Dalton, H.B., Scott, J.M., Liu, J., Waight, T.E., Pearson, D.G., Brenna, M., Le Roux, P., and Palin, J.M., 2017, Diffusion-zoned pyroxenes in an isotopically heterogeneous mantle lithosphere beneath the Dunedin Volcanic Group, New Zealand, and their implications for intraplate alkaline magma sources: Lithosphere, doi:10.1130/L631.1.

GSA Data Repository Item

Diffusion-zoned pyroxenes in an isotopically heterogeneous mantle lithosphere beneath the Dunedin Volcanic Group, New Zealand, and their implications for intraplate alkaline magma sources

Dalton et al. (2017)

1. Representative images of samples.
2. Summary of Bald Hill flow, Foulden Maar dike and Summer Hills flow.
3. Representative wavelength dispersal spectroscopy analyses of reported xenoliths.
4. Examples of core to rim zoning in additional samples.
5. Representative trace element analyses of analyzed pyroxene grains.
6. Laser ablation line scans across pyroxene grain boundaries.
7. Summary of Sr and Nd isotope ratios in Dunedin Volcanic Group peridotite pyroxenes.

1. Representative images of samples

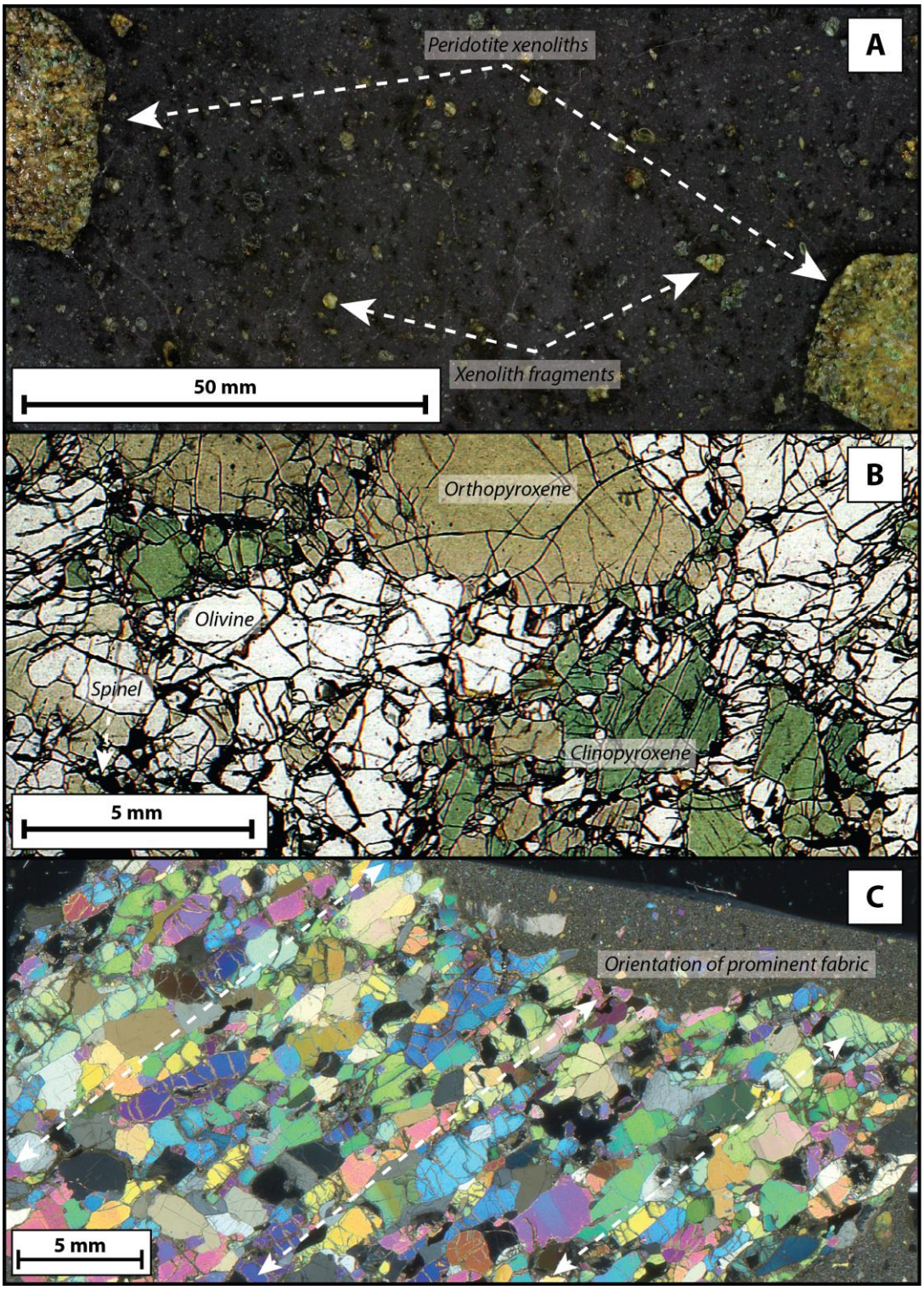


Figure DS1. Representative images of xenoliths. 1A. Xenoliths in a polished slab, 1B. Scanning thin sections and then enhancing the colours slightly makes distinguishing the mineral phases straightforward; olivine is colourless, orthopyroxene is tan coloured, clinopyroxene is khaki, spinel is dark brown. Note that the spinel is concentrated in orthopyroxene. Sample SUM-10. 1C. Some xenoliths display a foliation. Sample FOU-15.

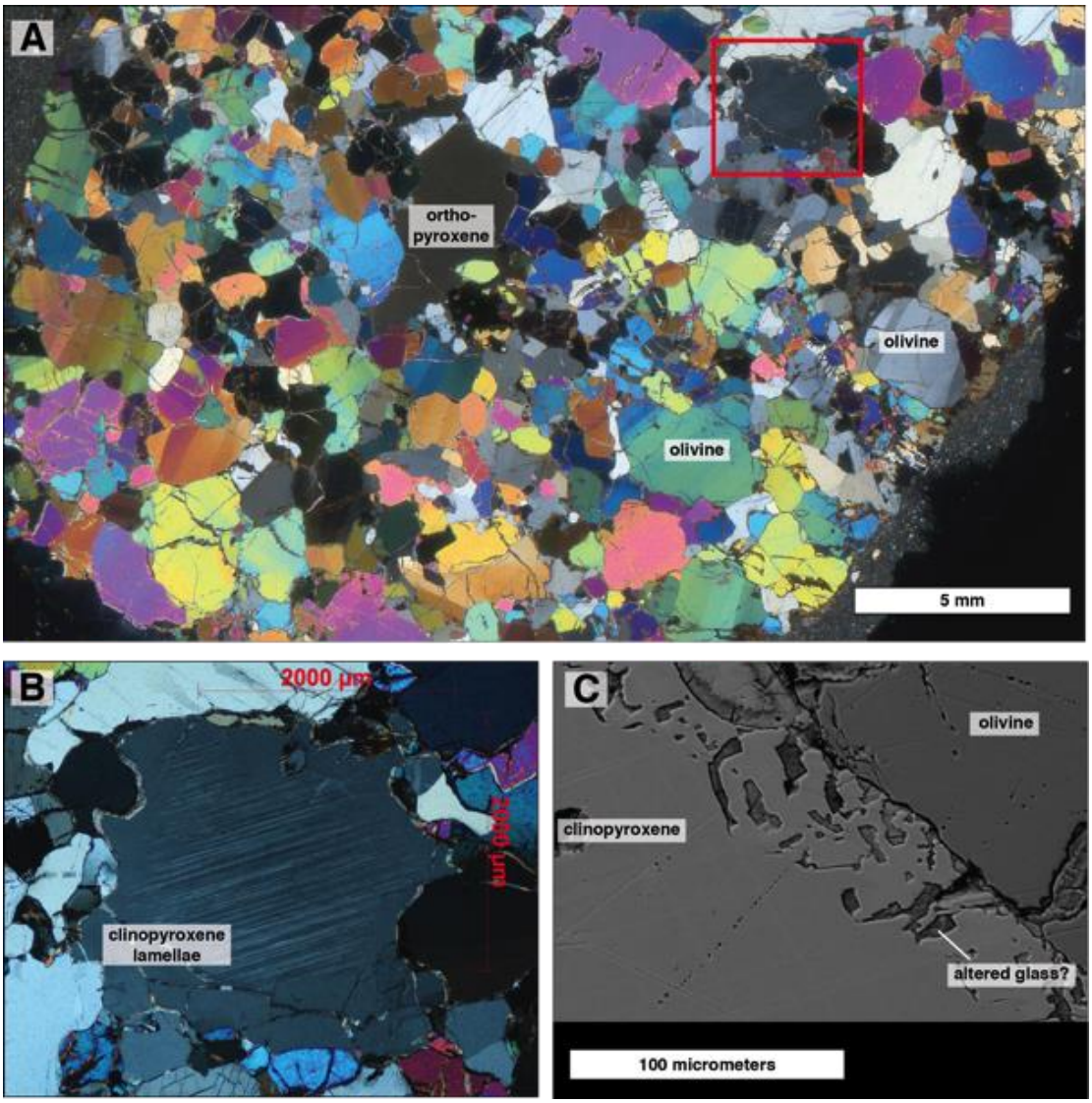


Figure DS2. Cross-polarised light image of SUM-6 illustrating the porphyroclastic texture that is observed in many of the studied peridotites. **2B** shows a detailed image of an orthopyroxene grain with narrow rods of clinopyroxene exsolution in the core. **2C.** Clinopyroxene grains from FOU-9 can be seen to have "spongy" margins.

