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Variations in hydration within perlitised rhyolitic lavas—evidence from Torfajökull, Iceland

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ABSTRACT

Perlitic fractures form due to the hydration of glassy, rhyolitic lavas. Perlitised lavas are also an important industrial commodity yet there has been little study on the mechanisms of outcrop perlitisation. Here the fracture populations, perlitisation and volatile concentrations of subglacial rhyolitic glassy facies have been studied adding a quantitative dimension to previous qualitative studies. Samples include hyaloclastite, perlitised and non-perlitised obsidian and microcrystalline rhyolite, which are all present in lava lobes at Torfajökull, Iceland. Fractures formed through cooling increase in spacing with increased distance inwards from the margins of lobes. The size distribution of perlitic beads is shown to follow a log-normal distribution. The degree of perlitisation and the total volatile content (measured using thermogravimetric analysis, TGA) of samples are shown to decrease with distance inwards from lobe margins. In general, increased perlitisation is accompanied by increased hydration although complexity exists within single outcrops. The elevated total volatile content of perlite is shown to be due to hydration by environmental water with the structural location of the water changing as total volatile content increases.

1. Introduction

Glass hydration is key to the formation of the economically important commodity perlite. Perlite is volcanic glass cut by abundant, delicate, intersecting and gently curved cracks surrounding cores of intact glass (McPhie et al., 1993). These cores/beads are usually circles/ovals in 2D and typically have diameters ranging from 0.1 mm to a few millimetres (Drysdale, 1991; Denton, 2010). Perlitised obsidian is also water-rich. Studies of hydrogen and oxygen isotopes have shown that elevated water content of perlites is the result of meteoric water being present in the glass not a water-rich original magma (Ross and Smith, 1955; Friedman and Smith, 1958, 1960; Marshall, 1961; Friedman et al., 1966; Bagdassarov et al., 1999). Water is introduced as water or hydroxyl molecules depending on total water content and temperature of hydration (Lacy, 1966; Stolper, 1982; Sodeyama et al., 1999; Roulia et al., 2006). The relative timings of lava cooling, fracturing and hydration in the perlitisation process have been examined qualitatively in previous publications (e.g. Drysdale, 1979, 1991; Allen, 1988; Davis and McPhie, 1996). This study attempts to quantify these parameters to further our understanding of perlitisation.

We present a study of field, thin section and volatile concentration measurements of variably perlitised rhyolitic samples allowing the identification of spatial variations in perlitisation and of total volatile content. Volatile content measurements of different textural zones along transects illustrate the volcanic facies that undergo most extensive hydration. These data allow a quantitative assessment to be made of the importance of fracturing during cooling in the perlitisation process.

2. Geological setting of samples analysed

Samples from two locations, Bláhnúkur and Dalakvíslfell, in Torfajökull, Iceland were analysed (Fig. 1). Torfajökull central volcano is the largest active silicic centre in Iceland where >80% of exposures are silicic in composition (Gunnarsson et al., 1998). Eruptions during glacial periods have resulted in a series of subglacial, subaqueous and subaerial silicic volcanic formations (McGarvie, 1984; Tuffen et al., 2001).

Bláhnúkur (Fig. 1) formed in a small-volume effusive subglacial eruption during the last glacial period (115–11 ka ago). Products are dominated by irregular- to cylindrical-shaped, locally perlitised, obsidian and microcrystalline rhyolite lava lobes, approximately 5 m high by 5 m wide (Fig. 2a), in a pale-grey perlitised hyaloclastite breccia (Furnes et al., 1980). Other facies include matrix- and clast-supported breccia and columnar-jointed lavas (Tuffen et al., 2001).

The rhyolite formations at Dalakvísl (Fig. 1) erupted approximately 70 ka ago (McGarvie et al., 2006; Tuffen et al., 2008) and include quench hyaloclastite and vesicle-poor obsidian lavas and lobes that are locally perlitised (Tuffen et al., 2008).

The majority of samples analysed in this study represent sequences through lava lobes erupted subglacially through hyaloclastite

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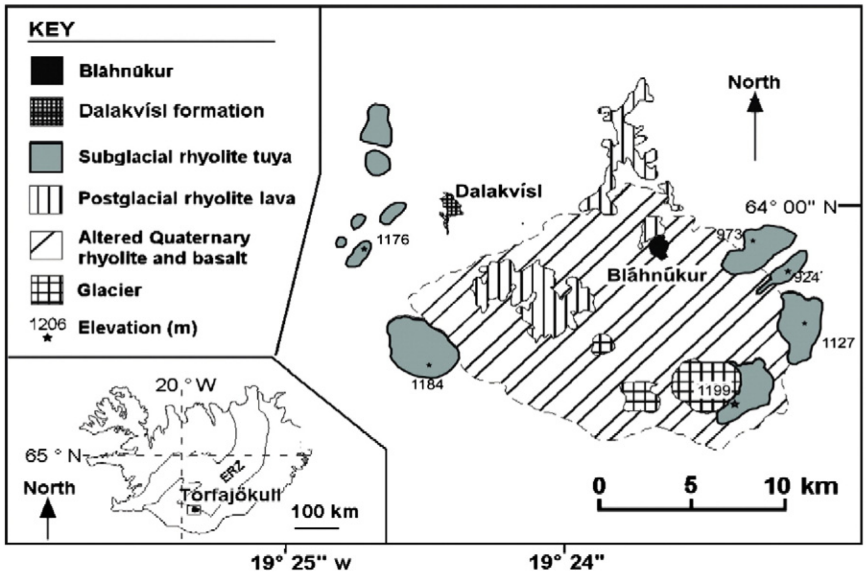

