

Article

Uranium Mineralization in the MacInnis Lake Area, Nonacho Basin, Northwest Territories: Potential Linkages to Metasomatic Iron Alkali-Calcic Systems

Kerstin Landry ¹, Erin Adlakha ^{1,*}, Andree Roy-Garand ¹, Anna Terekhova ¹, Jacob Hanley ¹, Hendrik Falck ² and Edith Martel ²

¹ Department of Geology, Saint Mary's University, 923 Robie St., Halifax, NS B3H 3C3, Canada

² Northwest Territories Geological Survey, 4601-B 52 Avenue, Yellowknife, NT X1A 1K3, Canada

* Correspondence: erin.adlakha@smu.ca

Supplementary Materials

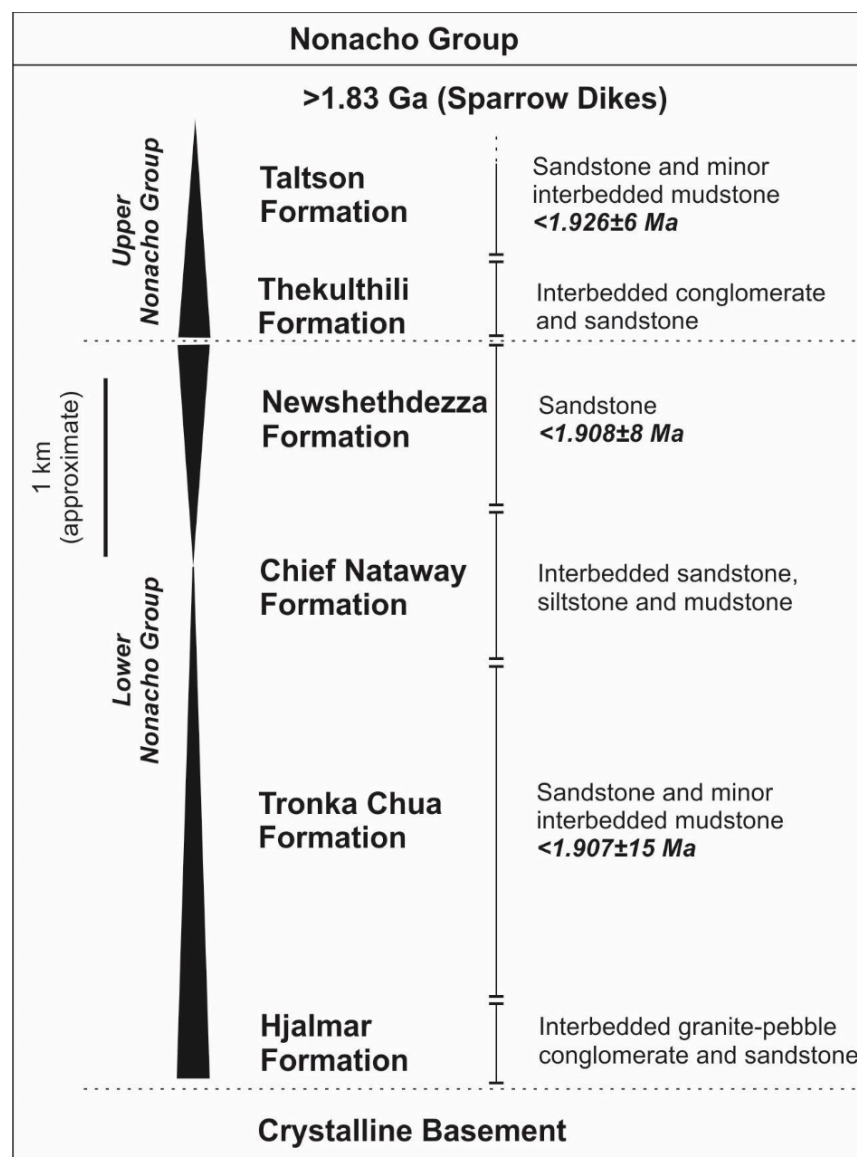


Figure S1. Generalized stratigraphic sequence of the Nonacho Group sediments after [34]. Vertical black bars reflect relative grain size variation (fining and coarsening upward sequences) with divisions into lower and upper Nonacho Group. Dashed lines indicate the stratigraphic location of unconformities. Minimum ages for select units are measured from youngest detrital zircons [33]. Absolute maximum age for Nonacho Group sediments is constricted by the 1.83 Ga Sparrow Dikes [37]. Figure modified after [29,33].

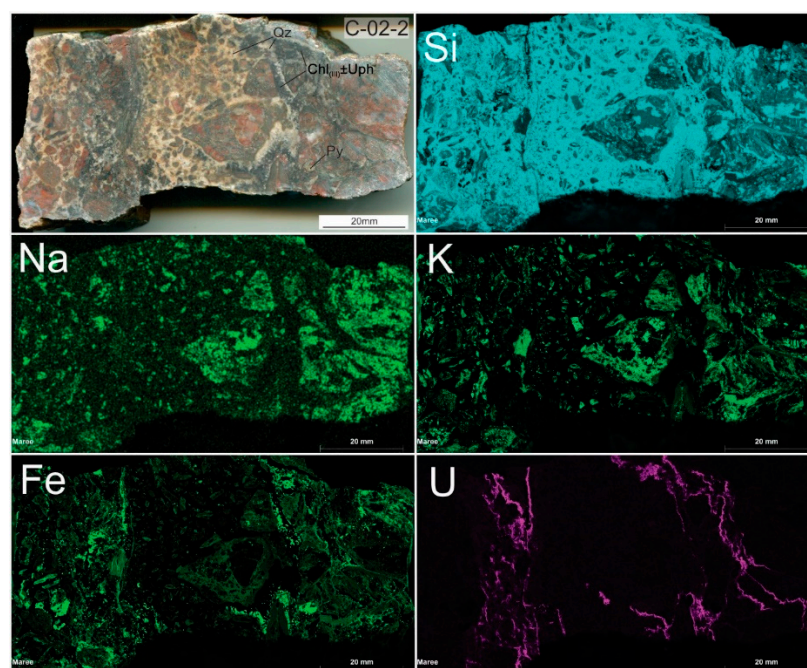


Figure S2. XRF false-colour elemental maps from sample C-02-2, a uranophane (Uph) mineralized quartz (Qz) breccia at the Cole occurrence. Abbreviations: chlorite (Chl), pyrite (Py).