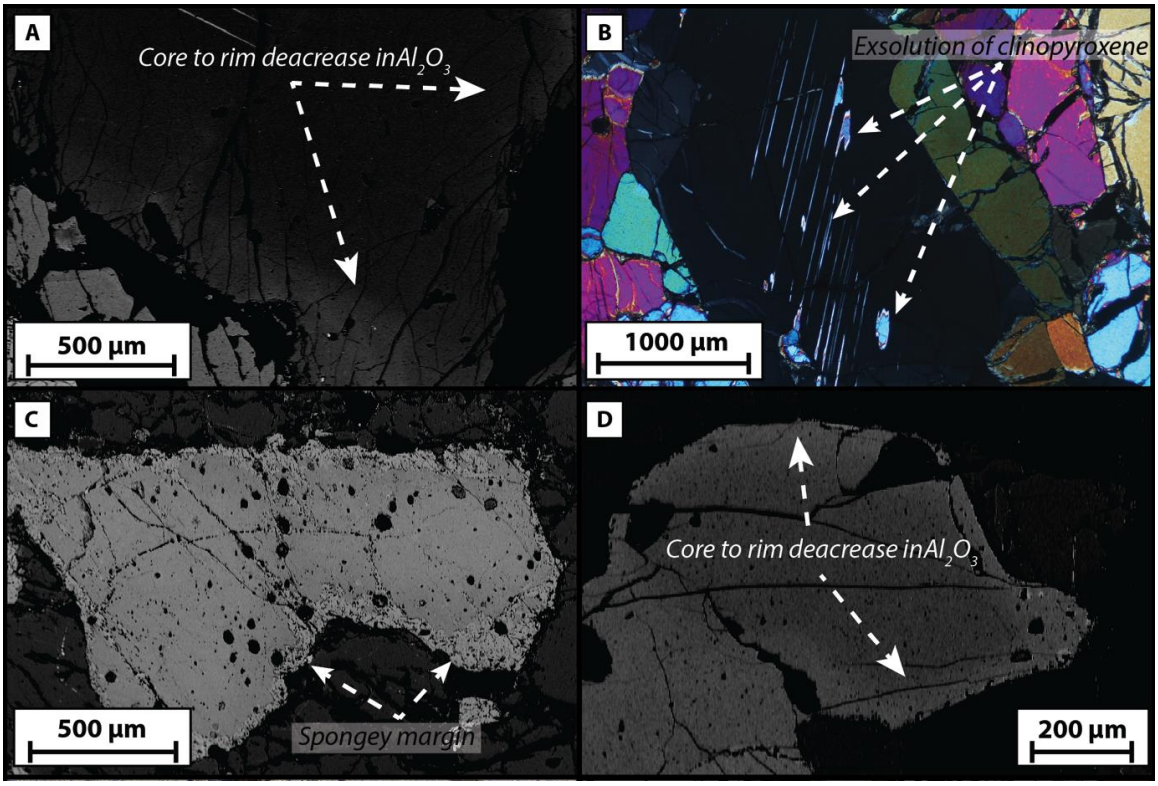


Figure DS3A. Backscatter electron image of orthopyroxene grain highlighting the decrease in Al_2O_3 concentration from core to rim. **3B.** Cross-polarised microphotograph of large orthopyroxene grain with exsolution of clinopyroxene. **3C.** Backscatter electron image of clinopyroxene with spongey margins. FOU-9. **3D.** Backscatter electron image of clinopyroxene grain highlighting the decrease in Al_2O_3 concentration from core to rim.

2. Summary of the Bald Hill flow, Foulden Maar dike and the Summer Hills flow

Xenoliths were collected from boulders on the top of the northern end of **Bald Hill**. The host basalt is an aphyric to poorly olivine porphyritic. The groundmass consists of microcrystalline clinopyroxene, plagioclase and oxides. It is chemically a basanite (Kaulfuss, 2013). Measured Sr, Nd and Pb isotopes are $^{87}Sr/^{86}Sr$ = 0.703112, $^{143}Nd/^{144}Nd$ = 0.512885, $^{208}Pb/^{204}Pb$ = 39.7074, $^{207}Pb/^{204}Pb$ = 15.6525 and $^{206}Pb/^{204}Pb$ = 19.9044 (Scott and Le Roux, unpublished data), and comparable with all other Dunedin Volcanic Group intraplate basalts.

The dike containing xenoliths at **Foulden Maar** occurs as several outcrops on a small knob known as Holly Hill just to the south of the diatreme (Lindqvist and Lee, 2009; Kaulfuss, 2013). Exposure is poor and it is unclear whether the dike cuts through sedimentary rocks or Otago Schist. Xenoliths were common in boulders emanating from the western end of the dike. The dike is almost identical to the Bald Hill flow. Chemical analysis shows it to be basanite (Kaulfuss, 2013). No Sr, Nd or Pb isotopic data are available.

The alkaline basalt at **Summer Hills** hosting the xenoliths was first described by Brown (1964), which remains the main study. It is a poorly exposed flow overlying Cenozoic sedimentary rocks; outcrops were restricted to areas where the underlying sediments have slumped and caused boulders of basalt to be exposed. The basanite contains augite, olivine, magnetite set in a matrix of labradorite, sanidine and nepheline. The chemical composition, presented in Brown (1964), is that of basanite. No isotopic data are available.

Brown, E.H., 1964, The Geology of the Mt Stoker area, Eastern Otago: New Zealand Journal of Geology and Geophysics, v. 7, p. 192-204.

Kaulfuss, U, 2013, Geology and paleontology of Foulden Maar. PhD Thesis, University of Otago, 332p.

Lindqvist J.K., Lee, D.E., 2009, High-frequency paleoclimate signals from Foulden Maar, Waipiata Volcanic Field, southern New Zealand: An Early Miocene varved lacustrine diamtomite deposit: Sedimentary Geology, v. 222. P. 98-110.

