Short Visit Grant X

MeMoVolc Short visit – Scientific Report

Proposal Title: Shallow conduit processes – magma degassing and microlite formation in Hekla Iceland.

Application Reference N°: 5520

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1. Purpose of the visit

The purpose of the visit to Labratorie Magmas et Volcans Clermont-Ferrand, France was to undertake chemical analysis on the eruption products from three historic (i.e. post 874 AD) events in Hekla volcano in Iceland. The main objectives were to measure with microprobe the major and volatile element composition of the erupted tephra and to quantify pre- and post-eruptive volatile content of these events.

During ascent of magmas volatiles are exsolved from the magma and as such are the driving force of volcanic eruptions. Original volatile content as well as the rate and degree it is released from the magma upon eruption exert strong control on magma vesiculation and fragmentation. Furthermore, volcanically-induced atmospheric effects are strongly linked to the amount of gases vented upon eruption, especially the mass of sulphur, chlorine and fluorine released into the atmosphere (e.g. Thordarson et al., 2001; 2003). Hence, for studies aimed at understanding shallow conduit processes as well as those aimed at evaluating the environmental and climatic effects of past events it is important to know the pre-eruptive volatile content of the erupted magma. When quantifying the amount of volatiles released into the atmosphere two methods have been employed: (1) direct measurements of the volatile mass released upon eruption by remote sensing (only applicable to modern day events and requires continuous monitoring for the duration of the eruption) and (2) by applying the "petrologic method", which is based direct analyses of the eruption products. By measuring the volatile concentrations in undegassed melt inclusions and degassed groundmass glass and using the difference between the two via mass-balance calculations to estimate the total amount vented into the atmosphere (e.g. Devine et al., 1984; Thordarson et al., 1996).The agreement between the results obtained by these methods for Icelandic eruptions is generally good (e.g. Moune et al., 2007). However, the petrologic method is the only method applicable to events pre-dating effective monitoring of gas-release upon eruption. Therefore it was utilized in this study, because our goal is to establish the volatile budget for the three historic Hekla eruptions in question.

2) Description of the work carried out during the visit

In preparation for the analytical work carefully selected tephra samples from each eruption were prepared for thin sectioning. Tephra grains in the size range of 125 µm to 250 µm were mounted directly into polished plugs for measurements of the degassed groundmass. The preparation for obtaining melt-inclusion-bearing crystals was more evolved. Step one was to crush the tephra samples and firstly separate the crystals from the glass, then the melt-inclusion-bearing crystals from those without inclusions. Plagioclase was the most abundant mineral phase (i.e. phenocryst) and thus the ideal phase for obtaining statistically valid sample set of melt inclusions. The crystals were then washed with acetone, mounted in epoxy and polished for the microprobe analyses. Sizes of the phenocrysts used for mounting ranged from 125 µm to 500 µm. Majority of the inclusions were sub-rounded, no inclusion analyzed had daughter minerals but few had shrinkage bubbles. This work was carried out at the University of Iceland.

The microprobe facilities at Labratorie Magmas et Volcans Clermont-Ferrand have a Cameca SX-100 and are supervised by Jean-Luc Devidal who introduced me to the facilities and the appropriate analytical procedure. Information on analytical and calibration procedures is presented in Óladóttir et al., (2011).

In total the composition was determined for 10-15 melt inclusions in each eruption (Table 1 and Table 2). The largest inclusions were analyzed with spot diameter of 20 µm and sample current of 8 nA, smaller inclusions were analyzed with 10 µm and 4 nA. The composition of the crystals hosting the melt inclusions was also measured. This is done to enable accurate assessment for the origin of the melt inclusions and to determine how representative they are of the erupted magma. Groundmass or tephra was measured with of 10 µm and sample current of 4 nA where possible, but also with 5 µm and 2 nA when the abundance of microlites was high making and it challenging to find pristine glass for analysis. In total were four days spent on the microprobe, from the 15th of October to the 18th 2013.

3) Description of the main results obtained

Major element and volatile (F, Cl and S) concentrations were measured. Composition of both melt inclusions and groundmass were determined. Potential modification of melt inclusion compositions by post-entrapment needs to be assessed, although previous study on volatiles in the Hekla system (Moune et al., 2007) this effect was deemed minimal in plagioclase hosted inclusions. Preliminary assessment of the results indicates that there is a systematic difference between the major elemental composition of the degassed groundmass in the three eruptions considered here. This variance is demonstrated on TAS diagram below (Fig. 1) showing that the Hekla 1991 tephra is most uniform in its composition while Hekla 1300, the largest eruption, has the widest span in SiO_2 and $Na_2O + K_2O$ (Figure 1).

