5.98	0.64	1.06	0.10	0.00	1.89	5.13	0.09	4.34	36.09	9.44	0.95	2.79	21.01	2653.58	81.05
	KY-6	2.89	9.97	2777.60	6.79	0.96	1.51	0.03	0.00	1.55	15.68	0.07	3.52	20.03	18.53	0.97	1.20	2.77	2340.51	23.00
	KY-7	0.90	9.91	2455.30	6.74	0.41	1.17	0.08	0.00	1.41	5.17	0.09	5.87	34.03	13.70	0.98	7.21	10.28	2001.81	59.85
	KY-34	4.26	9.71	1340.70	7.99	1.15	1.92	0.26	0.07	7.04	11.69	0.24	7.69	33.60	54.61	0.96	13.17	8.06	820.13	95.99
	KY-37	1.59	6.90	1120.90	6.72	0.72	1.07	0.03	0.04	2.38	12.34	0.16	4.19	59.68	9.47	0.63	3.25	17.47	639.70	249.34
	KY-43	2.47	5.84	1010.40	7.77	0.96	1.57	0.09	0.06	4.85	13.54	0.25	5.16	42.96	10.17	0.82	7.61	22.27	523.74	303.87
Siliceous	KY-8	1.15	7.89	2545.90	6.44	0.94	1.38	0.08	0.00	1.82	5.63	0.09	8.36	48.65	8.01	0.90	2.32	14.37	2121.21	80.76
	KY-9	0.68	7.89	2721.60	5.92	0.52	0.79	0.08	0.00	1.51	4.69	0.09	6.30	41.73	8.97	0.94	5.54	14.77	2301.83	80.97
	KY-10	0.95	7.40	4079.30	6.67	0.93	1.47	0.10	0.00	1.48	4.42	0.08	6.58	40.60	9.07	0.97	5.65	17.44	3646.22	97.39
	KY-11	0.70	9.30	2493.40	7.33	0.94	1.48	0.03	0.00	1.01	5.43	0.07	12.78	42.16	7.71	0.88	1.89	9.91	2092.40	77.06
	KY-12	0.97	7.03	2739.30	6.40	0.92	1.56	0.02	0.00	0.94	5.81	0.07	10.69	44.28	9.56	0.86	1.80	10.13	2341.22	74.21
	KY-13	0.57	7.53	3004.90	5.62	0.56	0.91	0.08	0.00	1.27	4.27	0.07	4.34	35.18	8.93	0.96	10.66	9.71	2562.35	96.77
	KY-14	0.71	8.25	2441.70	6.68	0.96	1.69	0.13	0.00	1.84	6.23	0.08	5.47	41.95	8.33	0.95	8.97	16.48	1992.58	86.73
	KY-15	0.53	7.28	4610.70	6.01	0.83	1.51	0.05	0.00	1.36	3.60	0.06	5.93	43.45	9.43	0.88	4.74	14.11	4171.43	83.59
	KY-16	0.43	8.10	33149.30	6.39	0.95	1.67	0.12	0.00	1.51	2.65	0.07	6.98	33.22	8.77	0.96	11.28	23.29	32712.58	293.27
	KY-17	0.47	8.51	14715.70	6.46	0.92	1.49	0.10	0.00	1.49	3.12	0.07	6.01	35.77	8.26	0.94	3.05	15.92	14277.16	96.83
	KY-39	0.89	6.57	1287.20	6.42	0.72	2.38	0.04	0.05	2.93	15.16	0.20	16.55	67.29	8.55	0.61	1.91	20.01	826.97	218.21
	KY-41	2.59	6.27	1259.20	7.32	0.79	1.42	0.03	0.06	2.12	14.34	0.21	3.86	34.34	9.33	0.85	6.18	15.78	785.66	226.73
	KY-42	2.69	5.05	1438.60	7.22	0.87	1.54	0.06	0.06	2.89	13.50	0.21	6.68	35.06	8.91	0.85	5.92	26.00	959.96	265.66
Carbonaceous shale	KY-18	1.36	7.34	2215.60	6.49	0.84	1.04	0.07	0.06	4.31	11.60	0.25	13.80	32.71	7.51	0.81	8.16	12.96	1765.39	219.56
	KY-19	1.36	7.44	1342.85	6.27	0.88	1.41	0.01	0.08	2.57	15.42	0.24	18.75	30.50	6.08	0.66	2.15	12.51	894.65	168.68
	KY-20	1.06	5.59	2452.50	5.66	0.61	0.89	0.03	0.10	3.40	12.08	0.26	14.89	34.68	6.56	0.54	3.23	13.24	2012.13	365.80