3. Representative wavelength dispersal spectroscopy analyses of reported xenoliths.

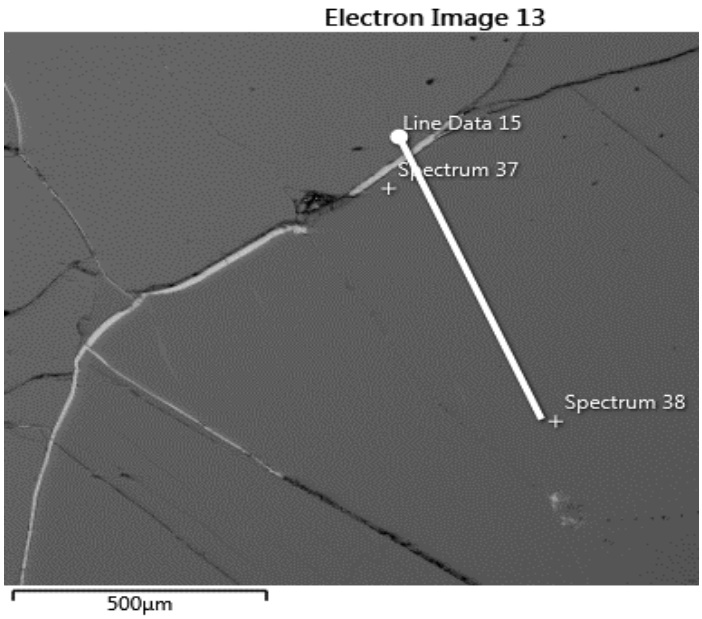
	Olivine										Spinel									
Sample	**BAL-4**	**BAL-8**	**FOU-3**	**FOU-9**	**FOU-15**	**SUM-4**	**SUM-6**	**SUM-11**	**SUM-12**	**SUM-15**	**BAL-4**	**BAL-8**	**FOU-3**	**FOU-9**	**FOU-15**	**SUM-4**	**SUM-6**	**SUM-11**	**SUM-12**	**SUM-15**
Analysis Location	**4.1.3**	**8.10.29**	**3.1.4**	**9.3.9**	**15.1.13**	**4.2.8**	**6.1.6**	**11.3.7**	**12.3.8**	**15.3.6**	**4.3.6**	**8.5.18**	**3.1.1**	**9.1.4**	**15.3.6**	**4.2.9**	**6.2.10**	**11.1.1**	**12.2.4**	**15.4.10**
SiO_2	40.97	40.83	40.96	41.02	41.26	40.05	41.00	40.59	40.36	39.59	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TiO_2	0.00	0.02	0.00	0.00	0.02	0.00	0.02	0.00	0.02	0.00	0.08	0.08	0.00	0.11	0.00	0.09	0.11	0.05	0.03	0.04
Al_2O_3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	49.66	58.81	57.79	42.02	42.70	60.35	38.90	61.22	55.77	61.07
FeO	8.61	9.59	8.95	8.54	8.40	10.06	9.34	10.07	8.77	10.17	11.86	10.76	9.72	12.36	12.40	10.34	11.90	9.76	9.58	10.56
MnO	0.11	0.10	0.12	0.12	0.13	0.16	0.09	0.11	0.09	0.14	0.17	0.13	0.10	0.22	0.21	0.14	0.22	0.10	0.13	0.12
MgO	50.21	48.75	49.52	50.28	49.83	49.40	50.08	48.49	50.11	49.88	18.24	19.91	20.24	18.07	16.93	20.48	15.56	19.37	19.28	19.42
CaO	0.00	0.04	0.05	0.10	0.04	0.04	0.05	0.04	0.03	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Na_2O	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cr_2O_3	0.00	0.00	0.00	0.04	0.03	0.02	0.00	0.00	0.03	0.00	20.22	10.87	12.54	26.80	27.66	10.37	33.04	8.85	14.94	10.03
Total	99.94	99.33	99.60	100.10	99.71	99.73	100.58	99.30	99.41	99.83	100.23	100.56	100.39	99.58	99.90	101.77	99.73	99.35	99.73	101.24
O	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
Si	1.00	1.00	1.00	1.00	1.01	0.99	1.00	1.00	0.99	0.98	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Al	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.57	1.78	1.75	1.38	1.40	1.80	1.30	1.85	1.72	1.82
Ti	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Fe	0.18	0.20	0.18	0.17	0.17	0.21	0.19	0.21	0.18	0.21	0.27	0.23	0.21	0.29	0.29	0.22	0.28	0.21	0.21	0.22
Mn	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.01	0.00	0.00	0.00
Mg	1.82	1.79	1.81	1.82	1.81	1.81	1.81	1.78	1.83	1.83	0.73	0.76	0.78	0.75	0.70	0.77	0.66	0.74	0.75	0.73
Ca	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Na	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cr	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.43	0.22	0.26	0.59	0.61	0.21	0.74	0.18	0.31	0.20
Total	3.00	2.99	3.00	3.00	2.99	3.01	3.00	3.00	3.01	3.02	3.00	3.00	3.00	3.01	3.00	3.00	2.98	2.98	2.99	2.99
Mg#	91.2	90.1	90.8	91.3	91.4	89.7	90.5	89.6	91.1	89.7	73.3	76.7	78.8	72.3	70.9	77.9	70.0	78.0	78.2	76.6
Cr#											21.5	11.0	12.7	30.0	30.3	10.3	36.3	8.8	15.2	9.9

*Mg# = 100*Mg/(Mg+Fe); Cr# = 100*Cr/(Cr+Al)

										Orthopyroxene										
Sample	**BAL-4**	**BAL-4**	**BAL-8**	**BAL-8**	**FOU-3**	**FOU-3**	**FOU-9**	**FOU-9**	**FOU-15**	**FOU-15**	**SUM-4**	**SUM-4**	**SUM-6**	**SUM-6**	**SUM-11**	**SUM-11**	**SUM-12**	**SUM-12**	**SUM-15**	**SUM-15**
Analysis	**4.5.11**	**4.5.12**	**8.8.23**	**8.8.24**	**3.3.12**	**3.3.15**	**9.4.11**	**9.4.12**	**15.5.27**	**15.5.28**	**4.3.10**	**4.3.11**	**6.3.14**	**6.3.15**	**11.4.8**	**11.4.9**	**12.1.1**	**12.1.2**	**15.4.8**	**15.4.9**
Location	**core**	**rim**	**core**	**rim**	**core**	**rim**	**core**	**rim**	**core**	**rim**	**core**	**rim**	**core**	**rim**	**core**	**rim**	**core**	**rim**	**core**	**rim**
SiO_2	55.35	56.03	55.39	56.32	55.65	56.09	57.03	56.45	56.33	56.80	54.12	54.38	56.75	56.61	54.46	55.86	54.72	55.34	55.22	56.07
TiO_2	0.07	0.05	0.08	0.07	0.02	0.00	0.00	0.00	0.03	0.03	0.16	0.11	0.00	0.03	0.07	0.08	0.05	0.00	0.09	0.05
Al_2O_3	3.52	2.91	4.40	3.77	3.71	3.57	2.85	3.51	2.84	2.33	4.94	3.77	2.82	2.58	4.98	3.77	4.67	3.83	4.34	3.36
FeO	5.62	5.64	6.22	6.08	5.86	5.79	5.32	5.17	5.43	5.55	6.51	6.30	5.31	5.31	6.29	6.24	5.63	5.49	6.66	6.62
MnO	0.11	0.17	0.14	0.16	0.17	0.14	0.13	0.14	0.12	0.14	0.20	0.15	0.15	0.18	0.13	0.15	0.10	0.14	0.13	0.11
MgO	34.31	34.61	33.40	33.90	33.80	34.01	34.70	34.07	34.30	34.69	33.22	33.65	33.08	33.67	32.70	33.44	33.79	34.17	33.33	33.76
CaO	0.48	0.43	0.47	0.50	0.40	0.38	0.60	0.88	0.52	0.44	0.60	0.51	0.55	0.55	0.53	0.41	0.96	0.47	0.76	0.44
Na_2O	0.03	0.04	0.00	0.03	0.00	0.06	0.14	0.16	0.01	0.02	0.05	0.03	0.05	0.00	0.04	0.06	0.10	0.03	0.07	0.06
Cr_2O_3	0.42	0.31	0.34	0.29	0.30	0.28	0.42	0.61	0.42	0.30	0.44	0.27	0.51	0.47	0.36	0.27	0.55	0.38	0.36	0.22
Total	99.91	100.19	100.44	101.12	99.91	100.32	101.19	100.99	100.00	100.30	100.24	99.17	99.22	99.40	99.56	100.28	100.57	99.85	100.96	100.69
O	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6
Si	1.91	1.93	1.90	1.92	1.92	1.92	1.94	1.92	1.94	1.95	1.87	1.90	1.96	1.95	1.89	1.92	1.88	1.91	1.89	1.92
Al	0.14	0.12	0.18	0.15	0.15	0.14	0.11	0.14	0.12	0.09	0.20	0.15	0.11	0.11	0.20	0.15	0.19	0.16	0.18	0.14
Ti	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Fe	0.16	0.16	0.18	0.17	0.17	0.17	0.15	0.15	0.16	0.16	0.19	0.18	0.15	0.15	0.18	0.18	0.16	0.16	0.19	0.19
Mn	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00
Mg	1.76	1.77	1.71	1.72	1.74	1.74	1.76	1.73	1.76	1.77	1.71	1.75	1.70	1.73	1.69	1.71	1.73	1.76	1.70	1.73
Ca	0.02	0.02	0.02	0.02	0.01	0.01	0.02	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.04	0.02	0.03	0.02
Na	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00
Cr	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Total	4.01	4.01	4.00	4.00	4.00	4.00	4.01	4.00	4.00	4.00	4.02	4.02	3.98	3.99	4.00	4.00	4.02	4.01	4.01	4.01
Mg#	91.6	91.6	90.5	90.9	91.1	91.3	92.1	92.2	91.8	91.8	90.1	90.5	91.7	91.9	90.3	90.5	91.5	91.7	89.9	90.1