Table S1. Abundance of major oxides in chlorite (wt.%) and their atomic proportions (based on 14O) from Type-III and Type-IV chlorite at MacInnis Lake occurrences, used to determine temperature (T in °C).

Showing Sample	Cole						Welch								Kult-82									
	C-02-2						W-01-1 1								K82-C1			K82-05						
ap- fu ^a	SiO ₂	25.35	25.60	25.68	25.56	25.44	25.85	25.82	25.58	25.31	26.91	25.36	25.87	25.95	26.11	25.56	25.44	25.85	25.46	25.40	25.25	25.76	25.62	25.39
	TiO ₂	0.06	0.09	0.09	0.02	0.08	0.07	0.08	0.18	0.11	0.12	0.10	0.08	0.04	0.05	0.02	0.08	0.07	0.08	0.09	0.11	0.15	0.10	0.10
	Al ₂ O ₃	19.51	19.27	19.19	18.94	18.75	18.85	18.17	18.49	18.36	18.25	18.29	17.84	18.37	18.21	18.94	18.75	18.85	19.00	18.75	18.95	18.98	18.80	19.03
	Cr ₂ O ₃	0.00	0.00	0.02	0.03	0.01	0.00	0.00	0.05	0.00	0.00	0.04	0.05	0.04	0.06	0.03	0.01	0.00	0.02	0.00	0.01	0.00	0.00	0.01
	NiO	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.02	0.00	0.03	0.00	0.01	0.00	0.01	0.00	0.00	0.00	0.00	0.03	0.02	0.01	0.00
	FeO	34.99	34.67	35.81	36.02	35.75	35.47	35.92	35.68	36.15	31.38	38.01	34.75	35.19	32.80	36.02	35.75	35.47	36.27	36.70	37.33	36.41	36.05	36.82
	MnO	0.57	0.63	0.61	0.57	0.63	0.59	1.66	1.72	1.64	2.19	1.15	1.65	1.71	2.39	0.57	0.63	0.59	0.62	0.57	0.57	0.58	0.60	0.60
	MgO	9.21	9.35	8.80	8.23	8.51	8.57	8.19	8.09	7.97	10.10	6.86	9.04	7.94	9.64	8.23	8.51	8.57	8.29	8.01	7.61	8.08	8.35	7.72
	CaO	0.01	0.02	0.00	0.00	0.03	0.04	0.00	0.01	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.03	0.02	0.03	0.02	0.04	0.01
	Na ₂ O	0.04	0.05	0.00	0.15	0.17	0.19	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.15	0.17	0.19	0.11	0.17	0.07	0.20	0.10
T	K ₂ O	0.00	0.02	0.00	0.07	0.04	0.04	0.01	0.02	0.00	0.08	0.00	0.02	0.09	0.02	0.07	0.04	0.04	0.04	0.05	0.03	0.02	0.00	0.01
	SrO	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.00	0.00	0.00	0.00
	F	0.60	0.00	0.00	0.00	0.00	0.00	0.00	0.20	0.00	0.00	0.00	0.00	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.30	0.00	0.20	0.20
	Cl	0.00	0.01	0.01	0.02	0.01	0.00	0.00	0.01	0.01	0.01	0.00	0.00	0.00	0.01	0.01	0.02	0.01	0.03	0.01	0.00	0.02	0.01	0.01

