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Petrogenesis of alkaline basalts at the tip of a propagating rift: Evidence from the Heimaey volcanic centre, south Iceland

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Abstract

Heimaey is the volcanic centre in the Vestmannaeyjar Volcanic System, situated at the tip of Iceland's propagating Eastern Volcanic Zone (EVZ). The Heimaey lavas are slightly alkaline, ne-normative, basalts with plagioclase, olivine and Ti-magnetite as phenocryst phases. Inversion modelling using REE suggests that a primary magma is generated by fractional melting over a depth interval of 100–65 km beneath Heimaey of a source similar to that of MORB. The primary magma fractionated 31% olivine and clinopyroxene en route to ponding at the base of the crust (30–35 km depth). Tectonic events as a result of the extensional stress exerted by the southwards propagating EVZ causes magmas to be emplaced into different levels of the crust where they evolve by fractional crystallization independently of each other (i.e. polybaric fractionation). During residence in a parental magma chamber at the mantle/crust boundary the fractionating assemblage is dominated by olivine and clinopyroxene, whereas olivine and plagioclase dominates the fractionating assemblage during residence in crustal magma chambers. The most evolved magma composition can be related to a parental Heimaey melt by 73% fractional crystallization of predominantly plagioclase, clinopyroxene and olivine. The residence times in crustal magma chambers are short as indicated by the absence of equilibrium phenocryst assemblages (e.g. lack of cpx-phenocrysts). Oxygen and radiogenic isotopes suggests that no crustal contamination occurred, and that the role of magma mixing is insignificant in the evolution of the Heimaey lavas. The polybaric evolution of the Heimaey lavas in small, isolated, magma chambers at different levels in the crust fits well with a southward propagation of the EVZ, with the rift-tip currently located beneath the Vestmannaeyjar Volcanic System.

Keywords: Iceland; Heimaey; Vestmannaeyjar; petrology; fractional crystallization; alkali basalt; propagating rift

1. Introduction

Iceland is situated at the confluence of the Mid-Atlantic Ridge (MAR) and a mantle plume (Vink, 1984), a setting which has resulted in anomalously high magma production rates compared with the rest of the North Atlantic region (Imsland, 1983; Staples et

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al., 1997; Darbyshire et al., 2000). The WNW motion of the plate boundary (DeMets et al., 1990) relative to the stationary mantle plume has caused periodical relocations of the main rift axis (Saemundsson, 1974, 1986; Johannesson, 1980; Oskarsson et al., 1982; Hardarson et al., 1997). The most recent relocation occurred approximately 3 Ma ago (Saemundsson, 1980; Einarsson, 1991), with the initiation of the Eastern Volcanic Zone (EVZ; see inset, Fig. 1). The present location of the mantle plume is believed to be under the Vatnajökull glacier (Gudmundsson, 2000), causing the EVZ to propagate southwards (Oskarsson et al., 1982) in what probably is a future attempt to adjoin with the submarine Reykjanes Ridge. Much of Iceland's petrological diversity is a direct result of rift propagation into older crust. Lavas erupted in the northern part of the EVZ are mainly tholeiitic in composition, similar to those of the Western Volcanic Zone (Jakobsson, 1979). Further south (e.g. Katla and Eyjafjallajökull) FeTi-rich basalts are dominating interlayered with silicic lavas. In the Vestmannaeyjar system, which is situated at the southernmost tip of the propagating rift, alkaline basalts are dominating. It is generally agreed that depth of magma evolution increases going south along the EVZ (Jakobsson, 1972; Oskarsson et al., 1982; Thy, 1991b). A compositional pattern similar to that of the EVZ has also been reported in a propagating segment at the Galapagos spreading centre by Christie and Sinton (1981), who attributed the compositional variation to the development of the subaxial magmatic system beneath the rift as it propagates through older crust. Several petrogenetic models have previously ascribed the formation of alkaline basalts in Iceland to a low degree of

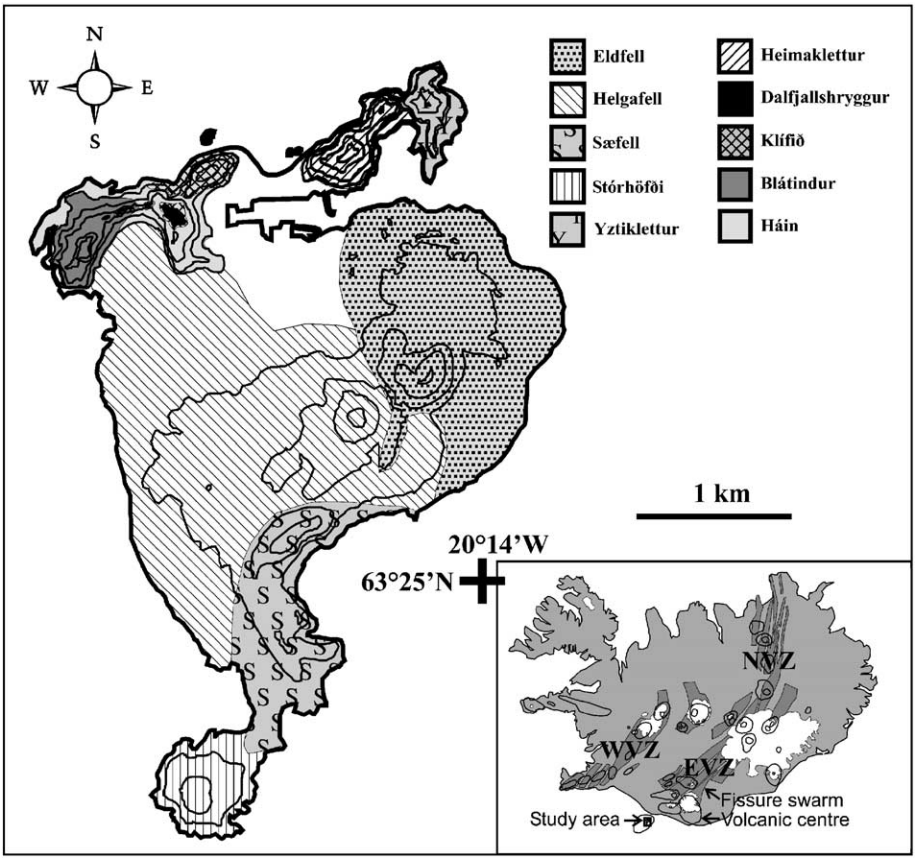

Fig. 1. Map showing the 10 eruptive units on Heimaey (modified from Mattsson and Höskuldsson, 2003). Inset shows location of Heimaey in relation to the Northern Volcanic Zone (NVZ), Western Volcanic Zone (WVZ) and the Eastern Volcanic Zone (EVZ).