										Clinopyroxene										
Sample	**BAL-4**	**BAL-4**	**BAL-8**	**BAL-8**	**FOU-3**	**FOU-3**	**FOU-9**	**FOU-9**	**FOU-15**	**FOU-15**	**SUM-4**	**SUM-4**	**SUM-6**	**SUM-6**	**SUM-11**	**SUM-11**	**SUM-12**	**SUM-12**	**SUM-15**	**SUM-15**
Analysis	**4.1.1**	**4.1.2**	**8.7.20**	**8.7.21**	**3.3.11**	**3.3.14**	**9.1.1**	**9.1.2**	**15.7.24**	**15.4.31**	**4.8.26**	**4.8.27**	**6.3.12**	**6.3.13**	**11.2.2**	**11.2.3**	**12.3.9**	**12.3.10**	**15.1.1**	**15.1.2**
Location	**core**	**rim**	**core**	**rim**	**core**	**rim**	**core**	**rim**	**core**	**rim**	**core**	**rim**	**core**	**rim**	**core**	**rim**	**core**	**rim**	**core**	**rim**
SiO_2	52.49	52.88	52.45	52.56	52.73	53.85	53.51	53.70	53.64	54.31	51.66	52.17	53.58	53.48	51.59	52.06	51.89	52.57	51.85	52.37
TiO_2	0.27	0.26	0.32	0.33	0.16	0.11	0.16	0.14	0.00	0.04	0.56	0.53	0.13	0.16	0.39	0.45	0.14	0.14	0.39	0.39
Al_2O_3	5.21	4.48	6.48	5.60	5.81	5.16	4.40	4.62	2.84	2.33	6.82	5.80	3.68	3.03	7.52	6.24	6.54	4.95	7.61	6.38
FeO	2.16	2.04	2.50	2.55	2.19	2.45	2.71	2.80	1.98	2.07	2.54	2.42	2.16	2.08	2.48	2.47	1.99	2.09	2.38	2.30
MnO	0.09	0.06	0.09	0.04	0.09	0.10	0.08	0.09	0.08	0.10	0.09	0.09	0.08	0.08	0.09	0.05	0.07	0.09	0.08	0.04
MgO	15.46	15.69	15.14	15.37	14.98	15.50	16.46	16.45	16.86	17.47	15.10	15.49	16.50	16.97	14.23	14.87	15.14	15.81	14.44	15.18
CaO	21.32	21.67	20.98	21.10	20.85	20.33	19.12	18.48	23.59	23.74	21.01	21.58	22.09	22.34	20.31	21.14	21.64	21.44	21.20	21.61
Na_2O	1.36	1.21	1.49	1.35	1.55	1.87	1.77	1.76	0.46	0.41	1.60	1.33	0.77	0.69	1.78	1.56	1.59	1.27	1.75	1.58
Cr_2O_3	1.11	0.95	0.73	0.59	0.79	0.71	1.14	1.04	0.84	0.50	0.78	0.64	1.21	0.79	0.87	0.64	1.16	0.89	0.90	0.73
Total	99.47	99.24	100.18	99.49	99.15	100.08	99.35	99.08	100.29	100.97	100.16	100.05	100.20	99.62	99.26	99.48	100.16	99.25	100.60	100.58
O	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6
Si	1.91	1.93	1.89	1.91	1.92	1.94	1.94	1.95	1.94	1.95	1.87	1.89	1.93	1.94	1.88	1.89	1.88	1.91	1.87	1.88
Al	0.22	0.19	0.28	0.24	0.25	0.22	0.19	0.20	0.12	0.10	0.29	0.25	0.16	0.13	0.32	0.27	0.28	0.21	0.32	0.27
Ti	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.01	0.00	0.00	0.01	0.01	0.00	0.00	0.01	0.01
Fe	0.07	0.06	0.08	0.08	0.07	0.07	0.08	0.08	0.06	0.06	0.08	0.07	0.07	0.06	0.08	0.08	0.06	0.06	0.07	0.07
Mn	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mg	0.84	0.85	0.81	0.83	0.81	0.83	0.89	0.89	0.91	0.94	0.81	0.84	0.89	0.92	0.77	0.81	0.82	0.86	0.77	0.81
Ca	0.83	0.85	0.81	0.82	0.81	0.78	0.74	0.72	0.91	0.91	0.81	0.84	0.85	0.87	0.79	0.82	0.84	0.84	0.82	0.83
Na	0.10	0.09	0.10	0.10	0.11	0.13	0.12	0.12	0.03	0.03	0.11	0.09	0.05	0.05	0.13	0.11	0.11	0.09	0.12	0.11
Cr	0.03	0.03	0.02	0.02	0.02	0.02	0.03	0.03	0.02	0.01	0.02	0.02	0.03	0.02	0.03	0.02	0.03	0.03	0.03	0.02
Total	4.00	4.00	4.00	4.00	4.00	4.00	4.01	4.00	4.00	4.01	4.02	4.01	3.99	4.00	4.00	4.01	4.02	4.01	4.01	4.01
Mg#	92.7	93.2	91.5	91.5	92.4	91.9	91.5	91.3	93.8	93.8	91.4	91.9	93.2	93.6	91.1	91.5	93.1	93.1	91.5	92.2

3. Examples of core-to-rim zoning in additional samples.



	spectrum 38	spectrum 37
	core	rim
Na2O	0.33	0.31
MgO	33.11	34.60
Al2O3	4.67	3.86
SiO2	54.82	56.52
K2O	0.00	0.00
CaO	0.44	0.35
TiO2	0.12	0.00
Cr2O3	0.24	0.21
MnO	0.14	0.00
FeO	6.18	6.17

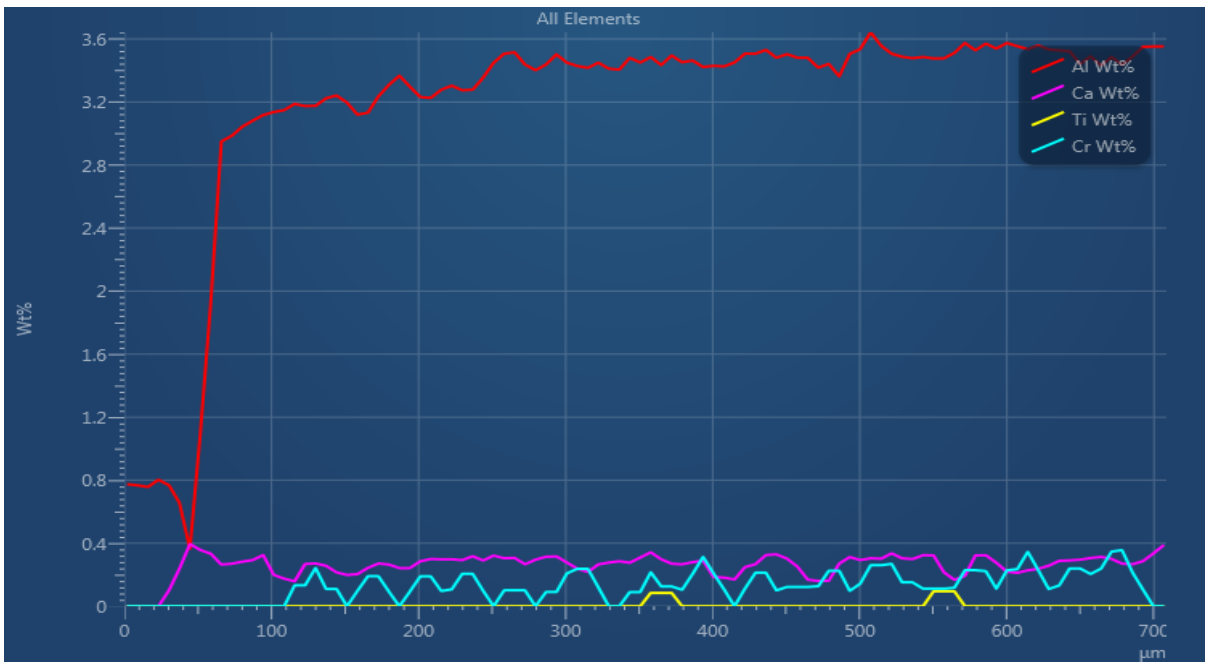
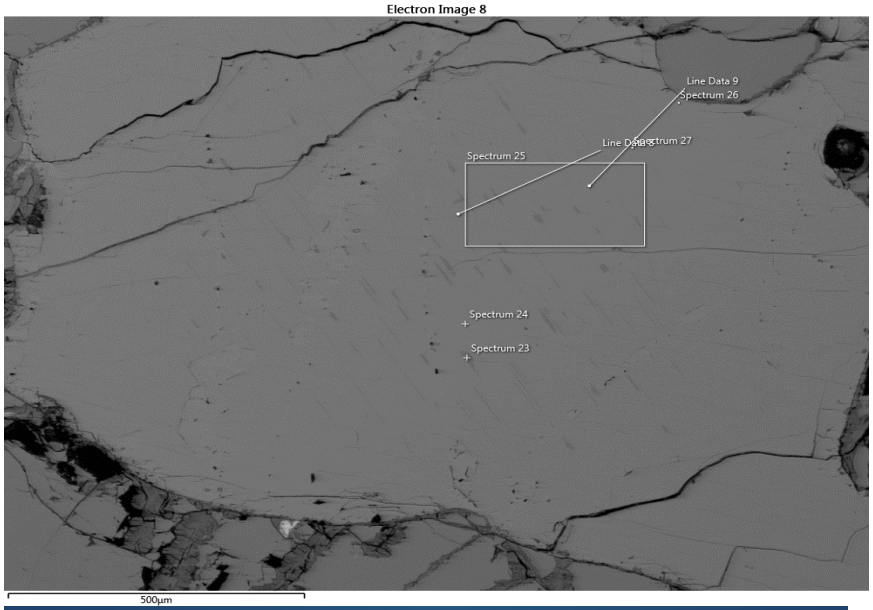
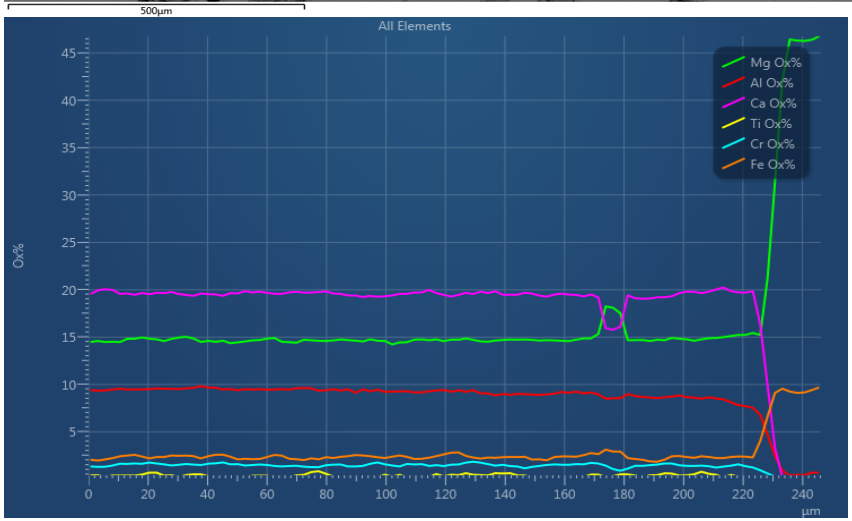