O	Al	1.2 6	1.2 2	1.2 1	1.2 0	1.2 1	1.1 8		1.1 7	1.2 1	1.2 0	1.0 9	1.1 9	1.1 7	1.1 6	1.1 6		1.2 0	1.2 1	1.1 8		1.22	1.21	1.23	1.19	1.20	1.22
	Su m	4.0 0	4.0 0	4.0 0	4.0 0	4.0 0	4.0 0		4.0 0	4.0 0	4.0 0	4.0 0	4.0 0	4.0 0	4.0 0	4.0 0		4.0 0	4.0 0	4.0 0		4.00	4.00	4.00	4.00	4.00	4.00
	Al	1.2 2	1.2 4	1.2 4	1.2 5	1.2 2	1.2 4		1.1 8	1.1 7	1.1 8	1.2 3	1.2 0	1.1 4	1.2 1	1.1 8		1.2 5	1.2 2	1.2 4		1.23	1.22	1.21	1.24	1.22	1.24
	Fe	3.1 6	3.1 5	3.2 5	3.3 0	3.2 8	3.2 4		3.3 0	3.2 6	3.3 4	2.8 4	3.5 2	3.1 8	3.2 2	2.9 9		3.3 0	3.2 8	3.2 4		3.32	3.37	3.42	3.32	3.29	3.37
	Mg	1.4 8	1.5 1	1.4 2	1.3 4	1.3 9	1.3 9		1.3 4	1.3 2	1.3 1	1.6 3	1.1 3	1.4 8	1.3 0	1.5 7		1.3 4	1.3 9	1.3 9		1.35	1.31	1.24	1.31	1.36	1.26
	Mn	0.0 5	0.0 6	0.0 6	0.0 5	0.0 6	0.0 5		0.1 5	0.1 6	0.1 5	0.2 0	0.1 1	0.1 5	0.1 6	0.2 2		0.0 5	0.0 6	0.0 5		0.06	0.05	0.05	0.05	0.06	0.06
	su m	5.9 1	5.9 6	5.9 7	5.9 4	5.9 5	5.9 3		5.9 8	5.9 0	5.9 9	5.9 0	5.9 7	5.9 6	5.8 9	5.9 5		5.9 4	5.9 5	5.9 3		5.96	5.95	5.92	5.92	5.92	5.92
OH	vac	0.0 9	0.0 4	0.0 3	0.0 6	0.0 5	0.0 7		0.0 2	0.1 0	0.0 1	0.1 0	0.0 3	0.0 4	0.1 1	0.0 5		0.0 6	0.0 5	0.0 7		0.04	0.05	0.08	0.08	0.08	0.08
	F	0.1 0	0.0 0	0.0 0	0.0 0	0.0 0	0.0 0		0.0 0	0.0 7	0.0 0	0.0 0	0.0 0	0.0 3	0.0 0	0.0 0		0.0 0	0.0 0	0.0 0		0.00	0.00	0.05	0.00	0.04	0.04
	Cl	0.0 0	0.0 0	0.0 0	0.0 0	0.0 0	0.0 0		0.0 0	0.0 0	0.0 0	0.0 0	0.0 0	0.0 0	0.0 0	0.0 0		0.0 0	0.0 0	0.0 0		0.00	0.00	0.00	0.00	0.00	0.00
	OH *	7.6 9	8.0 0	8.0 0	7.9 9	8.0 0	8.0 0		8.0 0	7.7 8	8.0 0	7.9 9	8.0 0	7.9 0	7.9 9	8.0 0		7.9 9	8.0 0	8.0 0		7.99	8.00	7.84	8.00	7.89	7.89
Fe# ^b T (°C)		0.6 8	0.6 8	0.7 0	0.7 1	0.7 0	0.7 0		0.7 1	0.7 1	0.7 2	0.6 4	0.7 6	0.6 8	0.7 1	0.6 6		0.7 1	0.7 0	0.7 0		0.71	0.72	0.73	0.72	0.71	0.73
c		345	331	329	324	327	318		313	327	326	290	321	313	311	311		324	327	318		329. 78	327. 49	335. 59	322. 69	325. 16	330. 73

^a Atom per formula unit (apfu) representing the atomic proportions of elements in each crystallographic site (T= tetrahedral, O = octahedral, OH = OH site).

^b Fe# = Fe/(Fe+Mg).

^c [44].

Table S2. Whole rock geochemical data in weight % and ppm for the Cole, Welch and Dussault occurrences.

Ana-lyte Sym-bol	Unit Sym-bol	Detect-ion Limit	Analysis Method	C- 01	C- 02	C- 03	C- 04	C- 05	C- 06	C- 09	C- 10	C- 11	W- 01	W- 03	W- 04	D- 03	D- 04	D- 05
Co ₃ O ₄	%	0.005	FUS-XRF	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005
