Geophysical Research Abstracts
Vol. 12, EGU2010-11923, 2010
EGU General Assembly 2010

Proximal tephra stratigraphy of the englacial 2004 Grímsvötn eruption, Iceland: event chronology and eruption dynamics

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Here we present a reconstruction of the 2004 englacial eruptive sequence, based on detailed field and laboratory study of the proximal tephra succession. upon Detailed logging and correlation of 48 vertical sections through the proximal tephra pile shortly after the event. This succession consists of a distinctly bedded sequence, representing at least six separate phases of activity. Detailed logging and correlation of 48 vertical sections through the proximal tephra pile shortly after the event has enabled analysis of the tephra transport and deposition regimes. Relationships throughout the bulk of the tephra succession are consistent with sustained but pulsating activity (Phases 2, 4, and 6), punctuated by intermittent discrete events (Phases 1, 3, and 5). Phase 1 of the eruption comprises a medium to coarse ash, widespread fall layer (25-30cm), and an overlying surge deposit, consisting of cross-bedded fine to medium ash (20-40cm). Both of these units are almost exclusively composed of black poorly-vesicular grains. Phase 2 consists of an up to 5m thick sequence of fine ash to medium lapilli tephra, displaying indistinct discordant cross-bedding, and highlighted by numerous single-grain thick pumice trains. Broken and abraded pumice fragments make up >90% of the lapilli size fraction and the ash-grade matrix is largely composed of shards of disintegrated pumice. Another distinctive feature is numerous pumice lenses that are variably continuous over tens to hundreds of centimetres, with maximum thicknesses of $\sim$30cm. We interpret these to represent the remnants of contemporaneous fall deposits. The observed structures within the units along with their widespread dispersal suggest that they were formed by sustained deposition that lasted for several hours to days at a time. The onset of Phase 3 is marked by bombardment of ballistic blocks (vent clearing) which form decimetre to metre deep impact sags in the surface of the pre-existing tephra pile. This was immediately followed by deposition of finely cross-bedded surge deposit (Phase 3). This is brown, fine to medium ash, with distinct low-angle cross-bedding on an mm to cm scale. It contains significant proportions of black poorly-vesicular tephra grains, like those found in the Phase 1 units. Phases 4 and 6 represent sustained pulsating activity featuring coupled fall and surge deposition (similar to Phase 2), while Phase 5 represents deposition by partial collapse of the column to the east, locally interrupting depositional patterns of Phase 4.

This study is the first detailed categorisation of deposits during the emergent phases of subglacial to englacial volcanism. As such it provides the necessary framework within which further studies of the dynamics of this end-member style of volcanism may be constructed.