

Appendix Table S1. Electron microprobe analysis (%) of garnet from the Niukutou deposit

Sample	Generation	SiO ₂	TiO ₂	Al ₂ O ₃	C ₂ O ₃	FeO	MnO	MgO	CaO	Total	And	Gro	Pyr
KUB213.1	Grt1	36.90	0.00	0.20	0.02	27.48	0.24	0.11	32.18	97.14	99.39	0.00	0.61
KUB213.2	Grt1	35.55	0.09	0.27	0.01	27.02	0.28	0.11	31.97	95.30	97.86	0.99	1.15
KUB213.3	Grt1	35.82	0.00	3.19	0.00	23.95	0.42	0.10	32.68	96.15	84.15	14.24	1.61
KUB213.4	Grt1	37.70	0.07	11.32	0.00	14.04	0.75	0.00	32.65	96.53	45.08	50.98	3.94
KUB213.5	Grt1	38.92	0.00	11.29	0.01	13.83	0.76	0.04	33.95	98.80	46.28	51.55	2.17
KUB214.1	Grt1	36.76	0.14	0.68	0.03	26.91	0.60	0.12	32.01	97.27	96.55	1.46	1.99
KUB214.2	Grt1	35.73	0.11	0.01	0.03	27.88	0.37	0.06	32.26	96.45	99.04	0.00	1.22
KUB214.3	Grt1	35.61	0.01	0.00	0.00	27.49	0.39	0.07	32.69	96.26	97.23	1.52	1.25
KUB214.4	Grt1	36.19	0.00	0.02	0.05	28.23	0.40	0.07	32.06	97.01	97.94	0.00	2.06
KUB214.5	Grt1	36.12	0.00	0.01	0.02	28.18	0.50	0.11	31.79	96.74	97.44	0.00	2.56
KUB214.6	Grt1	38.06	0.04	10.73	0.00	14.83	0.73	0.03	33.85	98.27	49.00	48.53	2.48
KUB214.7	Grt1	38.05	0.02	11.12	0.04	14.51	0.67	0.03	33.28	97.73	46.70	49.88	3.41
NZB271-1	Grt2	35.09	0.00	1.68	0.03	26.13	0.70	0.16	33.99	97.79	88.06	2.25	9.69
NZB271-2	Grt2	35.50	0.00	0.04		28.28	0.67	0.14	33.32	97.94	97.27	2.12	0.61
NZB271-3	Grt2	35.27	0.00	0.02	0.04	28.09	0.78	0.17	33.52	97.87	95.80	2.47	1.72
NZB271-4	Grt2	35.34	0.00	0.49		27.49	0.75	0.12	33.73	97.92	93.31	2.23	4.46
NZB271-5	Grt2	35.42	0.00	0.10		28.49	0.74	0.09	33.44	98.27	97.67	2.09	0.24
NZB269.1	Grt2	37.88	0.00	11.45	0.00	13.64	1.16	0.07	32.40	96.59	44.43	50.89	4.68
NZB269.2	Grt2	36.36	0.00	14.72	0.01	3.86	0.18	2.88	36.19	94.20	11.21	78.51	10.28
NZB273.1	Grt2	40.49	0.00	20.33		2.62	0.00	0.12	35.93	99.49	7.60	91.36	1.04
NZB273.2	Grt2	35.00	0.00	0.18	0.01	27.64	0.24	0.08	33.98	97.14	94.43	4.67	0.90
NZB124	Grt2	36.10	0.00	8.57	0.07	17.03	0.43	0.07	33.47	95.74	58.33	40.10	1.57
NZB086.1	Grt2	35.85	0.00	0.04	0.03	27.61	1.41	0.14	33.39	98.47	93.27	3.77	2.95
NZB086.2	Grt2	35.51	0.00	0.11	0.02	27.71	1.43	0.12	32.43	97.32	96.63	3.37	0.00

