



Mantle-derived trace element variability in olivines and their melt inclusions

David A. Neave^{a,*}, Oliver Shorttle^{b,c,d}, Martin Oeser^a, Stefan Weyer^a, Katsura Kobayashi^d

^a Leibniz Universität Hannover, Institut für Mineralogie, Callinstraße 3, 30167 Hannover, Germany

^b Department of Earth Sciences, University of Cambridge, Downing Street, Cambridge, CB2 3EQ, United Kingdom

^c Institute of Astronomy, University of Cambridge, Madingley Road, Cambridge, CB3 0HA, United Kingdom

^d The Pheasant Memorial Laboratory for Geochemistry and Cosmochemistry, Institute for the Study of the Earth's Interior, Okayama University, Misasa, 682-0193, Japan

ARTICLE INFO

Article history:

Received 4 July 2017

Received in revised form 4 December 2017

Accepted 5 December 2017

Available online xxxx

Editor: T.A. Mather

Keywords:

olivine
melt inclusions
trace elements
mantle heterogeneity
geochemical variability
Iceland

ABSTRACT

Trace element variability in oceanic basalts is commonly used to constrain the physics of mantle melting and the chemistry of Earth's deep interior. However, the geochemical properties of mantle melts are often overprinted by mixing and crystallisation processes during ascent and storage. Studying primitive melt inclusions offers one solution to this problem, but the fidelity of the melt-inclusion archive to bulk magma chemistry has been repeatedly questioned. To provide a novel check of the melt inclusion record, we present new major and trace element analyses from olivine macrocrysts in the products of two geographically proximal, yet compositionally distinct, primitive eruptions from the Reykjanes Peninsula of Iceland. By combining these macrocryst analyses with new and published melt inclusion analyses we demonstrate that olivines have similar patterns of incompatible trace element (ITE) variability to the inclusions they host, capturing chemical systematics on intra- and inter-eruption scales.

ITE variability (element concentrations, ratios, variances and variance ratios) in olivines from the ITE-enriched Stapafell eruption is best accounted for by olivine-dominated fractional crystallisation. In contrast, ITE variability in olivines and inclusions from the ITE-depleted Háleyjabunga eruption cannot be explained by crystallisation alone, and must have originated in the mantle. Compatible trace element (CTE) variability is best described by crystallisation processes in both eruptions. Modest correlations between host and inclusion ITE contents in samples from Háleyjabunga suggest that melt inclusions can be faithful archives of melting and magmatic processes. It also indicates that degrees of ITE enrichment can be estimated from olivines directly when melt inclusion and matrix glass records of geochemical variability are poor or absent. Inter-eruption differences in olivine ITE systematics between Stapafell and Háleyjabunga mirror differences in melt inclusion suites, and confirm that the Stapafell eruption was fed by lower degree melts from greater depths within the melting region than the Háleyjabunga eruption. Although olivine macrocrysts from Stapafell are slightly richer in Ni than those from Háleyjabunga, their overall CTE systematics (e.g., Ni/(Mg/Fe), Fe/Mn and Zn/Fe) are inconsistent with being derived from olivine-free pyroxenites. However, the major element systematics of Icelandic basalts require lithological heterogeneity in their mantle source in the form of Fe-rich and hence fusible domains. We thus conclude that enriched heterogeneities in the Icelandic mantle are composed of modally enriched, yet nonetheless olivine-bearing, lithologies and that olivine CTE contents provide an incomplete record of lithological heterogeneity in the mantle. Modally enriched peridotites may therefore play a more important role in oceanic magma genesis than previously inferred.

© 2017 Elsevier B.V. All rights reserved.

1. Introduction

Fractional melting of a chemically, isotopically and lithologically heterogeneous mantle results in compositionally diverse oceanic basalts (Dupré and Allègre 1983; Hirschmann and Stolper 1996;

* Corresponding author.

E-mail address: d.neave@mineralogie.uni-hannover.de (D.A. Neave).

