Abstract

Large scale subglacial eruptions are enigmatic. Their eruption and emplacement dynamics are not well understood due to the incompleteness of preserved units. The Snæbýlisheiði unit, south Iceland, forms a ca. 27 cubic km elongate, flat-topped ridge of volcaniclastic debris coupled with and intruded by coherent basalt and represents a large-scale subglacial basaltic fissure eruption, where both the eruption and ridge growth occurred subglacially. It is preserved in its entirety from the eruption site stretching over 34 km towards the modern day coastline. Snæbýlisheiði differs from typical Icelandic subglacial deposits in being elongate perpendicular to the controlling rift direction reflecting the high eruption rates and the overlying glacier slope at the time of eruption. Investigation of the source area reveals voluminous volcaniclastic debris encased by and complexly intruded into by coherent basalt; I infer early and continuing production of pyroclastic deposits with near-synchronous emplacement of peperitic intrusions. Volcaniclastic debris accumulated at the eruption site and prograded towards the present coastline by deposition in an enlarging drainage network. Deposition took place both in migrating and converging tunnels and during short intervals of sheet flow during outbreak floods. The main body of the deposit is characterized by complexly bedded volcaniclastic debris coupled with and intruded by a longitudinally extensive basalt sheet. The deposits result from an intricate depositional and intrusive history, with a longitudinally extensive internal basalt sheet comprising complex and irregular coherent bodies with dikes, apophyses, horns, tendrils, and lobate fingers that extend into the surrounding host debris. Peperitic margins, where dynamic mingling or quench fragmentation occurred, are common. The basalt sheet fed higher-level intrusions through irregular apophyses as it propagated down-flow to produce the multilevel intrusions exposed today. During propagation the coherent basalt sheet concentrated into gently meandering and locally bifurcating conduits having sheet-lobe extensions. This channelized or conduit-concentrated magma propagation was very thermally and mechanically efficient, insulating the molten basalt and hence reducing rheological changes from cooling. This efficiency is reflected by the intrusions’ propagation more than 34 km from the source area or eruption site with little change to overall intrusion
morphology. The sheet forms apophyses and tendrils into the overlying sediment where it
dynamically mingled to form extensive peperitic textures. In places, apophyses locally
intersected the sediment-water interface and shed clasts into flowing water. These
“contorticlasts” have “rolled-up” forms encasing matrix-forming debris. The main body of the
intrusion propagated through the host in a channelized fashion, gently meandering within the
edifice, with thin sheet-like extensions along the margins. Tendrils and apophyses extending
from the main body extended into the overlying host, where they experienced enhanced cooling
and frictional interactions resulting in efficient brittle fragmentation. The resulting fragments
are typically angular, dense, and glassy medium lapilli to coarse ash sized and make up the bulk
of the distal deposits. Where apophyses remain attached to the basal intrusion the margins
fragment in the ductile regime forming fluidal-type fragments. Bed contacts are sharp to
diffuse, locally erosive, indicating deposition from traction or/and high-concentration flows.
Shedding of contorticlasts into bedload beneath flowing water requires that their source
intrusions shoaled, hence implying the voluminous intrusions would have also been transferring
heat into the water with only a thin, deforming clastic blanket to reduce the heat flux into water
and hence overlying ice.

As the eruption is influenced by the ice, the ice is influenced by the eruption. The vast
amounts of heat release during fragmentation will melt ice above the fragmentation zone.
Using simplified ice mechanics and thermodynamic principles the total volume of ice melted
can be calculated for a subglacial volcano of any type. For the Snæbýlisheiði unit, the thermal
model was constructed to consider the consequences of the formation of the unit based on field
and other observational data. The thermal model for the extent of ice melted by the
emplacement of the Snæbýlisheiði unit combined with field observations and dissolved volatile
contents in matrix glass suggests that the eruption likely occurred during the PreBoreal or
Younger Dryas stadials. This is the first description of a complete unit formed by a large-scale
subglacial basaltic fissure eruption.