CuO	%	0.005	FUS-XRF	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	0.017	< 0.005	0.177
NiO	%	0.003	FUS-XRF	0.005	0.004	< 0.003	< 0.003	< 0.003	0.006	< 0.003	< 0.003	< 0.003	0.007	< 0.003	0.003	0.004	< 0.003	0.005
SiO ₂	%	0.01	FUS-XRF	60.53	68.64	71.12	65.08	65.42	63.72	66.67	71.37	69.01	62.09	88.03	88.52	86.43	70.2	65.96
Al ₂ O ₃	%	0.01	FUS-XRF	16.44	14.39	14.37	15.4	13.05	16.33	13.43	13.83	14.43	18.05	5.48	5.25	6.3	14.1	14.16
Fe ₂ O ₃ (T)	%	0.01	FUS-XRF	4.75	3.93	2.24	6.49	3.71	5.55	3.13	2.13	3.98	5.66	2.42	2.85	1.97	5.13	6.51
MnO	%	0.001	FUS-XRF	0.062	0.035	0.016	0.022	0.07	0.056	0.062	0.021	0.046	0.07	0.033	0.047	0.032	0.059	0.056
MgO	%	0.01	FUS-XRF	2.02	1.23	0.71	1.28	1.85	2.02	1.23	0.59	1.74	1.81	0.61	0.71	0.41	1.28	1.49
CaO	%	0.01	FUS-XRF	2.27	0.41	0.44	0.47	3.83	1.82	3.16	0.63	0.95	0.22	0.06	0.1	0.16	0.26	0.13
Na ₂ O	%	0.01	FUS-XRF	3.42	2.53	2.97	1.75	2.87	3.19	2.6	3.11	3.35	1.92	0.42	0.61	1.82	2.12	0.52
K ₂ O	%	0.01	FUS-XRF	4.65	4.51	6.18	4.95	3.78	4.29	4.93	5.96	3.89	5.4	1.79	1.46	1.26	3.82	5.43
TiO ₂	%	0.01	FUS-XRF	0.6	0.59	0.2	0.43	0.27	0.72	0.44	0.18	0.4	0.54	0.19	0.21	0.18	0.59	0.45
P ₂ O ₅	%	0.01	FUS-XRF	0.2	0.2	0.21	0.15	0.1	0.22	0.14	0.05	0.15	0.14	0.04	0.05	0.1	0.17	0.1
Cr ₂ O ₃	%	0.01	FUS-XRF	0.02	0.01	0.01	0.01	< 0.01	0.02	< 0.01	< 0.01	< 0.01	0.02	0.01	0.01	0.01	0.01	0.02
V ₂ O ₅	%	0.003	FUS-XRF	0.014	0.012	0.011	0.011	0.008	0.013	0.008	0.01	0.008	0.019	0.005	0.008	0.003	0.01	0.021
LOI	%		GRAV	3.68	2.43	1.16	3.44	5.13	2.65	3.32	1.73	2.59	3.2	1.06	1.17	1.04	2.16	3.72
Total	%	0.01	FUS-XRF	98.66	98.93	99.64	99.5	100.1	100.6	99.13	99.62	100.5	99.16	100.2	101	99.76	99.91	98.74
B	ppm	20	TD-MS	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20
Li	ppm	0.5	TD-MS	32.1	33.8	20.1	35.7	42.4	29.1	14.3	14.9	29.7	48.9	17.2	29.6	17.9	37.6	63.6
Cd	ppm	0.1	TD-MS	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	0.6	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
V	ppm	1	TD-MS	67	68	51	73	49	67	44	49	45	71	44	52	22	61	111
Cr	ppm	1	TD-MS	26	20	19	21	20	44	19	12	23	57	52	51	43	61	69
Mn	ppm	1	TD-MS	493	285	143	200	580	453	481	176	351	552	281	377	251	469	424
Hf	ppm	0.1	TD-MS	7.7	2.8	1	0.9	5.3	7	8.2	1	4.9	1.9	0.4	0.6	1.5	4.2	2.6
Ni	ppm	0.5	TD-MS	12.3	5	2.9	4	4.4	8.4	3.2	1.3	4.3	35.7	14	14.2	8.3	30.3	28.8