KUK002.1	Grt2	37.00	0.00	3.15	0.00	24.24	0.43	0.04	32.75	97.61	84.39	13.88	1.73
KUK002.2	Grt2	37.30	0.06	2.29	0.04	25.07	0.59	0.08	32.60	98.03	88.58	9.69	1.73
KUK002.3	Grt2	37.49	0.00	2.30	0.00	23.94	0.39	0.04	32.98	97.13	84.08	14.85	1.07
KUK002.4	Grt2	37.32	0.04	4.82	0.00	21.77	0.55	0.00	32.81	97.31	76.12	22.34	1.54
KUK002.5	Grt2	36.87	0.00	0.35	0.00	27.23	0.34	0.06	32.92	97.77	95.85	3.10	1.05
KUK002.6	Grt2	37.31	0.00	0.82	0.04	26.66	0.55	0.12	32.20	97.71	95.30	2.86	1.83
NKB67B.1	Grt2	36.08	0.00	0.50	0.02	27.94	0.44	0.05	33.67	98.69	96.00	2.75	1.25
NKB67B.2	Grt2	35.70	0.00	0.43	0.01	27.94	0.41	0.06	33.51	98.05	96.51	2.32	1.17
NKB67B.3	Grt2	37.86	0.00	12.02	0.01	13.10	1.07	0.01	35.29	99.36	42.44	55.20	2.36
NKB67B.4	Grt2	35.65	0.00	0.13	0.00	27.80	0.45	0.07	33.90	98.00	94.71	3.96	1.33
NKB67B.5	Grt2	35.74	0.00	0.77	0.07	26.94	0.43	0.13	33.72	97.79	92.33	6.15	1.51

Appendix Table S2. Electron microprobe analysis (%) of pyroxene from the Niukutou deposit

Sample	Generation	SiO ₂	TiO ₂	Al ₂ O ₃	Cr ₂ O ₃	FeO	MnO	MgO	CaO	Total	Jo	Di	Hd
NKB080	Px1	49.57	0.04	0.32	0.04	24.16	2.91	0.89	22.03	99.96	10.22	5.50	84.28
NKB022	Px1	48.32		0.17		25.50	2.41	2.41	22.10	100.92	7.64	13.44	78.93
NKB19	Px1	49.74		0.09	0.12	23.15	3.34	3.34	21.66	101.43	10.42	18.34	71.24
NKB17	Px1	48.99		0.41	0.03	24.61	2.74	2.74	22.01	101.53	8.64	15.21	76.15
NKB57	Px1	49.61		0.24	0.02	23.40	4.44	4.44	21.67	103.81	12.65	22.27	65.08
NZB274	Px1	49.46		0.18	0.03	25.46	1.80	0.83	22.15	99.92	6.31	5.11	88.58
KUK003	Px1	52.75	0.07	0.00	0.00	10.09	0.99	11.53	23.93	99.35	3.16	64.93	31.91
KUB241	Px1	48.11	0.01	0.51	0.00	23.30	4.13	0.62	21.24	97.92	14.59	3.86	81.56
NZB272	Px1	48.80		0.75	0.04	24.30	3.10	3.75	18.70	99.44	9.20	19.60	71.20
KUB211-1-1	Px1	49.10	0.02	0.23	0.00	22.53	3.26	1.31	22.08	98.53	11.67	8.23	80.10
KUB211-2-1	Px1	50.51	0.00	0.08	0.00	23.00	3.03	1.31	22.44	100.38	10.74	8.17	81.10
KUK009-1-1	Px2	49.98	0.00	0.19	0.03	21.90	6.45	0.48	21.49	100.53	22.17	2.90	74.93
KUK009-2-1	Px2	49.64	0.04	0.21	0.00	21.40	6.99	0.84	21.53	100.66	23.54	5.00	71.47
NKB-24	Px2	49.77		0.01	0.01	14.29	14.33	0.06	21.27	99.73	23.79	41.87	34.35
KUB-24	Px2	48.64	0.07	0.09	0.04	20.32	6.92	1.53	21.61	99.21	23.31	9.07	67.62
NKB025	Px2	50.09		0.25		16.40	9.24	9.24	21.56	106.79	22.38	39.39	38.22
NZB-144	Px2	49.00		0.61		18.07	9.32	1.13	20.79	98.92	31.85	6.77	61.38
NZB-128.1	Px3	48.32	0.00	0.36	0.06	11.52	18.06	0.68	18.29	97.29	58.77	3.92	37.32
NZB-128.2	Px3	49.13		0.32	0.03	12.02	16.47	0.39	21.16	99.52	56.61	2.35	41.04
NZB-128.3	Px3	48.64	0.01	0.09	0.10	14.90	13.72	0.61	21.02	99.09	46.43	3.63	49.95
NZB-131	Px3	49.08	0.03	0.61	0.03	9.28	19.44	0.71	20.25	99.42	64.98	4.19	30.82
NZB-132	Px3	49.24		0.20		15.75	12.60	0.72	21.32	99.82	42.72	4.29	52.99