	KY-21	0.54	6.43	1500.30	5.62	0.84	1.26	0.01	0.00	0.71	7.01	0.05	7.02	30.71	8.79	0.76	1.84	8.75	1094.56	83.90
	KY-22	1.08	9.08	1171.90	5.25	0.86	1.53	0.17	0.00	2.91	4.32	0.11	10.98	77.51	11.08	0.67	2.25	126.82	817.20	219.71

	KY-23	2.49	6.39	1874.10	5.86	0.81	1.17	0.06	0.13	5.42	15.21	0.67	23.33	40.25	11.06	0.42	2.32	36.10	1443.58	329.42
	KY-24	2.28	7.99	1473.20	5.25	0.82	1.33	0.03	0.09	3.83	14.34	0.31	25.20	53.17	10.13	0.48	1.98	23.22	1088.97	264.12
	KY-25	2.93	8.34	1449.10	5.59	0.79	1.14	0.03	0.12	3.67	15.46	0.38	24.20	52.57	10.65	0.46	2.10	24.15	1046.65	298.57
	KY-26	3.64	7.68	1671.80	6.62	0.84	1.30	0.04	0.08	3.07	15.90	0.29	29.38	67.89	13.88	0.46	1.85	25.60	1261.69	320.89
	KY-27	4.14	7.19	1692.40	5.62	0.73	1.24	0.22	0.08	5.40	15.36	0.37	26.86	66.82	15.20	0.46	2.72	30.07	1289.95	417.40
	KY-28	4.20	4.25	1808.30	6.28	0.72	1.08	0.04	0.06	4.69	13.86	0.28	7.41	48.99	17.19	0.55	4.10	13.94	1363.19	380.48
	KY-29	3.81	7.23	1543.30	6.57	0.86	1.24	0.25	0.06	5.93	10.22	0.23	27.92	103.33	19.78	0.90	15.45	42.76	1126.45	1290.11
	KY-30	3.17	5.81	1322.10	6.14	0.44	0.76	0.08	0.04	5.49	12.66	0.24	13.34	61.73	12.83	0.66	4.49	21.58	874.44	282.64
	KY-31	2.03	5.31	1432.90	5.88	0.55	0.79	0.01	0.06	1.97	14.72	0.23	14.45	53.01	8.98	0.54	1.96	10.82	989.25	209.28
	KY-32	2.35	5.37	1112.40	6.09	0.66	1.03	0.05	0.06	3.73	13.96	0.28	22.62	57.22	9.86	0.66	4.85	13.81	682.60	310.11
	KY-33	3.59	5.85	1237.20	6.94	0.78	1.32	0.06	0.07	5.10	12.81	0.23	20.44	62.38	15.18	0.59	4.88	16.98	822.35	387.15
	KY-35	3.24	6.56	1204.90	6.92	0.69	0.99	0.25	0.06	5.81	11.33	0.22	5.96	42.53	16.41	0.91	18.16	20.41	729.54	1454.50
	KY-36	2.97	7.42	1133.90	7.57	0.76	1.26	0.09	0.06	5.26	12.83	0.23	4.40	68.75	12.58	0.63	3.58	20.73	650.15	331.97
	KY-38	1.04	6.28	1248.00	6.74	0.66	1.37	0.03	0.04	2.80	13.74	0.18	7.72	64.92	9.40	0.63	2.26	18.43	769.36	224.30
	KY-40	1.71	8.93	1327.00	7.40	1.00	1.87	0.04	0.05	3.04	10.57	0.13	28.91	120.37	10.31	0.70	3.91	16.33	935.85	198.93
average		1.84	7.20	3306.59	6.31	0.79	1.18	0.08	0.03	2.42	9.38	0.16	9.92	42.83	23.33	0.81	4.44	17.06	2910.63	213.93
average (Member 1)		1.65	6.44	4188.46	5.83	0.79	0.64	0.09	0.01	0.28	6.57	0.08	3.22	21.55	61.80	0.97	2.24	4.09	3856.75	72.60
average (Member 2)		0.97	8.51	5821.13	6.42	0.79	1.39	0.09	0.00	1.59	5.61	0.08	6.34	37.90	10.69	0.94	5.21	15.75	5380.41	89.98
average (Member 3)		2.44	6.80	1448.88	6.47	0.78	1.30	0.08	0.06	3.90	12.85	0.25	15.06	55.50	12.87	0.66	5.01	23.80	1008.23	350.67

Table S3. Race earth element concentrations (ppm) of the Niutitang Formation shales.

