

QUATERNARY ICE SHEET THICKNESS, JÖKULHLAUPS AND RAPID DEPRESSURIZATION OF PILLOW BASALTS A. Höskuldsson¹, M.R. Carroll² and RSJ Sparks³. 1)South Iceland Institute of Natural History, Strandvegur 50, 900 Iceland. 2)Dipt. di Scienze della Terra, Via Gentile III da Varano, Università di Camerino, 62032 Camerino, Italy. 3)University of Bristol, Wills Memorial Bld. Queensroad, BS1-8RJ, Bristol UK.

Introduction: In this presentation we report results from analysis of pillow basalt formations in Kverkfjöll, NE-Iceland. Pillow basalt formations are commonly found in Iceland. These formations record to eruption under glacial conditions, with most examples being related to the last glaciation. These formations are well preserved and pristine glass can be found on the pillow rims in all cases. The sharp division of pillows and hyaloclastites that is observed in many sub glacial volcanic formations is thought to reflect pressure conditions surrounding the vent at time of the eruption.

Morphological studies of pillows, viscosity calculation and analogue experiments suggest that pillows size spectrum is primarily controlled by eruption rate and viscosity [1]. Existence of extensive lava flows on the sea floor has, on the other hand, been explained by very high eruption rate [2].

Vesicular glassy rims observed on pillow margin a result from quenching of the magma when it comes in contact with water.

Confining pressure influences degassing of the magma and degassing is further limited by the actual amount of volatiles in the magma prior to eruption. At low pressures the most abundant volatile in magma is H₂O. Glass from quenched pillow rims can thus be useful to determine the pressure under which the magma was extruded.

The Mount Virkisfell pillows

The outer crust of the pillows consists of well-formed basaltic glass with thickness ranging from 7 cm to 0.1 cm. On average the glassy rims of Virkisfell are 1.5±0.5 cm thick.

Radial prismatic cooling joints are prominent from the outer rim of each pillow towards its center. The joints do not penetrate into the vesiculated cores of the pillows. However, in pillows lacking a vesiculated core the joints reached the pillow center.

Concentric bubble layers, 5-10 cm thick, are best developed along the sides and top half of the pillows. Between the bubble layers there is a 1 to 7 cm thick bubble-free zone. Vesicular cores showed a maximum size of 170 cm long and 60 cm thick in a pillow that measured 200 cm long and 114 cm high.

Zone of accumulated plagioclase crystals were observed in about 93% of the pillows, typically in the lower half of the pillows. Thickness of the accumulation layer varies, but it is most commonly about 16 cm.

Spaces between the pillows were partially filled with fragments of glassy rim from adjoining pillows and by silty sediments.

Shape and size distribution of pillow lobes

The pillows are most frequently ellipsoidal (46%) to spherical in shape (31%). About 16% of the pillows had sagged tip and only 7% of pillows in the pile are flat sheets. The pillows are slightly flattened, that is the V-axis is in general smaller than is the H-axis. In average the H-axis of the Virkisfell pillows is 1.13±0.85 m and the average V-axis is 0.72±0.41 m. Frequency histogram for the V/H axis ratio of the pillows shows the median value to be 0.75. This reflects the flattened nature of the pillow lobes. The average size spectrum of the pillows elsewhere in Kverkfjöll ranges from H-axis of 1.3-1.6 m and for V-axis 0.8-1.2 m. Measurements of H- and V-axis indicates that the pillows in Virkisfell are in general larger than those that have been previously described from southern Iceland where average H-axis is measured 0.64 m and average V-axis 0.39 m [3].

Vesiculation in the pillows

Vesiculation in the pillows is present from the rim to the core. The glassy sideromelan rim shows vesicularity of 10-20%. Through the crystallized portion of the pillow to the core, vesicular bands occur on regular intervals. The vesicular bands have porosity similar to that of the glassy rim (10-25 vol%). When reaching the core of the pillow vesicularity increases drastically. About 79% of pillows measured in Virkisfell contained a vesiculated core. Vesicularity of the cores was measured as low as 40% and as high as 60% with the average of 49±5%. The cores vary in size but most frequently V-axis is 0.15-0.20 m and the H-axis between 0.30-0.45 m. The shape of the cores is in general reflecting the shape of the pillows. Cores most commonly occur at the distance of some 0.25 m from the bottom of the pillows.