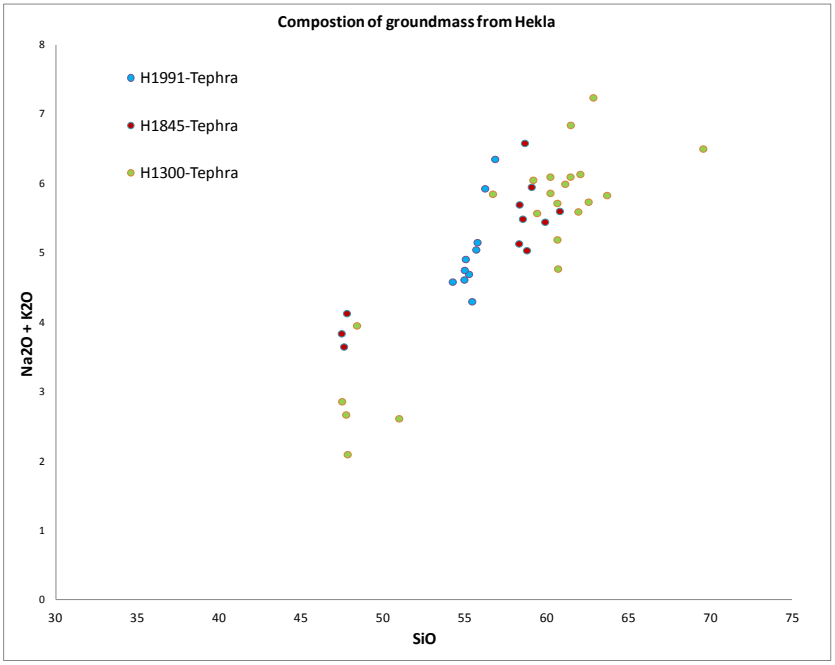

Figure 1: Composition of the degassed groundmass or tephra. There is a very small range in SiO content of Hekla 1991 compared to the oter two eruptions. Hekla 1300 has the larges spread both in SiO and $Na_2O + K_2O$.

Melt-inclusion-bearing crystals in Hekla 1845 and 1991 are relatively homogenous in terms of their composition, while Hekla 1300 crystal exhibit a greater variance. Examples of the plagioclase compositions from Hekla 1991 and 1845 are in Table 1 and Table 2 shows Hekla 1300 plagioclase compositions.

Sulphur concentrations in degassed groundmass range from 191 ± 28 ppm to 264 ± 13 ppm for Hekla 1991 tephra; from 88 ± 21 ppm to 707 ± 53 ppm for Hekla 1845 and for Hekla 1300 the range is 129 ± 20 to 1034 ± 76. Significant variance was observed in the eruptions of 1845 and 1300, when compared to 1991 where variance was almost within detection limit. Melt inclusions from Hekla 1991 have a wider range in their sulphur contents (i.e. 1053 ± 74 down to 196 ± 31 ppm) than the degassed tephra; Hekla 1845 melt inclusions range from 584 ± 44 to 214 ± 16 ppm of Sulphur, showing the lowest melt inclusion variance of the three eruptions; melt inclusions from Hekla 1300 show a similar range as the tephra from 1586 ± 84 ppm to 282 ± 31 ppm of sulphur.

H1991							
SiO2	Al2O3	FeO	CaO	Na2O	K2O	Total	Comment
53.21	28.80	0.50	12.31	4.52	0.15	99.48	BC6 core
53.59	28.75	0.43	11.94	4.50	0.15	99.37	BC6 rim
56.97	26.55	0.48	9.36	5.97	0.28	99.61	BC7 rim
56.70	26.46	0.54	9.43	6.03	0.30	99.46	BC7 core
53.55	28.59	0.69	11.74	4.83	0.18	99.57	BC8 rim
53.25	28.29	0.47	12.07	4.74	0.17	98.99	BC8 core
53.55	28.25	0.61	12.00	4.52	0.14	99.08	BC9 core
53.99	28.32	0.50	11.73	4.67	0.16	99.37	BC9 rim
54.00	28.40	0.36	11.52	4.88	0.17	99.34	BC20 rim
53.49	28.61	0.54	11.86	4.73	0.15	99.38	BC20 core
54.14	28.48	0.58	11.73	4.93	0.17	100.02	BC15 rim
53.65	28.39	0.49	11.78	4.82	0.18	99.31	BC15 core
H1845							
SiO2	Al2O3	FeO	CaO	Na2O	K2O	Total	Comment
55.44	27.72	0.27	10.52	5.33	0.18	99.45	CC2 core
55.11	28.06	0.41	10.79	5.25	0.16	99.79	CC2 rim
54.21	28.28	0.41	11.52	4.83	0.18	99.43	CC3 core
53.70	28.38	0.45	11.79	4.71	0.15	99.19	CC3 rim
54.02	28.25	0.41	11.56	4.70	0.17	99.12	CC4 rim
54.03	27.85	0.38	11.49	4.80	0.16	98.71	CC4 core
56.16	27.10	0.28	10.15	5.47	0.22	99.37	CC5 core
54.34	28.08	0.39	11.41	4.84	0.17	99.22	CC5 rim
54.02	28.19	0.53	11.44	4.75	0.17	99.10	CC6 rim
54.88	28.20	0.52	11.02	4.94	0.18	99.75	CC6 core
53.92	28.15	0.32	11.47	4.85	0.15	98.86	CC7 rim
54.46	28.11	0.55	11.39	4.83	0.18	99.52	CC7 core