Lithology	Samples	La	Ce	Pr	Nd	Sm	Eu	Gd	Tb	Dy	Y	Ho	Er	Tm	Yb	Lu	Ce/Ce*	Eu/Eu*	Y/Y*	Pr/Pr*	Y/Ho	La_N/Yb_N	Er/Nd	∑REY
Mudstone	KY-1	9.52	24.19	3.17	12.81	3.64	0.42	2.90	0.57	4.15	17.38	0.96	3.09	0.49	3.20	0.45	1.00	0.60	0.70	1.05	18.19	0.22	0.24	86.95
Chert	KY-2.1	4.46	8.14	1.21	5.44	1.74	0.15	1.58	0.25	1.46	6.15	0.28	0.80	0.11	0.69	0.10	0.80	0.43	0.76	1.05	21.66	0.48	0.15	32.57
	KY-2.3	3.11	4.37	0.81	3.54	1.29	0.38	1.15	0.18	1.10	6.04	0.22	0.64	0.09	0.55	0.08	0.63	1.49	0.97	1.15	26.91	0.42	0.18	23.57
	KY-2.5	3.11	4.31	0.75	3.15	2.22	1.13	0.80	0.13	0.79	6.24	0.17	0.51	0.07	0.47	0.07	0.65	3.67	1.37	1.16	37.41	0.48	0.16	23.93
	KY-2.9	2.18	2.28	0.32	1.26	0.60	0.29	0.31	0.04	0.26	1.82	0.06	0.21	0.04	0.25	0.04	0.61	3.13	1.11	1.11	28.45	0.66	0.17	9.97
	KY-2.11	10.99	18.43	4.01	17.94	7.25	3.09	5.32	0.74	4.31	43.25	0.97	2.73	0.32	1.55	0.20	0.62	2.34	1.68	1.19	44.41	0.53	0.15	121.10
Organic-rich blackshales	KY-2.2	14.53	20.59	3.28	13.35	3.44	0.54	3.59	0.64	4.36	28.27	0.96	2.97	0.47	2.97	0.44	0.69	0.72	1.10	1.14	29.46	0.36	0.22	100.41
	KY-2.4	12.83	15.33	2.43	9.17	2.03	0.45	2.10	0.40	2.96	22.62	0.72	2.36	0.37	2.56	0.39	0.63	1.03	1.23	1.19	31.50	0.37	0.26	76.73
	KY-2.6	13.08	14.02	2.12	7.59	1.48	0.33	1.47	0.28	2.17	18.08	0.55	1.93	0.32	2.27	0.35	0.60	1.06	1.31	1.20	32.61	0.43	0.25	66.04
	KY-2.10	22.69	33.13	6.95	30.31	7.02	1.81	9.76	1.53	10.16	94.92	2.41	7.23	0.95	5.37	0.74	0.60	1.00	1.53	1.20	39.39	0.31	0.24	234.97
	KY-2.8	13.45	13.86	2.09	7.43	1.52	0.34	1.55	0.28	2.01	16.38	0.50	1.70	0.27	1.91	0.30	0.59	1.04	1.30	1.20	33.03	0.52	0.23	63.58
Phosphorite	KY-2.7	39.17	64.90	15.66	73.92	19.26	4.51	27.53	4.14	24.78	218.29	5.27	14.62	1.78	9.35	1.22	0.58	0.89	1.52	1.18	41.41	0.31	0.20	524.40
Black shale	KY-3	10.14	17.15	2.02	6.86	1.37	0.42	1.03	0.16	1.10	6.75	0.26	0.92	0.15	1.05	0.17	0.87	1.67	1.00	1.09	25.53	0.71	0.13	49.56
	KY-4	9.38	19.27	2.35	8.80	1.72	0.40	1.46	0.22	1.47	8.28	0.34	1.11	0.18	1.19	0.18	0.95	1.19	0.94	1.06	24.48	0.58	0.13	56.34
	KY-5	9.22	19.76	2.52	10.19	2.37	0.57	2.22	0.35	2.15	11.90	0.47	1.47	0.22	1.44	0.21	0.94	1.17	0.94	1.04	25.14	0.47	0.14	65.08
	KY-6	9.36	19.29	2.46	9.08	1.72	0.44	1.34	0.18	1.15	6.72	0.26	0.87	0.14	0.94	0.15	0.93	1.35	0.98	1.09	26.13	0.74	0.10	54.09
	KY-7	10.91	21.48	2.73	10.24	2.03	0.44	1.83	0.28	1.79	10.24	0.39	1.30	0.20	1.31	0.20	0.91	1.06	0.97	1.08	25.92	0.62	0.13	65.36
	KY-34	12.01	23.85	2.83	10.17	1.67	0.46	1.36	0.18	1.13	5.43	0.26	0.85	0.14	0.90	0.14	0.94	1.44	0.79	1.07	20.74	0.98	0.08	61.38