Kelemen et al. 1997; Sobolev et al. 2007; Shorttle et al. 2014). However, geochemical records of mantle heterogeneity are subject to progressive degradation as melts undergo concurrent mixing and crystallisation during ascent (MacLennan, 2008a; Rubin et al., 2009; Shorttle, 2015). Assimilation, reactive porous flow and repeated replenishment, mixing and tapping of steady state reservoirs may all further contribute to the blurring and overprinting of mantle signals (O'Hara 1977; Langmuir 1989;

Michael and Schilling 1989; Lissenberg and MacLeod 2016; O'Neill and Jenner 2016). Melt inclusions trapped within primitive macrocrysts nevertheless provide glimpses into the compositional systematics of primary melts because they are theoretically insulated from changes in external magmatic environments. For example, melt inclusion suites frequently preserve greater variability in trace element and isotope compositions than the melts that carry them (Sobolev and Shimizu, 1993; MacLennan, 2008b). However, the ability of melt inclusions to faithfully record primary magmatic signals has been repeatedly questioned because of their susceptibility to syn- and post-entrapment modification (e.g., Roedder, 1979; Qin et al., 1992; Danyushevsky et al., 2000, 2004; Baker, 2008).

Geochemical variability is also recorded in macrocryst compositions (e.g., Davidson and Tepley, 1997; Wimpenny and MacLennan, 2011; Foley et al., 2013). For example, elevated Ni and Fe/Mn in primitive magmatic olivines have been interpreted as evidence for melt supply from olivine-free mantle domains by some workers (Sobolev et al., 2005, 2007; Herzberg, 2011), though separating the effects of source and process on these elements' systematics remains difficult (Putirka et al., 2011; Matzen et al., 2013; Herzberg et al., 2016; Lynn et al., 2017). One reason for this difficulty is that incompatible trace element (ITE) datasets, which are primarily obtained from melt inclusions, are seldom integrated with compatible trace element (CTE) datasets, which are primarily acquired from olivines, despite the fact that both datasets contain complementary forms of magmatic information: in principle, ITEs are more sensitive to melting processes while CTEs are more sensitive to source compositions (Le Roux et al., 2011). However, the ITE data from natural olivines which could facilitate integration of the olivine and melt inclusion archives are currently scarce, largely because the challenges associated with performing routine *in situ* microanalysis of trace elements at ppb levels are only now being overcome (e.g., Stead et al., 2016).

In this study, we combine analyses of ITEs and CTEs in olivine macrocrysts with new and published analyses of ITEs in melt inclusions to validate the reliability of melt inclusion archives (cf., Danyushevsky et al., 2004). We thus consider whether degrees of magmatic ITE enrichment can be estimated from olivines directly in samples where no analysable inclusions are present and assessments of geochemical variability are consequently restricted. We then investigate whether compositional variability in forsteritic olivines and their inclusions is dominated by processes taking place in the mantle (i.e. melting) or the crust (i.e. crystallisation). By focusing on two spatially associated yet variably enriched primitive eruptions from Iceland, we investigate how olivine and melt inclusion records of geochemical variability manifest on intra- and inter-eruption scales. We pay particular attention to variance in our compositional data and describe how this underexploited property of geochemical datasets can be used to determine the causes of trace element variability and hence study geological processes. Finally, we evaluate whether olivine CTE contents serve as faithful indicators of lithological heterogeneity in the mantle more widely, and discuss the role played by olivine-free source regions in the generation of Icelandic magmas.

