

Supplemental Document 4 – MELTS Modeling Details

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MELTS Modeling Procedures, Justification, and Outcome

Simulations of crystallization in an MgO-rich TVZ basalt, the Waimarino basalt, using MELTS_Excel (Gualda and Ghiorso 2015) may provide some constraints on our question of a pressure differential causing the observed pyroxene signatures. Graham and Hackett (1987) modeled Type 5 andesites of the TVZ (Ohakune is considered a Type 5 andesite) from Waimarino basalt via the crystallization of olivine, clinopyroxene, plagioclase, and chrome spinel. Conway et al. (2018) indicate that Ohakune and Pukeonake magmas lie along a mixing trend between Ruapehu dacites and Waimarino basalt compositions. Thus, the Waimarino basalt is implicated as at least a part of the petrogenesis of high-Mg# andesites. It can therefore be utilized in models as a basis for testing hypotheses regarding the pressure dependence of the Hi-Al and Lo-Al groups.

We ran cooling crystallization simulations (i.e. decrease temp from liquidus (~1300°C) to 800°C) at varying constant-pressure scenarios (2.0 kbar, 5.3 kbar, and 8.0 kbar) on Waimarino basalt TVZ-11 (Gamble et al. 1990; see Table D1 below) with 3.0 wt. % H₂O. Runs at lower H₂O contents did not saturate olivine and were not considered because of this. Models were constrained in f_{O_2} at the NNO buffer. The 5.3 kbar depth was based on thermobarometry results from this study and others, discussed in the main text; the 2.0 and 8.0 kbar scenarios were chosen as other plausible pressures of crystallization in an arc magmatic system. MELTS calculated the composition of modeled melts, and crystals derived from such melts.

These simulations showed, at an Mg# equivalent to the average of Ohakune clinopyroxenes & at 2.0 kbar, Jd in pyroxene is 0.0088. At 5.3 kbar the modeled pyroxenes have a Jd of 0.0120, and at 8.0 kbar show 0.0152. The 5.3 kbar and 8.0 kbar results are both within the range of Jd that we observe in natural Ohakune samples. This is summarized in Table D2 below.

Table D1

Oxide	SiO ₂	TiO ₂	Al ₂ O ₃	Fe ₂ O ₃	MnO	MgO	CaO	Na ₂ O	K ₂ O	P ₂ O ₅	LOI
Wt. %	52.26	0.47	12.70	9.28	0.16	13.17	9.61	1.64	0.43	0.05	0.7

The non-normalized major element oxide composition (in weight percent) of Waimarino basalt TVZ-11 used as input for modeling, taken from Gamble et al. 1990.

Table D2

Group	Temperature (°C)	Mg#	Jadeite
Lo-Al (Observed)	1033*	83**	0.0115 (average)
Hi-Al (Observed)	1025*	82**	0.0148 (average)
2.0 kbar (MELTS)	1095	81	0.0088
5.3 kbar (MELTS)	1035	80	0.0120
8.0 kbar (MELTS)	1159	79	0.0152
*Constrained by thermobarometry; see main text. Temperatures of MELTS runs are reported from the output.			
** Average values calculated from observed data			

Table summarizing observed pyroxenes, and modeled clinopyroxenes from MELTS_Excel simulations.

References

- Gamble JA, Smith IEM, Graham IJ, Kokelaar BP, Cole JW, Houghton BF, Wilson CJN (1990) The petrology, phase relations, and tectonic setting of basalts from the Taupo volcanic zone, New Zealand, and the Kermadec Island arc-Havre trough, SW Pacific. *J Volcanol Geotherm Res* 43(1-4):253-270. doi: [10.1016/0377-0273\(90\)90055-K](https://doi.org/10.1016/0377-0273(90)90055-K)
- Graham IJ, Hackett WR (1987) Petrology of calc-alkaline lavas from Ruapehu Volcano and related vents, Taupo Volcanic Zone, New Zealand. *J Petrol* 28(3):531-567.
- Gualda GAR, Ghiorso MS (2015) MELTS_Excel: A Microsoft Excel-based MELTS interface for research and teaching of magma properties and evolution. *Geochemistry, Geophysics, Geosystems* 16(1):315-324.