	KY-37	5.64	15.01	1.85	7.79	1.88	0.48	1.90	0.30	1.86	7.68	0.39	1.21	0.18	1.15	0.17	1.06	1.20	0.72	1.00	19.59	0.36	0.15	47.49
	KY-43	8.50	21.81	2.83	11.99	2.87	0.72	3.02	0.48	2.98	12.61	0.63	1.87	0.26	1.70	0.25	1.01	1.15	0.74	1.02	20.07	0.37	0.16	72.53
Siliceous	KY-8	13.32	27.68	3.61	14.44	3.36	0.77	3.29	0.49	2.90	15.96	0.61	1.87	0.28	1.81	0.27	0.92	1.09	0.96	1.06	26.26	0.54	0.13	90.67
	KY-9	11.86	25.52	3.22	13.04	2.93	0.69	2.90	0.43	2.56	14.06	0.53	1.61	0.24	1.54	0.23	0.95	1.10	0.96	1.03	26.61	0.57	0.12	81.35
	KY-10	12.09	25.56	3.37	13.74	3.33	0.80	3.24	0.49	2.86	15.35	0.59	1.76	0.26	1.65	0.25	0.92	1.14	0.94	1.05	26.00	0.54	0.13	85.34

	KY-11	20.53	40.02	5.07	19.93	4.36	1.09	4.35	0.64	3.79	24.30	0.80	2.42	0.35	2.28	0.34	0.90	1.18	1.11	1.05	30.25	0.66	0.12	130.27
	KY-12	16.01	33.22	4.40	17.94	4.10	0.99	4.16	0.63	3.75	22.24	0.79	2.39	0.35	2.27	0.34	0.91	1.12	1.03	1.05	28.07	0.52	0.13	113.60
	KY-13	10.48	23.56	3.03	12.20	2.76	0.65	2.70	0.41	2.49	12.85	0.52	1.56	0.23	1.50	0.22	0.96	1.13	0.90	1.05	24.67	0.51	0.13	75.15
	KY-14	10.22	23.50	2.94	12.08	2.83	0.69	2.78	0.43	2.57	13.20	0.54	1.63	0.24	1.57	0.24	0.98	1.16	0.90	1.02	24.63	0.48	0.13	75.44
	KY-15	10.61	24.46	3.19	12.85	2.92	0.69	2.91	0.44	2.62	14.36	0.56	1.66	0.25	1.61	0.25	0.96	1.11	0.95	1.05	25.73	0.49	0.13	79.37
	KY-16	12.47	28.00	3.71	15.74	4.04	1.03	3.84	0.55	3.12	17.21	0.63	1.85	0.26	1.69	0.26	0.94	1.22	0.98	1.03	27.33	0.55	0.12	94.40
	KY-17	11.91	25.42	3.29	13.35	3.36	0.94	3.10	0.45	2.66	14.31	0.55	1.63	0.24	1.55	0.24	0.93	1.36	0.95	1.05	26.16	0.57	0.12	83.00
	KY-39	19.21	40.63	4.94	19.68	3.78	0.88	3.89	0.55	3.27	17.72	0.70	2.14	0.31	2.03	0.30	0.96	1.07	0.94	1.03	25.48	0.70	0.11	120.04
	KY-41	5.49	14.11	1.80	7.52	1.91	0.56	1.81	0.29	1.84	8.12	0.40	1.24	0.18	1.18	0.18	1.02	1.42	0.76	1.02	20.54	0.34	0.16	46.62
	KY-42	10.86	26.59	3.39	13.61	2.97	0.74	2.90	0.44	2.72	12.12	0.57	1.77	0.26	1.70	0.26	1.00	1.19	0.78	1.05	21.16	0.47	0.13	80.92
Carbonaceous shale	KY-18	15.13	34.53	3.94	15.53	3.35	0.82	3.21	0.44	2.59	12.24	0.54	1.61	0.23	1.48	0.23	1.03	1.17	0.83	1.00	22.82	0.75	0.10	95.86
	KY-19	18.73	40.23	5.20	20.78	4.21	0.96	4.20	0.59	3.39	17.17	0.69	2.10	0.30	2.02	0.30	0.94	1.07	0.89	1.05	24.71	0.69	0.10	120.89
	KY-20	14.62	34.44	4.32	18.38	4.63	1.18	4.77	0.71	4.05	19.97	0.83	2.42	0.36	2.18	0.33	0.99	1.18	0.87	1.00	23.92	0.49	0.13	113.21