Ana-lyte Sym-bol	Unit Sym-bol	Detect-ion Limit	Analysis Method	C- 01	C- 02	C- 03	C- 04	C- 05	C- 06	C- 09	C- 10	C- 11	W- 01	W- 03	W- 04	D- 03	D- 04	D- 05
Er	ppm	0.1	TD-MS	1.6	1.6	1	4.9	1.5	2.8	1.2	0.6	1.1	1.4	0.9	1.1	1	2.4	1.9
Be	ppm	0.1	TD-MS	2.5	2.9	1.5	6	2.8	2.7	1.7	1.3	2.5	5	1.4	1.3	1.7	4.5	5.2
Ho	ppm	0.1	TD-MS	0.5	0.5	0.4	1.9	0.5	1	0.4	0.2	0.4	0.5	0.3	0.3	0.3	0.8	0.6
Hg	ppb	10	TD-MS	30	40	40	80	160	40	40	60	30	20	< 10	10	30	20	10
Ag	ppm	0.05	TD-MS	0.1	2.81	0.16	41.3	13.1	< 0.05	0.19	5.21	0.51	0.34	0.61	0.25	4.68	0.15	46.9
Au	ppb	0.02	BLEG-MS	2.2	6	9.9	92	78	0.7	0.3	167	4.1	0.7	0.9	6	2	0.4	3.8
Cs	ppm	0.05	TD-MS	2.1	2.25	1.13	4.72	2.23	1.75	0.96	1.06	1.97	14.3	3.59	2.82	4.46	13.4	12.6
Co	ppm	0.1	TD-MS	10.1	6.4	4.3	4.8	8.6	11.7	7	2.2	6.4	15.6	6	6.1	3.9	11.2	13.6
Eu	ppm	0.05	TD-MS	1.43	0.79	0.98	4.78	0.93	2.28	2.4	0.62	1.23	0.52	0.55	0.39	0.26	0.84	0.86
Bi	ppm	0.02	TD-MS	0.12	21.1	1.38	188	57.8	0.36	0.62	3.37	2.22	62.8	32.3	37.6	46.8	1.34	> 2000
Se	ppm	0.1	TD-MS	< 0.1	3.3	1	127	25.5	< 0.1	0.3	2.9	0.5	1	4.3	1.5	1.5	< 0.1	66.8
Zn	ppm	0.2	TD-MS	54.3	30.1	7	25.6	48.9	65.2	38.8	18.5	43.6	70.7	29.8	38.6	24	48.2	51.7
Ga	ppm	0.1	TD-MS	13.3	11.4	1.3	16.3	12.4	17	12.5	3.6	15.1	28.9	8.4	9.6	6.8	19.4	18.7
As	ppm	0.1	TD-MS	4.6	13.6	2.9	53.2	33.6	3.4	3.5	7	6.4	1.2	0.7	0.8	2.3	2	7.1
Rb	ppm	0.2	TD-MS	142	142	112	169	97.4	121	91.2	91.7	98.3	305	106	89.8	80.9	221	292
Y	ppm	0.1	TD-MS	12.6	20.5	9.2	66.4	19.2	24.1	13	5	13.6	12.5	10.6	10.3	10.8	20.4	21.8
Zr	ppm	1	TD-MS	312	143	32	97	178	291	351	117	199	66	16	21	58	214	91
Nb	ppm	0.1	TD-MS	5.6	6.2	4.3	2.8	5.7	1.2	5.7	0.3	8.8	0.2	2.9	4.6	4.8	2.9	10.4
Mo	ppm	0.05	TD-MS	0.88	0.7	0.91	1.05	0.75	0.61	0.77	0.87	0.81	0.13	1.17	1.5	2.24	0.46	0.68
In	ppm	0.1	TD-MS	< 0.1	< 0.1	< 0.1	0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
Sn	ppm	1	TD-MS	1	1	2	< 1	< 1	2	1	< 1	1	4	2	2	3	9	5
Sb	ppm	0.1	TD-MS	1.7	4.5	2.5	8.6	9.5	0.2	1.5	5.2	5.6	< 0.1	0.2	0.3	0.8	0.1	1.9
Te	ppm	0.1	TD-MS	< 0.1	2.1	< 0.1	6.1	3.9	< 0.1	< 0.1	3	0.2	0.6	3.1	13.5	0.8	< 0.1	22.2
Ba	ppm	1	TD-MS	1610	1800	2970	1930	1440	1450	1860	3550	1250	1330	558	397	386	605	961
La	ppm	0.1	TD-MS	104	34.4	36.2	42.2	30.5	148	321	96.2	46.5	28.5	16.3	16.3	11.1	62.5	26.9
Ce	ppm	0.1	TD-MS	190	58.4	69.4	199	49.6	264	585	112	78.4	49.3	46.2	33.5	16.7	118	76.3
Pr	ppm	0.1	TD-MS	21.4	6.7	8.7	26.6	6.3	29.7	60.7	11.1	7.7	4.2	6.9	4.2	1.9	13.5	10.7
Nd	ppm	0.1	TD-MS	73.4	22.2	31.4	106	23.6	98	187	31	29	13.9	27.7	13.7	6.7	43.7	36.9
Sm	ppm	0.1	TD-MS	10	4.2	5.8	22.9	3.9	13	22.1	4.3	6.7	3.3	2.9	2.3	2	7.5	5.2
Gd	ppm	0.1	TD-MS	5.7	3.2	3.3	17.7	3.4	9.1	10.6	2.2	4.6	2.8	2.5	2	1.5	5.3	4.5
Tb	ppm	0.1	TD-MS	0.5	0.4	0.4	1.8	0.4	0.9	0.7	0.2	0.4	0.4	0.3	0.3	0.2	0.6	0.4
Dy	ppm	0.1	TD-MS	2.8	2.4	2	10.2	2.7	5.1	3.1	1.2	2.4	2.4	1.5	1.8	1.6	4.1	2.9
Cu	ppm	0.2	TD-MS	7.6	7.6	14.2	9.7	7.5	1.9	3.3	12.4	6.8	26.3	16.8	11.1	144	19.2	1380
Ge	ppm	0.1	TD-MS	< 0.1	0.2	< 0.1	0.4	0.2	< 0.1	< 0.1	< 0.1	0.1	0.5	0.1	0.2	0.1	0.1	0.3
Tm	ppm	0.1	TD-MS	0.2	0.2	0.1	0.5	0.2	0.3	0.1	< 0.1	0.1	0.2	0.1	0.1	0.1	0.3	0.2
Yb	ppm	0.1	TD-MS	1.2	1.4	0.8	2.9	1.3	2.3	0.8	0.6	0.8	1.5	0.7	1	1	2.2	1.6
Lu	ppm	0.1	TD-MS	0.2	0.3	0.1	0.5	0.2	0.4	0.1	0.1	0.1	0.2	0.1	0.1	0.2	0.3	0.3
Ta	ppm	0.1	TD-MS	0.1	0.3	0.1	< 0.1	0.3	< 0.1	0.1	< 0.1	0.4	< 0.1	0.2	0.4	0.6	0.3	0.9
Sr	ppm	0.2	TD-MS	257	218	414	139	233	418	570	431	194	52	14	21.7	45.6	46.2	22
W	ppm	0.1	TD-MS	0.5	1.3	0.8	1.1	0.7	< 0.1	1	0.4	1.5	< 0.1	0.5	0.4	1.5	0.7	2.3
Re	ppm	0.001	TD-MS	< 0.001	< 0.001	< 0.001	0.001	< 0.001	0.001	0.001	< 0.001	< 0.001	< 0.001	< 0.001	0.001	0.002	< 0.001	0.001
Tl	ppm	0.05	TD-MS	0.84	0.89	0.77	1.17	0.63	0.79	0.61	0.71	0.62	2.12	0.7	0.58	0.45	1.49	2.01
Pb	ppm	0.5	TD-MS	12.4	786	501	547	308	13.8	25.3	782	134	487	520	756	320	16.4	1590
Th	ppm	0.1	TD-MS	22.3	20.8	1.6	13.8	30.3	20.4	58.5	39.6	14	21.1	5.7	10.6	10.2	39.7	14.4
U	ppm	0.1	TD-MS	14.4	802	15.8	3480	1250	6.8	11.2	126	469	1510	711	1220	1530	15.7	2090