Figure DS4. Back-scattered electron image of zoning in an orthopyroxene in unpublished sample SUM-4. The lower panel shows the line scan (Line Data 15).





	23	24	27	26	Line 8	25	Difference	Difference
	OPX	CPX core	CPX mid	CPX rim	reinteg ration	Area scan	Line 8 minus 24	25 minus 24
Na2O	0.41	1.92	1.78	1.58	1.75	1.82	-0.17	-0.10
MgO	32.80	14.43	14.66	15.13	15.79	15.29	1.36	0.86
Al2O3	5.04	7.66	7.36	6.22	7.67	7.81	0.01	0.15
SiO2	54.82	51.71	52.00	51.42	52.16	52.51	0.45	0.80
K2O	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CaO	0.55	20.60	21.01	20.83	19.70	20.45	-0.90	-0.15
TiO2	0.00	0.45	0.46	0.44	0.44	0.42	-0.01	-0.03
Cr2O3	0.21	0.91	0.82	0.81	0.88	0.82	-0.03	-0.09
MnO	0.14	0.00	0.00	0.00	0.00	0.00	0.00	0.00
FeO	6.36	2.51	2.51	2.58	2.83	2.62	0.32	0.11

Figure DS5. Clinopyroxene with narrow orthopyroxene exsolution in SUM-13. The middle panel is a Line 9, in the area of zoning at a clinopyroxene-olivine margin. Data measured above show that the difference in elements between the cpx core and the re-integration composition (Line 8) or the area scan (25) is very small, except for SiO_2. EDS analyses.

2. Representative trace element concentrations (ppm) for pyroxene grains

	Orthopyroxene								Clinopyroxene									
Sample	**BAL-4**	**FOU-3**	**FOU-9**	**FOU-15**	**SUM-4**	**SUM-6**	**SUM-12**	**SUM-15**	**BAL-4**	**BAL-8**	**FOU-3**	**FOU-9**	**FOU-15**	**SUM-4**	**SUM-6**	**SUM-11**	**SUM-12**	**SUM-15**
K									3.3	0.6	6.2	39.6	11.6	2.4	4.5	2.7	1.8	0.1
Sc	15	13	13	21	15	18	13	13	72	61	60	70	60	66	59	66	64	62
Ti	360	287	249	64	706	270	225	485	1431	1759	799	721	153	3104	674	2525	893	2329
V	83	83	71	92	99	96	87	93	239	222	234	274	193	270	234	253	231	245
Cr	2554	1878	2969	2678	2062	3343	2864	2059	6073	4232	5426	8998	4891	4448	6682	4295	5961	4742
Mn	1015	1036	1003	1017	1173	1013	1108	1168	565	623	605	762	538	606	590	628	548	596
Co	50	59	61	50	60	52	57	58	17	17	18	27	17	18	20	18	17	17
Ni	630	811	953	628	779	664	764	752	288	284	290	472	306	297	359	289	286	271
Cu	1.3	1.2	3.2	1.8	0.5	1.0	0.6	0.8	1.2	1.2	0.8	4.0	1.5	1.3	1.3	1.3	1.2	1.3
Zn	28.7	32.8	35.9	28.3	30.1	32.3	28.2	26.9	5.9	5.5	6.9	12.9	8.2	5.9	7.4	5.1	5.1	5.0
Ga	2.0	2.1	1.7	1.5	2.7	1.8	2.1	2.6	2.3	2.7	2.6	3.7	1.2	3.7	1.9	3.6	2.7	3.5
Rb	0.15	0.01	0.01	0.12	0.00	0.00	0.00	0.00	0.02	0.01	0.03	0.02	0.02	0.03	0.01	0.02	0.02	0.01
Sr	0.06	0.02	0.85	0.04	0.01	0.09	0.01	0.02	25.6	4.9	12.2	413.8	25.8	8.7	32.9	20.4	8.8	35.9
Y	0.42	0.57	0.82	0.14	0.65	0.20	0.38	0.50	10.8	13.2	9.8	10.9	2.0	15.7	2.9	16.3	9.8	15.4
Zr	0.34	0.24	1.01	0.09	0.42	0.39	0.08	0.46	11.2	4.8	2.2	27.6	0.9	12.9	6.0	11.8	2.0	16.2
Nb	0.01	0.01	0.06	0.05	0.00	0.02	0.00	0.00	0.12	0.07	0.18	1.46	1.21	0.03	0.23	0.06	0.04	0.02
Cs	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ba	0.00	0.03	0.01	0.02	0.00	0.03	0.00	0.00	0.00	0.01	0.06	1.02	0.05	0.01	0.01	0	0.01	0.01
La	0.003	0.002	0.063	0.006	0.000	0.004	0.001	0.001	1.03	0.01	0.57	25.51	1.78	0.02	0.71	0.1	0.21	0.42
Ce	0.003	0.016	0.352	0.004	0.001	0.008	0.002	0.003	1.43	0.13	1.09	89.43	1.47	0.42	1.94	0.63	0.42	2.01
Pr	0.002	0.001	0.061	0.000	0.000	0.002	0.000	0.001	0.25	0.08	0.14	9.8	0.09	0.2	0.28	0.19	0.07	0.43
Nd	0.000	0.003	0.329	0.002	0.004	0.014	0.000	0.005	1.78	1.03	0.73	36.08	0.29	1.96	1.47	1.81	0.44	2.91
Sm	0.003	0.002	0.092	0.003	0.004	0.010	0.003	0.004	0.81	0.77	0.34	4.99	0.06	1.14	0.44	1.15	0.29	1.22
Eu	0.004	0.003	0.033	0.002	0.004	0.003	0.001	0.002	0.34	0.36	0.17	1.46	0.02	0.51	0.15	0.5	0.15	0.48
Gd	0.014	0.016	0.116	0.004	0.014	0.013	0.005	0.013	1.29	1.44	0.75	3.36	0.08	1.89	0.43	1.9	0.75	1.78
Tb	0.003	0.005	0.019	0.001	0.006	0.002	0.003	0.004	0.26	0.31	0.18	0.43	0.02	0.38	0.07	0.4	0.19	0.38
Dy	0.042	0.057	0.132	0.015	0.063	0.022	0.036	0.053	1.90	2.33	1.55	2.29	0.22	2.85	0.5	2.95	1.56	2.76
Ho	0.014	0.018	0.031	0.005	0.019	0.009	0.013	0.018	0.43	0.53	0.38	0.41	0.08	0.63	0.11	0.65	0.38	0.6
Er	0.065	0.088	0.090	0.026	0.098	0.030	0.061	0.081	1.27	1.55	1.17	0.99	0.29	1.82	0.32	1.88	1.2	1.81
Tm	0.015	0.017	0.014	0.008	0.019	0.007	0.013	0.016	0.18	0.22	0.17	0.13	0.05	0.26	0.05	0.26	0.17	0.26
Yb	0.145	0.173	0.118	0.092	0.205	0.081	0.137	0.162	1.22	1.64	1.32	0.84	0.41	1.82	0.41	1.88	1.3	1.85
Lu	0.027	0.033	0.018	0.016	0.036	0.014	0.025	0.030	0.17	0.22	0.18	0.11	0.07	0.25	0.06	0.25	0.18	0.25
Hf	0.021	0.008	0.028	0.004	0.032	0.012	0.004	0.020	0.44	0.33	0.12	0.84	0.03	0.74	0.19	0.55	0.12	0.58
Ta	0.001	0.001	0.002	0.002	0.000	0.001	0.000	0.000	0.00	0.00	0.02	0.11	0.04	0.00	0.02	0.00	0.00	0.00
Pb	0.531	0.011	0.014	0.456	0.007	0.790	0.009	0.007	0.04	0.02	0.09	0.24	0.55	0.01	0.02	0.02	0.02	0.03
Th	0.003	0.001	0.001	0.005	0.000	0.005	0.000	0.000	0.39	0.02	0.28	0.15	0.29	0.00	0.06	0.01	0.01	0.00
U	0.002	0.001	0.001	0.008	0.000	0.002	0.000	0.000	0.11	0.01	0.12	0.03	0.11	0.00	0.03	0.00	0.00	0.00