	KY-21	12.07	24.79	3.10	11.75	2.37	0.54	2.44	0.36	2.14	11.73	0.45	1.37	0.20	1.35	0.20	0.93	1.05	0.95	1.07	25.94	0.66	0.12	74.86
	KY-22	28.56	56.32	7.67	33.39	8.03	1.90	8.29	1.14	6.23	39.95	1.23	3.40	0.45	2.74	0.39	0.88	1.09	1.15	1.03	32.54	0.77	0.10	199.67
	KY-23	17.94	37.99	4.99	20.20	4.48	1.16	4.52	0.67	3.69	18.41	0.78	2.23	0.34	2.01	0.32	0.92	1.21	0.87	1.05	23.73	0.66	0.11	119.73
	KY-24	28.20	55.76	7.05	28.90	6.12	1.43	6.28	0.88	5.07	30.04	1.04	3.07	0.44	2.79	0.42	0.91	1.08	1.04	1.03	28.86	0.75	0.11	177.49
	KY-25	28.09	56.32	6.79	27.34	5.48	1.29	5.73	0.78	4.44	26.66	0.92	2.79	0.40	2.54	0.39	0.94	1.08	1.05	1.02	28.89	0.82	0.10	169.96
	KY-26	28.17	59.75	7.44	31.02	6.63	1.55	6.92	0.96	5.57	33.34	1.14	3.37	0.46	2.98	0.44	0.95	1.07	1.06	1.01	29.36	0.70	0.11	189.72
	KY-27	30.19	62.85	7.80	33.00	6.90	1.64	7.15	0.99	5.55	33.37	1.14	3.39	0.46	2.90	0.44	0.94	1.10	1.06	1.00	29.23	0.77	0.10	197.78
	KY-28	10.20	23.89	2.88	11.37	2.39	0.62	2.28	0.34	2.13	9.30	0.45	1.40	0.21	1.38	0.21	1.01	1.25	0.75	1.03	20.48	0.55	0.12	69.06
	KY-29	32.72	72.47	11.00	52.70	12.61	2.93	12.68	1.70	9.29	54.55	1.83	5.00	0.64	3.75	0.54	0.87	1.09	1.05	1.01	29.77	0.64	0.09	274.42
	KY-30	17.10	35.14	4.40	17.24	3.47	0.80	3.46	0.49	2.80	14.73	0.58	1.78	0.26	1.68	0.25	0.93	1.09	0.92	1.05	25.41	0.75	0.10	104.19
	KY-31	17.22	39.70	4.35	16.83	3.22	0.77	3.46	0.49	2.98	16.25	0.63	1.96	0.29	1.91	0.30	1.06	1.07	0.95	0.99	25.89	0.66	0.12	110.36
	KY-32	19.75	43.89	5.24	21.59	4.57	1.06	5.10	0.72	4.19	25.07	0.87	2.62	0.37	2.34	0.36	0.99	1.02	1.05	1.00	28.76	0.62	0.12	137.73

	KY-33	22.68	44.81	5.63	22.00	4.32	1.01	4.59	0.65	3.81	20.65	0.79	2.43	0.35	2.25	0.33	0.91	1.06	0.95	1.05	26.10	0.74	0.11	136.29
	KY-35	8.65	19.86	2.55	10.49	2.47	0.62	2.52	0.40	2.42	11.21	0.51	1.51	0.23	1.41	0.21	0.97	1.16	0.81	1.03	22.16	0.45	0.14	65.05
	KY-36	7.19	17.26	2.22	8.99	2.10	0.56	2.17	0.34	2.11	9.08	0.44	1.36	0.21	1.31	0.20	0.99	1.22	0.75	1.04	20.52	0.41	0.15	55.53
	KY-38	10.88	25.03	3.19	13.01	2.85	0.69	2.78	0.41	2.47	11.91	0.52	1.58	0.23	1.46	0.22	0.97	1.15	0.84	1.03	22.79	0.55	0.12	77.22
	KY-40	40.21	80.27	11.93	56.39	13.81	3.57	15.00	2.00	10.76	65.59	2.05	5.59	0.71	4.21	0.61	0.84	1.16	1.11	1.01	31.97	0.71	0.10	312.70

$Ce/Ce^* = 2Ce_N/(La + Nd)_N$, $Eu/Eu^* = 2Eu_N/(Sm+Gd)_N$, $Pr/Pr^* = 2Pr_N/(Ce + Nd)_N$, $Y/Y^* = 2Y_N/(Dy + Ho)_N$, where N referred to normalization of concentrations against the shale standard PAAS **Error! Reference source not found.**.