Fig. 1. Map showing the locations of Bláhnúkur and the Dalakvísl formation, within the Torfajökull central volcano, Iceland (modified from Tuffen, 2001). The Dalakvísl formation refers to the volcanic rocks at Dalakvíslfell. ERZ is Eastern Rift Zone.

(fractured glass). Lava lobes are common at Bláhnúkur and are also present at Dalakvísl. Lava lobes contain different textural zones that probably relate to their cooling regimes (Tuffen et al., 2001; Fig. 2a). Not all textural zones are present in each lobe. A 10 m-wide subglacial dyke intruded within hyaloclastite was also studied (Fig. 2b).

3. Method

3.1. Field studies

Sampling transects across lava lobes with a well-exposed perlitised obsidian zone were oriented perpendicular to the zone boundaries. Samples from the dyke were collected along a transect perpendicular to the dyke margin and parallel to the columnar joints. The spacing between joints formed due to cooling (henceforth called major fractures) was measured by tape measure at the location of each sample.

3.2. Thin section characterisation of fractures

The degree of perlitisation was estimated by eye, down the microscope, as the percentage of the thin section made up of perlitic beads/cores of intact glass or containing arcuate fractures. Any macroperlite was omitted from the estimate (due to the beads being larger in diameter than the thin section). Errors are estimated at around $\pm 10\%$.

Bead diameters were measured using colour digital photographs and an image analysis program. Where the bead was not circular in thin section, the long axis was measured as the diameter. Areas of the thin section that contained phenocrysts and vesicles were avoided. Efforts were made to measure at least 50 beads in each

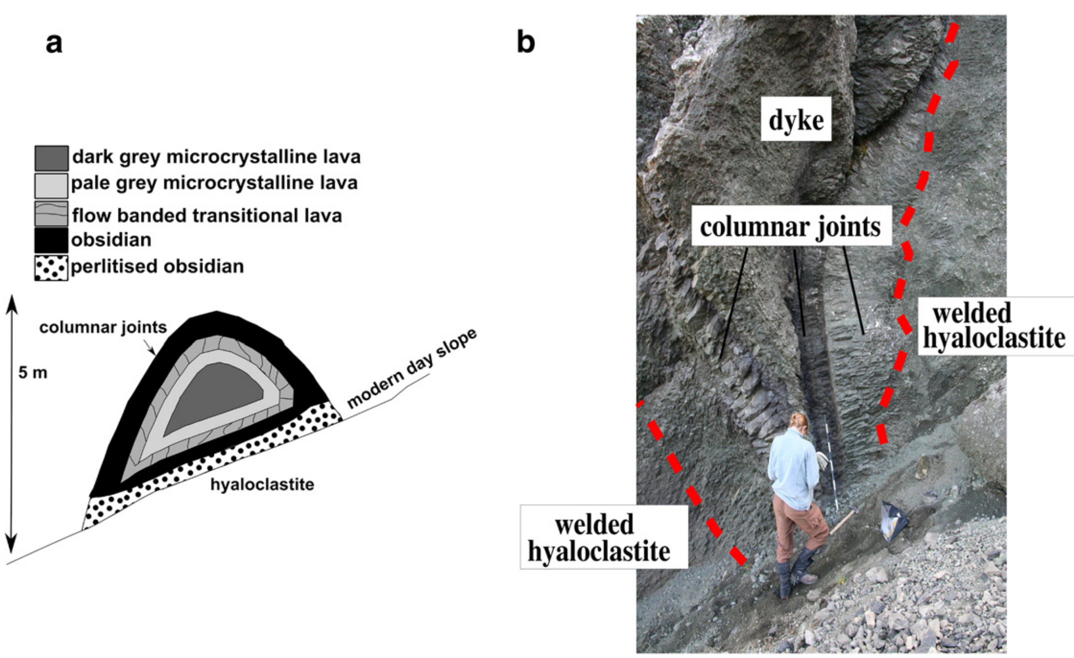

Fig. 2. Images depicting (a) a schematic cross-section of a Torfajökull lava lobe and (b) an overview of a perlitised dyke with columnar joints. The red dashed line indicates the margins of the dyke.