5. Laser ablation line scans across rims of pyroxenes.

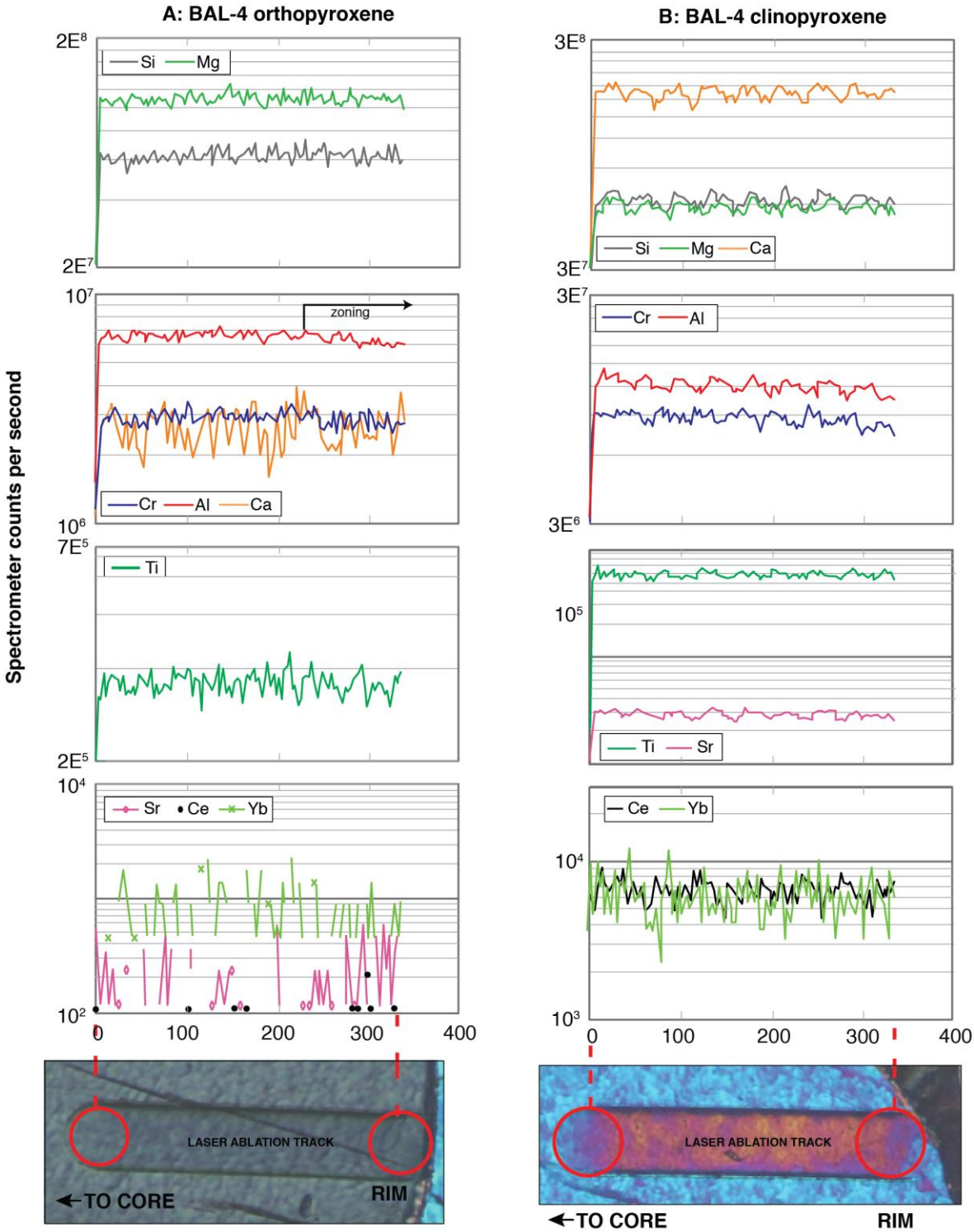


Fig. DS6. Line scan over an orthopyroxene grain and clinopyroxene in BAL-4 showing the element trends as the rim is approached. Gaps in the data represent elements below LA-ICP-MS detection limit. All analyses began at the cores.

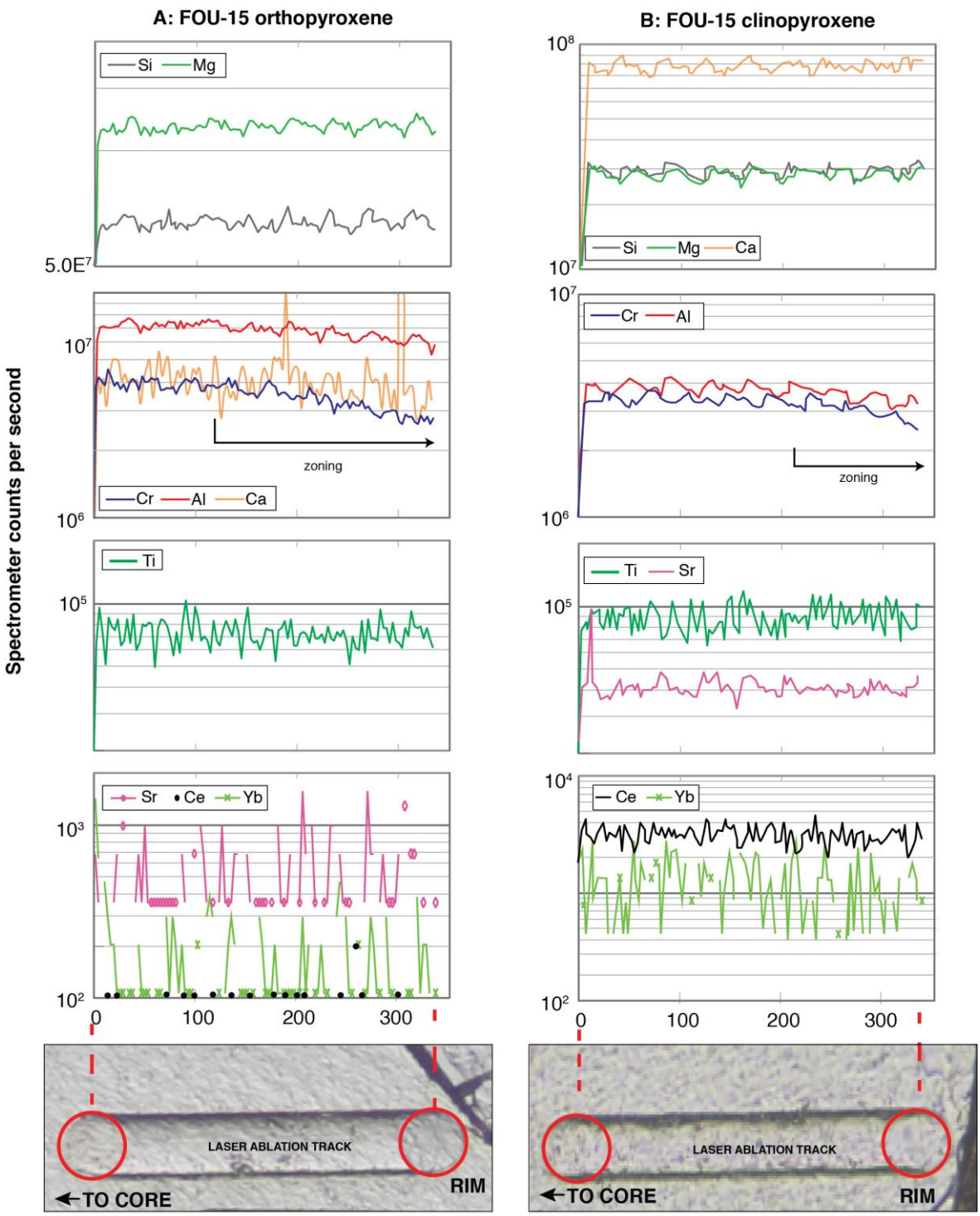


Fig. DS7. Line scan over an orthopyroxene grain and an clinopyroxene in FOU-15 showing the element trends as the rim is approached. Gaps in the data represent elements below LA-ICP-MS detection limit. All analyses began at the cores.