Appendix Table S3. Electron microprobe analysis (%) of ilvaite from the Niukutou deposit

Sample	Generation	SiO ₂	TiO ₂	Al ₂ O ₃	FeO	MnO	MgO	CaO	Total	Mn-ilv%	Fe ³⁺	Fe ²⁺	Fe ₂ O ₃
KUB226.1	1	30.84	0.00	0.46	46.88	3.61	0.20	13.24	95.23	10.87	0.78	1.85	13.94
KUB226.2	1	29.53	0.00	0.76	46.74	3.40	0.25	12.73	93.41	11.04	0.88	1.81	15.27
KUB226.3	1	30.84	0.00	0.46	46.88	3.61	0.20	13.24	95.23	10.87	0.78	1.85	13.94
KUB214.8	1	30.75	0.04	0.42	47.54	3.63	0.02	13.68	96.07	10.07	0.80	1.85	14.40
KUB214.9	1	30.23	0.17	0.37	48.94	1.78	0.13	14.01	95.62	5.63	0.83	1.92	14.76
KUB214.10	1	30.28	-	0.15	48.45	3.76	0.21	13.73	96.58	11.57	0.91	1.79	16.36
NKB051b	2	30.44		1.03	45.39	5.70	0.10	13.59	96.24	16.32	0.83	1.70	14.86
NKB092	2	30.23		0.06	46.45	5.77	0.08	13.65	96.24	16.56	0.91	1.70	16.22
NZB004.1	2	30.50	0.07	0.26	45.77	5.57	0.34	13.72	96.23	17.14	0.86	1.69	15.48
NZB004.2	2	30.12	0.01	0.18	46.64	4.65	0.39	13.68	95.67	14.99	0.90	1.73	15.95
KUB239	2	29.45	0.06	0.51	46.23	4.82	0.33	13.24	94.64	15.51	0.93	1.70	16.41
NZB133	3	30.05	0.08	0.83	44.92	7.20	0.16	13.55	96.79	21.06	0.92	1.58	16.49
KUB217	3	30.19	0.12	0.06	41.82	9.95	0.15	13.07	95.36	28.63	0.90	1.46	15.99
NZB-135	3	29.95		1.28	38.58	13.27	0.28	12.97	96.32	38.89	0.93	1.22	16.64

Appendix Table S4. Electron microprobe analysis (%) of epidote and chlorite from the Niukutou deposit

Sample	minerals	SiO ₂	TiO ₂	Al ₂ O ₃	FeO	MnO	MgO	CaO	Total
NZB144	epidote	37.801		24.64	9.16	0.78	0.02	23.40	95.81
NDS2	epidote	38.669		25.12	9.32	0.06		23.00	96.15
NKB065	epidote	38.622		22.64	11.96	0.03		22.89	96.14
NZB259	epidote	38.618		23.62	10.88	0.05	0.02	22.84	96.03
JYB5	epidote	38.909		26.22	7.83	0.03	0.01	23.04	96.02
JYB6	epidote	39.056		24.59	10.13	0.04	0.03	23.01	96.86
JYB12-1	epidote	38.047	0.013	23.54	12.57	0.14	0.03	23.76	98.10
NZB84.1	chlorite	25.53		18.78	0.12	32.50	2.10	8.33	0.01
NZB84.2	chlorite	26.32		18.65	0.10	32.00	2.12	8.97	0.04