Table 1: Analyzes of the melt inclusion bearing mineral phase, majority of the analyzed plagioclase has this composition for Hekla 1991 and Hekla 1845, Hekla 1300 did show variance in few grains (Table 2).

The crystal composition results from Hekla 1300 indicate a more complex story then for the two younger events, all crystals show no signs of zoning, furthermore are there analyses of Hekla 1300 tephra grains with no microlite crystallization and high Sulphur concentrations with SiO content as low as 47.7 % (Figure 1) when the average SiO is around 59.4%. This supports field based observations that the Hekla 1300 eruption is of more complexity then the two younger eruptions.

H1300							
SiO2	Al2O3	FeO	CaO	Na2O	K2O	Total	Comment
55.56	27.81	0.31	10.55	5.48	0.20	99.91	DC8 core
55.67	27.09	0.43	10.23	5.53	0.18	99.13	DC8 rim
55.44	27.42	0.28	10.35	5.25	0.20	98.94	DC9 core
55.48	27.19	0.40	10.43	5.46	0.21	99.17	DC9 rim
55.57	26.94	0.29	10.26	5.53	0.20	98.79	DC11 rim
55.06	27.02	0.46	10.41	5.50	0.19	98.63	DC11 core
55.69	27.17	0.38	10.35	5.43	0.18	99.21	DC12 core
55.04	27.32	0.31	10.86	5.21	0.18	98.92	DC12 rim
55.83	27.09	0.33	9.99	5.47	0.20	98.91	DC13 core
55.81	27.28	0.48	10.22	5.48	0.19	99.47	DC13 rim
55.33	27.55	0.41	10.60	5.30	0.18	99.36	DC15 core
55.21	27.83	0.44	10.73	5.13	0.18	99.52	DC15 rim
55.68	27.38	0.30	10.37	5.45	0.21	99.39	DC18 core
55.17	27.62	0.43	10.77	5.15	0.17	99.31	DC18 rim
H1300							
SiO2	Al2O3	FeO	CaO	Na2O	K2O	Total	Comment
47.11	33.00	0.53	16.80	1.90	0.05	99.39	DC4 core
47.47	32.56	0.42	16.85	1.81	0.05	99.16	DC4 rim
46.36	33.13	0.49	17.32	1.51	0.03	98.83	DC7 core
46.65	32.63	0.61	17.35	1.61	0.03	98.88	DC7 rim
47.91	32.25	0.52	16.49	2.17	0.04	99.38	DC10 core
47.28	32.61	0.44	16.90	1.89	0.05	99.17	DC10 core
46.21	33.14	0.57	17.58	1.59	0.05	99.15	DC17 rim
47.42	32.52	0.74	16.74	1.93	0.06	99.42	DC17 core

Table 2: Analyzes of plagioclase with melt inclusions in Hekla 1300, crystal from the lower part e.g. had the highest concentration of Sulphur in a melt inclusion.

From this short overview of the initial results from the chemical analyses it is clear that a further processing and examination of the data is required..

4) Future collaboration with the host institution

The facilities at Labratorie et Magmas in Clermont-Ferrand are state-of-the-art and if we require further microprobe work the laboratory is the obvious choice. I look forward to further collaboration and discussion with Dr. Sigmarsson due to his expertise in this line of research and his knowledge on the geochemistry of Hekla magmas (e.g. Sigmarsson et al., 1992).

5) Projected publications / articles resulting or to result from the grand (ESF must be acknowledged in publications resulting from the grantee´s work in relation with the grant)

The results obtained in the short visit will be published as a part of a larger package concerning each of the Hekla eruption analyzed. All publications planed are intended as part of work towards a PhD at the University of Iceland. In all these publications the funding from ESF will be duly acknowledged.

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