Table S3. Whole rock geochemical data in weight % and ppm for the Kult-82, Island and Pyramid occurrences.

Analyte Symbol	Unit Symbol	Detection Limit	Analysis Method	K82-01	K82-05	K82-06	K82-07	K82-09	K82-10	I-01	I-02	I-03	I-04	I-05	I-06	I-08	I-09	I-10	I-11	I-12A	I-12B	I-13	PY-02	PY-05
Co3O4	%	0.005	FUS-XRF	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	0.006	<0.005	0.006	0.007	0.006	<0.005	<0.005	0.005	0.005	<0.005	<0.005	0.009	<0.005	0.001
CuO	%	0.005	FUS-XRF	0.008	0.019	0.006	0.045	0.007	0.053	0.005	0.008	0.01	0.057	0.019	0.005	<0.005	0.106	0.01	0.005	0.115	0.008	0.005	0.005	0.0047
NiO	%	0.003	FUS-XRF	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	0.017	0.009	0.009	<0.003	0.007	0.006	<0.003	<0.003	0.004	0.008	<0.003	<0.003
SiO2	%	0.01	FUS-XRF	74.28	56.82	48.66	50.13	75.37	46.15	66.04	57.78	72.09	52.43	54.48	54.13	73.24	57.55	48.85	53.95	65.62	73.35	57.73	74.4	82.98
Al2O3	%	0.01	FUS-XRF	12.58	18	19.12	12.13	12.93	16.49	15.49	13.81	10.09	14.99	13.69	13.72	13.07	14.31	13.98	13.4	13.1	10.65	12.53	13.05	4.6
Fe2O3(T)	%	0.01	FUS-XRF	1.72	4.06	5.87	5.25	1.2	7.91	4.12	14.09	6.56	15.23	14.85	14.25	1.39	10.85	13.24	14.89	5.89	4.07	15.15	1	3.96
MnO	%	0.001	FUS-XRF	0.017	0.058	0.109	0.233	0.012	0.144	0.027	0.223	0.141	0.261	0.342	0.241	0.021	0.186	0.22	0.242	0.104	0.09	0.226	0.009	0.044
MgO	%	0.01	FUS-XRF	0.37	0.8	2.5	3.84	0.26	1.4	0.76	3.54	2.57	5.07	6.01	6.72	0.36	3.44	5.98	7.04	2.03	1.81	3.77	0.15	0.92
CaO	%	0.01	FUS-XRF	0.1	5.01	7.16	11.31	0.13	7.49	0.83	0.28	0.28	0.56	0.47	0.37	0.64	0.29	9.28	0.32	0.55	0.52	0.21	0.36	1.14
Na2O	%	0.01	FUS-XRF	3.19	7.59	5	2.18	3.24	4.94	3.7	4.08	1.52	3.7	1.21	2.12	3.06	1.94	3.06	1.53	1.79	2.94	2.77	2.57	0.12
K2O	%	0.01	FUS-XRF	5.64	2.69	3.57	3.6	6.15	3.41	6.21	1.4	3.17	1.48	2.56	1.36	6.26	5.08	0.71	1.62	6.16	3	2.03	7.08	1.25
TiO2	%	0.01	FUS-XRF	0.12	0.52	0.73	0.47	0.16	0.59	0.74	1.13	0.81	1.53	1.58	1.41	0.04	1.32	1.24	1.46	0.86	0.66	1.18	0.06	0.43
P2O5	%	0.01	FUS-XRF	0.03	0.22	0.26	0.46	0.03	0.23	0.56	0.09	0.14	0.18	0.14	0.17	0.01	0.16	0.11	0.17	0.32	0.29	0.1	0.01	0.29
Cr2O3	%	0.01	FUS-XRF	0.01	<0.01	<0.01	0.02	<0.01	<0.01	<0.01	0.01	<0.01	0.03	0.03	0.02	0.01	0.03	0.03	0.02	<0.01	0.01	0.02	0.01	<0.01
V2O5	%	0.003	FUS-XRF	0.008	0.012	0.017	0.008	0.005	0.022	0.013	0.055	0.03	0.079	0.065	0.062	0.004	0.061	0.057	0.071	0.03	0.016	0.07	0.003	0.017
LOI	%		GRAV	0.87	4.42	7.57	10.66	0.55	7.93	1.45	3.52	2	3.68	4.77	4.77	1.3	3.47	2.62	4.53	1.82	1.65	3.22	0.69	2.2
Total	%	0.01	FUS-XRF	98.93	100.2	100.6	100.3	100	96.76	99.95	100	99.42	99.29	100.2	99.38	99.42	98.82	99.35	99.25	98.4	99.06	99.02	99.38	98.5
B	ppm	20	TD-MS	<20	<20	<20	<20	<20	60	<20	<20	1.19	1.78	<20	<20	<20	<20	<20	0.51	<20	<20	1.66	<20	3910
Li	ppm	0.5	TD-MS	7.2	13.6	33.9	36.2	4.4	124	15.1	44.6	<20	<20	72.6	73.3	5.5	43.5	18.7	<20	29.6	29.9	<20	2.5	<20
Na	%	0.01	TD-MS	2.46	>3.00	>3.00	1.47	2.33	>3.00	2.55	>3.00	45.2	53	0.83	1.42	2.27	1.34	1.99	75.1	1.3	2.17	42	2	46.3
Mg	%	0.01	TD-MS	0.14	0.35	1.32	2.01	0.08	0.66	0.28	2.05	1.14	2.97	3.04	3.35	0.14	1.75	2.92	1.3	1.06	0.99	2.15	0.05	0.12
Al	%	0.01	TD-MS	6.43	9.97	9.9	6.11	6.64	6.99	8.17	7.27	1.42	2.86	6.73	6.64	7.02	6.44	6.83	4.09	6.38	5.4	2.08	7.45	0.56
K	%	0.01	TD-MS	3.36	2.59	3.3	3.16	3.59	2.2	4.75	1.19	5.31	7.88	1.98	1.16	4.58	4.41	0.56	7.34	3.09	1.99	6.66	>5.00	2.5
Ca	%	0.01	TD-MS	0.08	3.58	5.05	7.77	0.09	5.03	0.57	0.16	1.57	1.14	0.32	0.22	0.45	0.2	6.05	1.38	0.38	0.36	1.7	0.27	1.07
Cd	ppm	0.1	TD-MS	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.17	0.36	0.3	<0.1	<0.1	<0.1	0.1	0.22	0.2	0.9	0.15	<0.1	0.82
V	ppm	1	TD-MS	31	49	69	48	22	105	49	308	0.1	<0.1	182	120	10	120	259	<0.1	119	62	0.3	4	<0.1