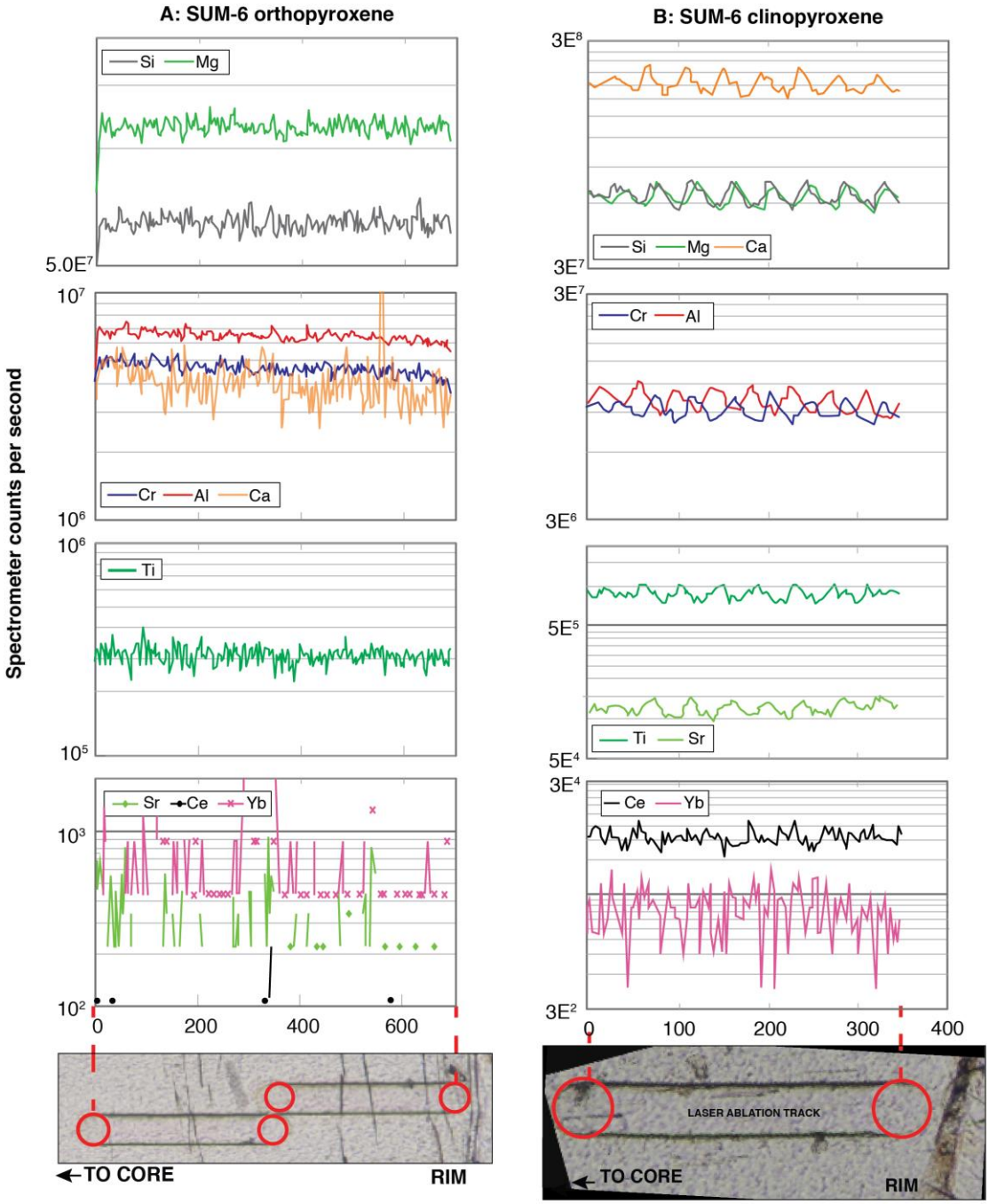


Fig. DS8. Line scan over an orthopyroxene grain and a clinopyroxene in SUM-6 showing the element trends as the rim is approached. Gaps in the data represent elements below LA-ICP-MS detection limit. All analyses began at the cores.

			Ma	Rb	Sr	87Rb/ 86Sr	87Sr/ 86Sr	87Sr/ 86Sr	Sm	Nd	147Sm/ 144Nd	143Nd/ 144Nd	143Nd/ 144Nd	epsNd	epsNd	1/Nd	TDM
				ppm	ppm		0	20	ppm	ppm		0	20	0	20		
Type 1 Trace element patterns (LREE depleted)																	
BAL8	**Bald Hill**	Dalton et al. (this study)	23 ?	0.17	11.49	0.0438	0.702774	**0.70276**	0.84	1.34	0.3773	0.51346	0.51341	**16.0**	**15.5**	0.7	0.28
MUR-2	**Murdering Beach**	Scott et al. (2014b)	14	0.03	18.49	0.0052	0.701690	**0.70169**	1.14	1.96	0.3498	0.51371	0.51367	**20.9**	**20.6**	0.5	0.62
PP3	**Murdering Beach**	McCoy-West et al. (2016)	14	0.02	57.99	0.0008	0.702466	**0.70247**	3.46	1.46	0.2585	0.51341	0.51338	**15.1**	**14.9**	0.7	0.86
PP3*	**Murdering Beach**	McCoy-West et al. (2016)	14	0.02	57.50	0.0012	0.702464	**0.70246**	3.40	1.48	0.2582	0.51341	0.51338	**15.1**	**15.0**	0.7	0.88
SUM11	**Summer Hills**	Dalton et al. (this study)	16 ?	0.34	19.57	0.0505	0.702056	**0.70204**	1.10	1.75	0.3782	0.51351	0.51346	**17.1**	**16.6**	0.6	0.33
OU45852	**Trig L, Pigroute**	McCoy-West et al. (2016)	19	0.00	0.88	0.0127	0.702057	**0.70205**	0.38	0.43	0.6826	0.51384	0.51375	**23.4**	**22.2**	2.3	0.22
OU45852*	**Trig L, Pigroute**	McCoy-West et al. (2016)	19	0.01	1.03	0.0147	0.702061	**0.70206**	0.40	0.44	0.6607	0.51379	0.51370	**22.4**	**21.3**	2.3	0.21
TRL-5	**Trig L, Pigroute**	Scott et al. (2014b)	19	0.05	1.29	0.1172	0.703536	**0.70350**	0.51	0.42	0.7344	0.51323	0.51313	**11.5**	**10.1**	2.4	0.02
TRL-10	**Trig L, Pigroute**	Scott et al. (2014b)	19	0.07	0.95	0.2232	0.702654	**0.70259**	0.38	0.36	0.6476	0.51380	0.51371	**22.6**	**21.4**	2.8	0.22
Mixture of Type 1 and Type 2 patterns																	
Das-4	**Mt Dasher**	Scott et al. (2014a,b)	16	0.17	71.17	0.0068	0.702897	**0.70290**	n.d.	0.78	0.3645	0.51443	0.51438	**35.0**	**34.5**	1.3	1.29
Das-4B	**Mt Dasher**	Scott et al. (2014a,b)	16	0.12	75.34	0.0045	0.702920	**0.70292**	0.50	0.83	0.3645	0.51461	0.51456	**38.5**	**38.1**	1.2	1.47
FP8	**Fortification Peak**	McCoy-West et al. (2016)	18	0.03	0.56	0.1783	0.704153	**0.70410**	0.04	0.02	0.2732	0.51401	0.51398	**26.8**	**26.6**	52.9	2.19
FP8*	**Fortification Peak**	McCoy-West et al. (2016)	18	0.04	0.60	0.2133	0.704202	**0.70414**	0.04	0.02	0.2836	0.51423	0.51419	**31.0**	**30.8**	52.4	2.32
FOU3	**Foulden Maar**	Dalton et al. (this study)	23	0.18	23.28	0.0217	0.703474	**0.70347**	0.34	1.05	0.1965	0.51380	0.51377	**22.6**	**22.6**	1.0	-5.67
PP1	**Murdering Beach**	McCoy-West et al. (2016)	14	0.09	21.43	0.0122	0.701973	**0.70197**	1.79	1.02	0.3454	0.51375	0.51371	**21.7**	**21.3**	1.0	0.69
PP1*	**Murdering Beach**	McCoy-West et al. (2016)	14	0.20	19.84	0.0293	0.701971	**0.70196**	1.72	0.97	0.3412	0.51366	0.51361	**19.9**	**19.5**	1.0	0.60
PP5	**Murdering Beach**	McCoy-West et al. (2016)	14	0.16	18.18	0.0260	0.702112	**0.70210**	2.09	1.16	0.3351	0.51339	0.51335	**14.7**	**14.4**	0.9	0.29
PP5*	**Murdering Beach**	McCoy-West et al. (2016)	14	0.23	19.09	0.0351	0.702076	**0.70207**	2.08	1.17	0.3397	0.51339	0.51334	**14.6**	**14.2**	0.9	0.27
WTL2	**Trig L, Pigroute**	McCoy-West et al. (2016)	19	0.03	26.43	0.0027	0.703186	**0.70319**	0.60	0.36	0.3664	0.51379	0.51374	**22.5**	**22.1**	2.8	0.63
Wan-2	**Wangaloa Diatreme**	Scott et al. (2014b)	20 ?	1.17	215.0	0.0157	0.703083	**0.70308**	0.67	1.10	0.3657	0.51322	0.51317	**11.3**	**10.9**	0.9	0.06
Wan-2B	**Wangaloa Diatreme**	Scott et al. (2014b)	20 ?	0.08	31.41	0.0073	0.702759	**0.70276**	0.95	1.49	0.3861	0.51322	0.51316	**11.3**	**10.8**	0.7	0.05
Wan-3	**Wangaloa Diatreme**	Scott et al. (2014b)	20 ?	0.06	35.58	0.0048	0.702715	**0.70271**	0.98	1.72	0.3432	0.51320	0.51316	**11.0**	**10.6**	0.6	0.05
Type 2 trace element patterns (variably LREE-enriched)																	
BAL4	**Bald Hill**	Dalton et al. (this study)	23 ?	0.48	33.50	0.0415	0.703552	**0.70354**	0.82	2.21	0.2229	0.51303	0.51301	**7.7**	**7.7**	0.5	-2.16
Ber-1	**Berwick Diatreme**	Scott et al. (2014b)	20 ?	0.29	388.8	0.0021	0.702880	**0.70288**	2.43	19.19	0.0766	0.51284	0.51283	**4.0**	**4.3**	0.1	0.35
Ber-2	**Berwick Diatreme**	Scott et al. (2014b)	20 ?	0.06	49.37	0.0033	0.702848	**0.70285**	0.98	2.52	0.2348	0.51301	0.51297	**7.2**	**7.1**	0.4	-1.14
Ber-4	**Berwick Diatreme**	Scott et al. (2014b)	20 ?	0.09	124.9	0.0020	0.702855	**0.70285**	4.35	15.34	0.1712	0.51289	0.51286	**4.9**	**4.9**	0.1	0.97
Das-1	**Mt Dasher**	Scott et al. (2014a,b)	16	0.16	116.8	0.0040	0.703356	**0.70335**	0.67	3.49	0.1149	0.51283	0.51281	**3.7**	**3.9**	0.3	0.51