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Vesicles

Vesicle shape varies between the banded vesicular zones and the cores. Vesicles in the cores are spherical in shape and in general larger than those vesicles observed in the vesicular banded zones. Vesicles in the banded zones are both spherical and elongated. The core vesicles are near spherical in shape. Vesicles were divided into two groups, single vesicles and coalesced vesicles. Shape analysis of the vesicles shows that they are equidimensional. Histograms for the measured major axis versus the measured minor axis shows that for single vesicles the most common ratio is 1.0 and that for coalesced vesicles 1.1. The surroundings of the banded zone vesicles are crystallized, whereas, in the cores crystals are finer grained, needle shaped in a glassy matrix. The core vesicles regularity and hyalocrystalline walls indicate a sharp and short growing period.

FTIR measurements

The FTIR measurements were carried out to determine the amount of water in the glassy rim of Mount Virkisfell pillows and other pillow formations in the Kverkfjöll area. The glass making up the rim is fresh and unaltered. For the Virkisfell pillow margins the average wt% H₂O content is 0.89±0.03. Highest values were measured at Karlsrani with an average wt% H₂O of 1.04±0.03. Other pillow formations in the Kverkfjöll area range in wt% H₂O as follows, Vegas-karð 0.85±0.02, Lindarhryggur 0.92±0.02, Krep-puhryggur 0.96±0.03 and Karlishryggur 0.95±0.04.

Estimation of eruption pressures

Infrared measurements of glassy pillow rim material showed no CO₂ above the detection limit (<30 ppm) and so in the following discussion we assume the major volatile component was H₂O. Following this approach, we calculate the following pressures from the measured H₂O contents of glassy pillow rims with no CO₂ and with 30ppm CO₂: Virkisfell - 78±6 to 133±4 bars, Karlsrani 110±9 to 154±6 bars, Vegas-karð 70±5 to 128±3 bars, Lindarhryggur 84±5 to 138±3 bars, Krep-puhryggur 93±6 to 143±4 bars and Karlishryggur 90±8 to 141±5 bars. Note that all of these must be considered as maximum pressures because it is possible to have eruption and quenching of supersaturated melts.

Recalculating the environmental pressures during the Kverkfjöll eruptions indicates that Virkisfell erupted under an ice sheet 863±67 to 1481±45 m thick. Other formations give estimated thickness ranging from 775 to 1714 meters. However, it shows that although the volcanic formations are close in

space they must vary enough in time to allow for variations in icesheet thickness.

Magma degassing and jökulhlaup

The sudden increase in porosity towards the core of the pillows suggests that some environmental factor changed drastically during the eruption of Virkisfell and the other pillow ridge formations investigated. Porosity increases have not been observed in the pillow formations at MOR [4]. Since pressure and crystallization principally control magma degassing, one of these must change in sub-glacial Icelandic environment. We can exclude crystallization since it occurs both in Iceland and in MOR. Pressure in MOR environment is stable and only changes slightly during eruption by upward accumulations. However, in Iceland, draining of melt water from above an erupting vent can change water pressure drastically. Jökulhlaup are common feature in Iceland and do occur when water trapped by glacier escapes from the eruptive vent [5] [6]. Observations of the eruption of Gjalp in 1996 at Vatnajökull Iceland do support the idea that a sudden decrease in water pressure above an erupting vent or cooling magma body can restart an eruption. In Gjalp it was observed that during the Jökulhlaup volcanic explosions reoccurred, this was about 3 weeks after the eruption ended. This suggests that magma stored within the volcanoclastic pile was remobilize due to pressure decrease above the vent. Magma at such a shallow depth has surely reached saturation with regards to water and thus is highly sensitive to all external pressure changes.

The Virkisfell magma had about 0.89±0.03 wt% H₂O at time of quenching. We can estimate the amount of water released during depressurization from the initial present estimate of 78 to 133 bars. Average porosity of the pillows cores is about 49±5%, taking account of the porosity in the pillow rims (about 20%) the net increase is about 29%. This represents about 29 to 44 bar depressurization or a drop in the water table of 290 to 440 m.

References:

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