Ana-lyte Sym-bol	Unit Sym-bol	Detec-tion Limit	Analy-sis Metho-d	K82 -01	K82 -05	K82 -06	K82 -07	K82 -09	K82 -10	I-01	I-02	I-03	I-04	I-05	I-06	I-08	I-09	I-10	I-11	I-12A	I-12B	I-13	PY-02	PY-05
Cr	ppm	1	TD-MS	16	15	12	86	11	38	11	150	119	233	138	127	11	122	111	234	56	18	202	14	97
Mn	ppm	1	TD-MS	130	462	841	1830	94	1150	220	1750	64	129	2530	1820	165	1360	1630	117	820	675	114	92	28
Fe	%	0.01	TD-MS	1.22	2.88	4.04	3.61	0.75	5.58	2.79	9.77	1080	1990	9.68	9.47	0.94	7.09	8.63	1870	4.08	2.85	1680	0.7	343
Hf	ppm	0.1	TD-MS	4.8	6.5	5.1	3.5	2	5	0.4	2.2	4.47	10.4	3.4	1.5	4.7	2	1.8	10.7	3.2	0.9	10.2	2.3	2.88
Ni	ppm	0.5	TD-MS	1.6	6.7	6.7	94.6	1.6	32	4.4	39.7	3	3.2	61.8	54.9	2.1	30	52.9	3.1	17.4	7.2	1.5	0.9	0.2
Er	ppm	0.1	TD-MS	0.6	7.7	2.3	4	0.8	3.5	1.4	3.8	32.9	76.2	6.6	4.1	1.1	5.1	2.9	67.3	2.7	1.7	70.3	0.3	23.6
Be	ppm	0.1	TD-MS	0.6	5.5	2.8	1.5	0.5	3.7	2	2.8	4.2	3.4	5.4	2.5	1.1	2.4	0.5	5.1	2.6	1.6	3.9	0.8	2.7
Ho	ppm	0.1	TD-MS	0.2	2.8	0.8	1.4	0.3	1.3	0.5	1.3	2.8	2.9	2.3	1.4	0.3	1.7	1	2.2	1	0.6	2.5	<0.1	1.9
Hg	ppb	10	TD-MS	10	10	20	30	20	30	30	50	1.6	1.2	20	10	20	20	20	2	20	20	1.4	20	0.9>
Ag	ppm	0.05	TD-MS	0.46	0.39	0.14	0.25	0.24	5.15	0.36	1.93	0.6	0.47	0.24	1.24	0.11	2.6	0.24	0.38	1.17	2.33	1.6	0.06	100
Au	ppb	0.02	BLEG-MS	63.8	7.7	3.7	1.5	2	67	0.2	25	nd	nd	0.4	0.7	0.1	nd	0.5	nd	4	3	nd	nd	nd
Cs	ppm	0.05	TD-MS	0.49	0.81	2.05	0.61	0.48	16.8	1.29	0.3	0.5	0.3	0.43	0.33	0.81	0.71	0.48	0.4	1.07	0.42	0.32	0.74	1.89
Co	ppm	0.1	TD-MS	4.2	7.2	12.2	13.8	1.5	18	5.4	42.1	19.6	43.4	44.6	48.5	3.2	38.6	43.1	32.4	23.3	16.6	56.9	0.9	80.8
Eu	ppm	0.05	TD-MS	1.28	2.12	1.83	2.66	1.06	1.93	4.34	3.68	3.17	1.75	2.97	1.28	0.21	1.92	1.23	1.8	3	2.79	2.29	0.44	2.01
Bi	ppm	0.02	TD-MS	2.13	0.98	0.38	0.37	1.75	34	1.82	32.1	10.3	11.7	10.2	27.5	0.42	16.2	0.13	15.7	18.2	21.7	40.9	0.05	522
Se	ppm	0.1	TD-MS	0.4	<0.1	0.2	<0.1	0.4	7	<0.1	1.9	<0.1	0.4	<0.1	<0.1	0.4	0.7	<0.1	<0.1	0.3	0.3	0.7	0.3	10.9
Zn	ppm	0.2	TD-MS	<0.2	17.9	73.6	117	1.4	<0.2	8.5	213	110	295	395	432	<0.2	147	157	388	95.6	86.6	247	11	26.7
Ga	ppm	0.1	TD-MS	5.3	14	23.5	13	6.2	<0.1	3.8	20.1	<0.1	20.1	20.5	18.7	5.5	23.5	17	8.6	<0.1	0.9	21.5	18.8	11.1
As	ppm	0.1	TD-MS	3.3	2	0.7	2	1.1	42.1	1.3	9.8	1.5	1.6	1	1.7	1.9	5.9	14.5	0.2	5.3	3	5.1	0.9	9.3
Rb	ppm	0.2	TD-MS	80.9	67.9	145	67.5	87.1	108	161	36.3	69.7	40.4	72	38.7	147	133	23.7	45.7	146	61.8	56.2	181	70.3
Y	ppm	0.1	TD-MS	8.1	55.6	20.2	35	7	31.5	14.9	42.9	41	34.2	55.2	38.3	8.4	51.2	22.7	48.6	28.7	20.2	40.9	1.9	42
Zr	ppm	1	TD-MS	168	249	219	153	117	204	57	82	97	103	128	59	122	70	65	99	171	63	41	67	10
Nb	ppm	0.1	TD-MS	1.3	11.5	3.9	8	0.6	6.7	0.7	3	0.5	0.2	0.1	0.2	1.7	1.4	1.1	0.2	2.1	1.2	0.4	2.8	0.7
Mo	ppm	0.05	TD-MS	1.53	0.34	0.09	0.81	1	0.18	2.68	0.93	0.42	<0.05	0.11	0.09	1.17	0.19	0.56	<0.05	1.01	1.01	0.07	1.73	0.69
In	ppm	0.1	TD-MS	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Sn	ppm	1	TD-MS	<1	3	<1	1	<1	1	<1	<1	<1	<1	<1	<1	<1	1	<1	<1	<1	<1	<1	<1	<1
Sb	ppm	0.1	TD-MS	5.6	1.3	1.3	1.7	4.5	6.3	0.1	0.7	<0.1	<0.1	<0.1	<0.1	0.6	0.2	0.2	<0.1	2	0.8	0.4	1.5	15.6
Te	ppm	0.1	TD-MS	0.6	<0.1	<0.1	<0.1	1	1	<0.1	1.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.1	<0.1	<0.1	0.5	1.2	0.1	<0.1	327
Ba	ppm	1	TD-MS	2900	1650	1310	2290	2300	4250	>5000	>2970	>5000	>2230	>5000	1970	>5000	194	320	3050	4490	3860	451	558	585
La	ppm	0.1	TD-MS	84.5	50	64.6	60.2	93.7	48.3	252	98.6	72.7	15.8	52.2	20.5	3.3	13.8	9.7	12.4	104	132	32.7	5.6	57.8
Ce	ppm	0.1	TD-MS	156	111	122	124	156	106	485	208	142	39.9	90.8	34.1	6.7	37.8	18.7	32.6	207	251	67.2	9.1	114
Pr	ppm	0.1	TD-MS	19.3	16.3	15.4	17.3	15.9	13.5	56.7	24.2	17.1	5.2	11.5	4.4	0.9	5.7	2.7	5	24.5	29.8	8.2	1.1	13
Nd	ppm	0.1	TD-MS	65.7	72	53.5	68.4	47.2	50.8	200	85.6	61.3	21.8	41.6	19.1	3.7	25.8	12.1	22.3	87	102	31.8	3.9	52.4
Sm	ppm	0.1	TD-MS	8.9	18	9.5	13.7	5.8	9.6	22.4	13.2	11.7	4.7	9.7	5.5	1.2	7.4	3.3	5.4	15	11.8	5.8	0.8	7.1