2. Geochemical context and sample preparation

The Reykjanes Peninsula of Iceland is an ideal location for studying the generation and evolution of oceanic basalts because primitive lavas are highly abundant (Jakobsson et al., 1978; Thirlwall et al., 2004). The Háleyjabunga lava shield and Stapafell table mountain in the Reykjanes-Svartsengi volcanic system at the south-western tip of the peninsula (Fig. 1a) have proven to be especially valuable for understanding the geochemical consequences of mantle melting (Gurenko and Chaussidon, 1995;

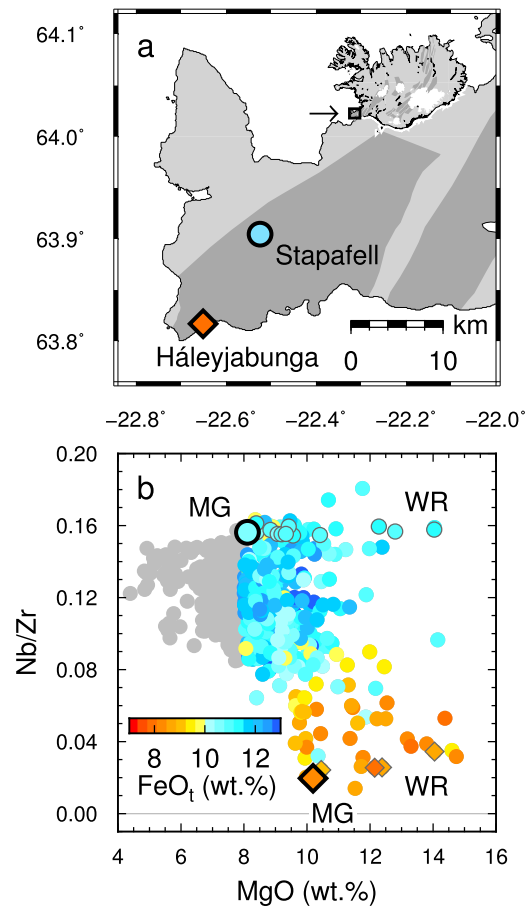


Fig. 1. (a) Map showing the location of the Háleyjabunga lava shield and Stapafell subglacial lava flow on the Reykjanes Peninsula of south-west Iceland. The two eruptions are located within the Reykjanes-Svartsengi volcanic system, the westernmost sub-aerial expression of the Mid-Atlantic Ridge on Iceland; dark grey fields show the outlines of different volcanic systems. (b) Combined major- and trace-element systematics of whole-rock and matrix glass samples from the Reykjanes Peninsula and Western Volcanic Zone of Iceland (Shorttle and MacLennan, 2011). Samples with MgO contents above 8 wt.% are coloured by their FeO_t contents to illustrate how major element variability correlates with incompatible trace element (ITE) enrichment. Whole-rock compositions from Háleyjabunga and Stapafell are shown as small outlined diamonds and circles respectively (WR; Hémond et al., 1993; Hardarson et al., 1997; Thirlwall et al., 2004, 2006; Peate et al., 2009). Average matrix glass compositions are shown as large outlined symbols (MG; Condomines et al., 1983; Gurenko and Chaussidon, 1995; Peate et al., 2009). Analytical uncertainties are comparable in size to the symbols. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

MacLennan, 2008b). Despite their spatial proximity and similar ages, these eruptions have strikingly different whole-rock trace element chemistries (Hémond et al., 1993; Hardarson et al., 1997; Thirlwall et al., 2004, 2006; Peate et al., 2009): Háleyjabunga and Stapafell are among the most ITE-depleted and ITE-enriched eruptions known from Iceland respectively (Fig. 1b; Gurenko and Chaussidon, 1995). These two eruptions are therefore ideal targets for testing whether variability in magmatic ITE enrichment can be resolved in the composition of olivine macrocrysts.

The difference in ITE enrichment between Háleyjabunga and Stapafell, which is as well shown in melt inclusions as in whole-rock samples (Fig. 2a), has been explained as a consequence of fractional melting in a single mantle column (Gurenko and Chaussidon, 1995). Namely, Gurenko and Chaussidon (1995) argued that ITE-depleted compositions represent instantaneous fractional melts formed by 17–18% melting of a spinel lherzolite source, while ITE-enriched compositions represent mixtures of ITE-depleted melts and enriched melts formed by 5.5% melting of a garnet lherzolite

Download English Version:

<https://daneshyari.com/en/article/8907197>

Download Persian Version:

<https://daneshyari.com/article/8907197>

[Daneshyari.com](https://daneshyari.com)