Appendix Table S5. The LA-ICP-MS in-situ microanalysis results of garnet, pyroxene and ilvaite in the Niukutou deposit

Sample	Type	Sc	V	Cr	Co	Zn	Cu	Rb	Sr	Cs	Ba	La	Ce	Pr	Nd	Sm	Eu
KUB213.1	Grt1	1.09	-	4.71	0.34	4.25	-	-	0.16	0.01	0.18	0.44	1.36	0.13	0.29	-	0.93
KUB213.2	Grt1	0.93	-	2.34	0.43	2.37	0.22	0.05	0.09	-	-	1.31	6.39	0.83	4.05	0.32	0.87
KUB213.3	Grt1	1.03	0.09	3.65	0.35	4.06	-	-	-	0.09	0.30	1.05	5.22	0.64	1.93	0.33	0.53
KUB213.4	Grt1	0.91	-	3.88	0.28	2.56	4.29	-	-	0.02	0.38	1.11	5.68	0.72	2.12	0.34	0.85
KUB213.5	Grt1	0.71	-	1.62	0.34	4.64	0.21	-	0.08	0.12	-	1.66	7.04	0.89	3.87	0.31	0.62
KUB214.1	Grt1	8.47	155.58	45.81	0.43	19.47	-	1.48	253.90	1.19	2.58	20.20	37.32	4.60	17.65	4.12	33.62
KUB214.2	Grt1	5.85	117.44	50.12	0.11	6.57	0.01	2.20	144.55	0.14	8.61	18.19	34.36	4.08	12.91	3.84	11.76
KUB214.3	Grt1	0.94	17.30	11.51	0.08	49.55	-	0.17	0.95	0.35	-	4.56	13.31	1.57	5.90	0.43	0.79
KUB214.4	Grt1	4.10	76.92	47.30	0.38	39.35	-	0.72	1.81	2.17	-	0.51	2.01	0.41	2.88	0.91	0.58
NKB67B.1	Grt2	3.55	18.36	13.59	0.21	1.55	-	0.20	0.09	0.17	0.17	2.40	6.07	0.62	2.23	0.41	0.33
NKB67B.2	Grt2	2.60	72.44	31.89	0.17	7.41	-	0.58	0.29	0.93	1.16	2.54	9.18	1.72	8.76	2.44	0.87
NKB67B.3	Grt2	0.80	0.98	3.07	-	1.42	0.14	-	0.19	0.02	-	0.23	0.48	0.21	1.77	0.97	0.48
NKB67B.4	Grt2	0.76	0.50	4.83	0.21	2.15	-	-	0.02	-	-	0.15	0.43	0.22	1.86	1.62	0.70
NZB272.1	Px1	1.75	1.85	24.64	0.36	97.40	2.04	0.03	3.77	0.17	0.86	0.12	0.12	0.04	0.24	0.22	0.06
NZB272.2	Px1	1.51	4.21	26.07	0.23	127.62	0.57	0.05	4.96	0.28	1.32	0.74	0.62	0.16	0.55	0.13	0.14
KUB241	Px1	5.85	14.50	89.18	4.03	206.87	0.13	1.38	2.87	0.32	0.90	0.12	0.28	0.03	0.17	0.04	-
KUK003	Px1	1.91	5.35	9.29	3.49	181.12	-	0.46	1.82	0.05	0.42	0.07	0.06	0.02	0.03	-	-
NKB24	Px2	4.29	270.42	19.18	9.72	198.49	1.55	1.13	23.45	2.66	0.87	0.60	1.14	0.19	0.76	0.23	0.19
KUB24	Px2	5.37	249.57	27.39	10.46	87.03	0.63	0.66	20.76	1.40	0.79	0.65	0.90	0.10	0.77	0.17	0.09
NKB025	Px2	1.76	1.46	4.04	2.01	189.34	-	0.71	20.71	3.04	0.18	0.29	0.19	0.01	0.13	-	0.02
NZB144	Px2	1.55	1.09	3.99	4.48	133.67	0.95	0.07	3.72	1.00	0.03	0.11	0.03	0.01	0.03	-	-
KUB214.8	Ilv1	1.09	0.30	3.26	0.08	137.50	0.86	0.17	0.54	-	0.38	4.56	1.47	0.37	1.14	0.15	0.46
KUB214.9	Ilv1	0.69	0.39	25.58	0.14	148.02	-	0.00	0.43	0.05	0.21	2.64	0.90	0.15	0.41	0.09	0.88
KUB214.10	Ilv1	0.95	9.68	101.22	0.19	105.80	2.12	0.04	1.37	-	0.44	3.83	3.63	1.05	6.16	1.35	8.70