			Ma	Rb	Sr	87Rb/ 86Sr	87Sr/ 86Sr	87Sr/ 86Sr	Sm	Nd	147Sm/ 144Nd	143Nd/ 144Nd	143Nd/ 144Nd	epsNd	epsNd	1/Nd	TDM
				ppm	ppm		0	20	ppm	ppm		0	20	0	20		
Das-1B	**Mt Dasher**	Scott et al. (2014a,b)	16	0.17	105.4	0.0045	0.702880	**0.70288**	0.33	1.75	0.1123	0.51282	0.51281	**3.6**	**3.8**	0.6	0.50
Das-2	**Mt Dasher**	Scott et al. (2014a,b)	16	0.30	28.94	0.0303	0.702750	**0.70274**	1.24	3.25	0.2299	0.51296	0.51293	**6.4**	**6.3**	0.3	-1.89
Das-2B	**Mt Dasher**	Scott et al. (2014a,b)	16	0.28	27.78	0.0292	0.702750	**0.70274**	1.20	3.21	0.2257	0.51296	0.51293	**6.4**	**6.3**	0.3	-2.58
FOR-1	**Fortification Peak**	Scott et al. (2014b)	18	1.30	321.6	0.0117	0.702841	**0.70284**	5.43	17.34	0.1892	0.51286	0.51283	**4.3**	**4.3**	0.1	1.84
FOR-6	**Fortification Peak**	Scott et al. (2014b)	18	0.52	31.00	0.0483	0.702793	**0.70278**	0.38	2.43	0.0929	0.51281	0.51280	**3.4**	**3.7**	0.4	0.44
FOR-7	**Fortification Peak**	Scott et al. (2014b)	18	0.32	21.66	0.0432	0.702579	**0.70257**	0.26	0.99	0.1582	0.51289	0.51287	**4.9**	**5.0**	1.0	0.74
FOR-7*	**Fortification Peak**	Scott et al. (2014b)	18	0.30	22.88	0.0374	0.702662	**0.70265**	0.27	1.07	0.1551	0.51290	0.51288	**5.1**	**5.2**	0.9	0.67
FOR-9	**Fortification Peak**	Scott et al. (2014b)	18				0.702565	**0.70257**	0.14	0.64	0.1362	0.51285	0.51283	**4.1**	**4.2**	1.6	0.62
WFP-1	**Fortification Peak**	McCoy-West et al. (2016)	18	0.25	120.0	0.0060	0.702725	**0.70272**	1.23	0.22	0.1058	0.51289	0.51288	**5.0**	**5.2**	4.6	0.38
WFP-2	**Fortification Peak**	McCoy-West et al. (2016)	18	0.02	20.45	0.2229	0.702811	**0.70275**	1.75	0.69	0.2371	0.51304	0.51301	**7.8**	**7.7**	1.5	-0.82
WFP-4	**Fortification Peak**	McCoy-West et al. (2016)	18	0.03	11.78	0.0063	0.703213	**0.70321**	1.34	0.25	0.1126	0.51280	0.51278	**3.1**	**3.3**	4.0	0.55
WFP-4*	**Fortification Peak**	McCoy-West et al. (2016)	18	0.02	13.45	0.0048	0.703173	**0.70317**	1.53	0.29	0.1156	0.51281	0.51279	**3.3**	**3.5**	3.4	0.55
WFP-5	**Fortification Peak**	McCoy-West et al. (2016)	18	0.46	15.26	0.0877	0.703046	**0.70302**	1.07	0.30	0.1675	0.51280	0.51278	**3.2**	**3.3**	3.4	1.17
WFP-11	**Fortification Peak**	McCoy-West et al. (2016)	18	0.39	73.66	0.0155	0.702680	**0.70268**	4.74	0.97	0.1244	0.51286	0.51284	**4.3**	**4.4**	1.0	0.52
FOU9	**Foulden Maar**	Dalton et al. (this study)	23	0.33	370.3	0.0026	0.702894	**0.70289**	5.42	36.43	0.0898	0.51289	0.51288	**5.0**	**5.2**	0.0	0.33
Kat-2	**Kattothyrst**	Scott et al. (2014a,b)	16 ?	1.62	340.1	0.0138	0.703083	**0.70308**	3.23	21.41	0.0910	0.51288	0.51287	**4.7**	**5.0**	0.0	0.35
Kat-2B	**Kattothyrst**	Scott et al. (2014a,b)	16 ?	1.55	337.4	0.0133	0.703115	**0.70311**	3.30	21.74	0.0917	0.51288	0.51287	**4.7**	**4.9**	0.0	0.35
Kat-3	**Kattothyrst**	Scott et al. (2014a,b)	16 ?	1.66	504.7	0.0095	0.702805	**0.70280**	10.18	46.10	0.1333	0.51287	0.51286	**4.6**	**4.8**	0.0	0.54
Kat-3B	**Kattothyrst**	Scott et al. (2014a,b)	16 ?	1.54	539.2	0.0083	0.702796	**0.70279**	10.81	48.89	0.1335	0.51288	0.51286	**4.8**	**4.9**	0.0	0.53
WRR-1	**Ram Rock**	McCoy-West et al. (2016)	16	0.00	4.85	0.0022	0.703555	**0.70355**	5.10	1.45	0.1714	0.51285	0.51283	**4.1**	**4.2**	0.7	1.11
WRR-5	**Ram Rock**	McCoy-West et al. (2016)	16	0.02	43.75	0.0015	0.702786	**0.70279**	2.86	0.01	0.0031	0.51284	0.51284	**4.0**	**4.5**	69.0	0.23
WRR-7	**Ram Rock**	McCoy-West et al. (2016)	16	0.02	19.69	0.0027	0.703168	**0.70317**	2.27	0.60	0.1592	0.51299	0.51297	**6.9**	**7.0**	1.7	0.47
WRR-9	**Ram Rock**	McCoy-West et al. (2016)	16	1.39	7.44	0.5407	0.702975	**0.70282**	0.49	0.09	0.1071	0.51293	0.51292	**5.8**	**6.0**	11.6	0.32
MUR-1	**Murdering Breach**	Scott et al. (2014a,b)	14	0.14	105.0	0.0038	0.702102	**0.70210**	2.22	5.14	0.2601	0.51307	0.51303	**8.4**	**8.2**	0.2	-0.30
SUM6	**Summer Hills**	Dalton et al. (this study)	16 ?	0.22	32.92	0.0191	0.702789	**0.70278**	0.43	1.47	0.1748	0.51290	0.51288	**5.1**	**5.1**	0.7	1.02
WTL-1	**Trig L, Pigroute**	McCoy-West et al. (2016)	19	0.02	4.98	0.0118	0.702564	**0.70256**	0.52	0.43	0.5101	0.51297	0.51290	**6.5**	**5.7**	2.3	-0.10
Trl-1	**Trig L, Pigroute**	Scott et al. (2014a,b)	19	0.03	8.96	0.0105	0.703193	**0.70319**	0.12	0.51	0.1433	0.51265	0.51263	**0.2**	**0.3**	2.0	1.11