Ana-lyte Sym-bol	Unit Sym-bol	Detection Limit	Analy-sis Method	K82 - 01	K82 - 05	K82 - 06	K82 - 07	K82 - 09	K82 - 10	I- 01	I- 02	I-03	I-04	I- 05	I- 06	I- 08	I- 09	I- 10	I-11	I- 12A	I- 12B	I-13	PY- 02	PY -05
Gd	ppm	0.1	TD-MS	5.4	14.6	6.7	10.5	3.9	7.5	11.1	10.6	9.8	5.8	10.1	5.8	1.2	8.1	3.8	7.9	10.4	8.4	7.2	0.5	6.5
Tb	ppm	0.1	TD-MS	0.4	2.1	0.7	1.3	0.3	1	0.8	1.3	1.4	1	1.5	0.9	0.2	1.1	0.6	1.4	1	0.7	1.1	< 0.1	0.7
Dy	ppm	0.1	TD-MS	1.7	13.5	4.2	7.4	1.5	6.3	3.5	7	7.7	5.9	10.8	6.4	1.4	7.8	4.2	9	5.5	3.4	7	0.3	4.1
Cu	ppm	0.2	TD-MS	70.1	128	39.7	331	44.7	400	16.8	57.9	91.4	446	153	35.2	5.8	773	73.9	20.7	886	62.4	36.6	6.3	52 40
Ge	ppm	0.1	TD-MS	< 0.1	< 0.1	0.4	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.3	0.1	0.2	0.4	0.2	0.1	< 0.1	0.1	0.2	0.2	
Tm	ppm	0.1	TD-MS	< 0.1	0.8	0.3	0.5	< 0.1	0.4	0.2	0.5	0.6	0.5	0.8	0.5	0.1	0.6	0.3	0.7	0.3	0.2	0.5	< 0.1	0.4
Yb	ppm	0.1	TD-MS	0.4	5.3	1.9	3	0.5	2.8	1	3.1	3.7	3.4	5.6	3.6	0.9	4.5	2.5	5.3	1.9	1.3	3.6	0.2	2.8
Lu	ppm	0.1	TD-MS	< 0.1	0.7	0.3	0.4	0.1	0.4	0.2	0.5	0.5	0.5	0.8	0.5	0.2	0.7	0.4	0.8	0.3	0.3	0.5	< 0.1	0.5
Ta	ppm	0.1	TD-MS	< 0.1	0.2	0.1	0.3	< 0.1	0.2	< 0.1	< 0.1	0.1	< 0.1	< 0.1	< 0.1	0.2	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	0.1	< 0.1
Sr	ppm	0.2	TD-MS	156	754	799	916	153	648	132 0	175	132	154	107	144	200	150	607	129	165	182	154	178	77. 1
W	ppm	0.1	TD-MS	1.1	0.1	0.2	0.3	0.5	0.1	0.6	0.3	0.2	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	0.6	0.3	0.1	0.2	1.3
Re	ppm	0.001	TD-MS	< 0.00 1	< 0.00 1	< 0.00 1	< 0.00 1	< 0.00 1	< 0.00 1	0.00 1	< 0.00 1	0.00 1	0.00 2	0.00 1	< 0.00 1	< 0.00 1	0.00 2	0.00 1	< 0.00 1	0.00 1	0.00 2	< 0.00 1	< 0.00 1	0.0 27
Tl	ppm	0.05	TD-MS	0.67	0.4	0.77	0.44	0.66	0.78	1.3	0.44	0.71	0.41	0.64	0.37	1.25	1.68	0.17	0.48	1.53	0.61	0.57	1.22	0.4 3
Pb	ppm	0.5	TD-MS	137	45.2	16.8	11.9	509	296 0	174	118 0	190	256	157	498	51.8	138	17.1	356	332	137 0	103 0	27	14 90
Th	ppm	0.1	TD-MS	33	2.6	8.1	11.2	34	5.4 >	31.9	2.4	9.2	3.2	5	2.8	42.7	1.3	1.3	3	5.9	7.6	1.7	55.1	2.4
U	ppm	0.1	TD-MS	197	18.4	13.5	2.2	78.1	100 00	48.2	240 0	401	356	206	975	17.4	834	4.1	669	788	741	221 0	3.7	72 20