KUB226.1	Ilv1	0.79	9.63	20.18	0.27	109.04	-	0.29	0.30	0.17	-	2.54	3.90	1.43	8.68	2.53	7.98
KUB226.2	Ilv1	0.75	1.20	19.47	0.27	207.20	1.14	-	0.67	0.09	0.08	3.14	3.22	0.68	2.83	0.22	0.66
NZB004.1	Ilv2	0.88	1.71	4.92	0.08	162.21	0.20	0.19	1.79	0.04	0.22	5.60	2.44	0.77	3.87	0.66	0.90
NZB004.2	Ilv2	1.09	0.59	7.09	0.05	167.04	-	0.03	0.58	0.01	-	3.21	1.01	0.31	1.87	0.47	0.53
KUB239	Ilv2	0.54	0.87	3.55	1.26	210.29	1.73	0.04	0.06	0.09	0.20	0.02	0.09	0.05	0.07	0.13	0.18
NZB133	Ilv3	0.90	7.06	5.33	1.35	193.07	-	-	0.23	0.06	-	0.47	0.75	0.29	2.54	1.28	0.27
NZB135	Ilv3	1.59	2.34	6.82	1.83	205.17	1.23	0.00	0.23	0.05	0.33	0.03	0.07	0.05	0.39	0.26	0.24

Cont. Table S5

Sample	Type	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu	Y	Hf	Ta	Zr	Nb	Pb	Th	U
KUB213.1	Grt1	0.06	0.01	-	-	-	-	-	-	0.01	-	0.02	0.02	-	0.00	-	0.39
KUB213.2	Grt1	0.13	-	0.08	0.01	-	-	-	-	0.04	-	0.01	0.47	0.02	-	-	1.41
KUB213.3	Grt1	0.20	-	-	-	-	-	-	0.01	-	-	0.02	0.03	-	0.04	0.05	0.89
KUB213.4	Grt1	0.06	-	-	-	-	0.01	-	-	0.04	-	0.01	0.26	-	0.10	0.02	1.08
KUB213.5	Grt1	0.41	-	-	0.02	-	-	-	-	0.06	-	0.02	-	-	0.13	-	1.35
KUB214.1	Grt1	6.69	1.01	10.23	3.24	9.15	0.92	5.97	0.81	118.97	0.56	3.53	27.92	24.61	9.28	5.81	9.99
KUB214.2	Grt1	3.52	0.56	5.25	1.19	3.08	0.48	3.10	0.21	40.90	0.42	0.04	8.41	0.05	3.19	4.61	4.73
KUB214.3	Grt1	0.85	0.06	0.34	0.04	0.16	0.07	0.68	0.22	3.02	0.31	0.07	15.94	0.42	0.48	8.15	2.42
KUB214.4	Grt1	1.83	0.25	2.49	0.68	2.31	0.40	2.38	0.28	23.46	0.88	0.28	27.53	4.06	0.55	3.07	1.15
NKB67B.1	Grt2	0.91	0.05	0.49	0.21	0.36	0.11	0.26	0.03	5.82	1.33	0.02	76.69	0.26	0.35	4.73	1.02
NKB67B.2	Grt2	1.72	0.30	1.74	0.35	1.28	0.19	1.21	0.34	11.96	1.62	0.48	68.56	3.09	2.20	12.83	2.08
NKB67B.3	Grt2	3.24	0.35	2.05	0.51	1.50	0.12	1.57	0.08	32.34	-	-	0.87	0.19	0.05	-	0.08
NKB67B.4	Grt2	1.99	0.29	1.79	0.30	0.65	0.14	0.28	0.12	21.00	-	-	-	-	0.07	-	0.11
NZB272.1	Px1	0.36	0.05	0.71	0.20	0.76	0.14	0.72	0.11	9.79	0.03	-	-	0.01	0.88	0.01	0.03
NZB272.2	Px1	0.35	0.03	0.32	0.11	0.31	0.03	0.16	0.01	4.81	-	-	0.23	0.05	1.56	0.05	0.20
KUB241	Px1	0.19	0.01	0.05	0.06	0.13	0.04	0.43	0.10	1.07	0.17	0.01	3.37	0.04	7.10	0.75	0.11

KUK002	Px1	-	0.00	0.09	-	-	0.01	0.33	0.06	0.33	0.19	-	3.41	0.01	3.12	0.17	0.08
NKB24	Px2	0.48	0.04	0.49	0.05	0.31	0.02	0.62	0.33	2.66	0.37	-	3.56	0.01	13.40	0.04	0.07
KUB24	Px2	0.32	0.03	0.22	0.10	0.11	0.02	0.54	0.20	1.72	0.20	0.02	3.48	-	1.21	0.02	0.04
NKB025	Px2	0.08	0.01	0.09	0.02	0.09	0.05	0.17	0.04	1.67	0.04	-	0.84	0.10	35.42	0.02	0.03
NZB144	Px2	0.09	-	0.06	0.02	0.02	0.01	0.25	0.01	0.83	0.11	-	0.46	0.01	17.35	-	-
KUB214.1	Ilv1	0.38	0.10	0.30	0.04	0.18	0.01	0.10	0.01	2.80	-	-	0.26	0.01	0.49	-	0.04
KUB214.2	Ilv1	0.03	0.01	0.08	0.01	0.02	-	-	0.01	0.26	-	0.01	0.09	-	0.38	0.02	0.22
KUB214.3	Ilv1	2.47	0.44	3.01	0.66	1.81	0.15	0.77	0.07	38.55	-	-	0.05	-	2.35	0.11	0.67
KUB226.1	Ilv1	4.66	0.85	5.22	1.11	3.15	0.29	1.69	0.25	58.49	-	-	0.39	0.03	1.55	0.14	1.06
KUB226.2	Ilv1	0.60	0.09	0.42	0.19	0.78	0.06	0.50	0.10	12.95	0.05	-	2.17	0.02	43.24	0.16	0.08
NZB004.1	Ilv2	1.30	0.11	0.87	0.23	0.76	0.05	0.74	0.05	12.21	-	-	0.05	0.01	1.91	0.01	0.27
NZB004.2	Ilv2	0.97	0.08	1.06	0.20	0.42	0.07	0.38	0.02	11.51	-	-	-	0.00	3.84	0.04	0.02
KUB239	Ilv2	0.16	0.01	-	-	-	-	-	-	0.10	0.09	0.03	-	0.09	0.06	-	0.02
NZB133	Ilv3	0.99	0.18	0.75	0.16	0.37	0.02	0.35	0.01	9.21	0.04	0.37	3.17	2.24	0.03	0.24	0.38
NZB135	Ilv3	0.56	0.19	1.01	0.45	1.93	0.14	1.69	0.42	20.97	-	0.03	1.05	0.05	0.03	0.01	0.01

Notes: “-” in the table represents the results which is below the lower limit of instrument test