THE ELUSIVE INTRUSIVE: A PETROLOGIC, STRUCTURAL, AND GEOCHEMICAL ANALYSIS OF AN IGNEOUS BODY IN VATNSDALSFJALL, NORTHWEST ICELAND

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INTRODUCTION

Iceland is a volcanic island composed primarily of Late Tertiary to Recent tholeiite basalts. The widespread and prolific volcanism that has created the island is the result of a unique interplay between the mid-Atlantic spreading ridge and the Iceland plume. Currently situated below Vatnöjokull, a glacier in central Iceland, the Iceland plume has been active for approximately 130 Ma and has been the driving force behind the island's abundant basaltic eruptions as well as the lithospheric doming that elevates the Iceland plateau (Tronnes, 2003).

For the past 60 Ma, the overlying plates have drifted to the northwest relative to the surface expression of the plume, which has remained in a relatively fixed position. The average rate of drift is 1–3cm/a; however, the lithospheric migration has come in a series of jumps and pauses rather than in smooth, continuous movement. This step-wise migration progresses via propagation of young faults and rifts in older crust (Tronnes, 2003).

As the overlying plates pass over the plume, areas that were at one time actively rifting eventually become inactive. This paper examines the petrology and geochemistry of a basaltic lens in one of these "abandoned" rift zones along the Skagi Peninsula in the northwest part of the country. Rifting ended in this area by approximately 7 Ma.

Extrusive units on the Skagi Peninsula include basaltic and rhyolitic lavas and tuffs. Numerous small intrusions of both mafic and silicic material were emplaced at shallow crustal levels during the primary rifting episode (Jordan, 2003).

The Hjallin Lens (Fig. 1), the focus of this paper, is a basaltic unit that was first classified by Annells (1968) as a shallow-level, olivine-free tholeiitic laccolith. However, a closer field investigation during the summer of 2003 has yielded support for an alternate interpretation: that the lens is in fact an extrusive feature, specifically, that it represents the ponding of a thick basaltic flow

Fig. 1. Panoramic view of the Hjallin Lens (outlined by dashes), looking roughly east.

in a pre-existing topographic low.

FIELD INVESTIGATION

The Hjallin Lens is a continuous igneous body that extends approximately 3000 m in the NNW–SSE direction and up to 800 m in the ENE–WSW direction. The lens reaches its greatest thickness (over 150 m) near the southern margin and appears to thin out farther to the north.

The lithology of the lens is virtually uniform throughout. The rock is a very hard, fine-grained, aphyric, non-vesiculated basalt that has cooled into well defined columnar joints. These joints reach heights of several meters and appear to be continuous throughout the lens. While most of the joints have a straight, vertical orientation, a few concentrated areas of irregular, curving jointing patterns crop out toward the southern margin of the lens. On a fresh surface, the rock is medium gray; weathered surfaces are brown to orange.

At its base, the lens is bounded by a rhyolitic ash flow tuff along a sharply defined contact (Fig. 2). This lower unit ranges in thickness from 0.5 m to 1.5 m. It chips easily, contains numerous small basalt pebbles, and is flow-banded in places.

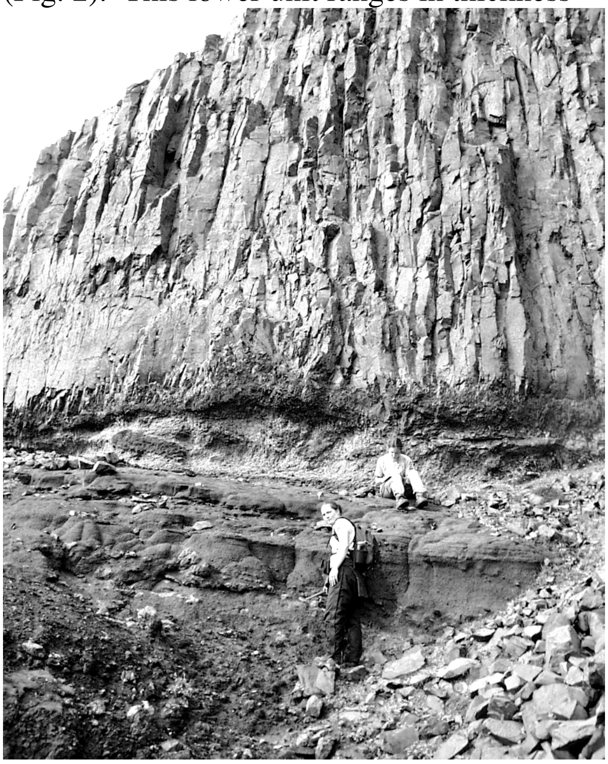

Fig. 2. Lower contact of the lens at its southern boundary. Sequence from top to bottom: columnar joints in the basalt lens, rhyolitic welded tuff (dark zone below columnar basalt), and sedimentary layers containing organic material.

At the southern end of the lens, a sedimentary layer underlies the ash flow tuff. This unit is a poorly lithified, well-bedded coarse- to medium-grained yellow-brown sandstone with rare carbonized and silicified organic material. Its upper contact with the lens is sharply defined; at its base, however, the sedimentary unit grades into a much coarser, polymict lahar.

The uppermost visible part of the lens is covered by a poorly drained pasture. Exposure at this level is limited to several glacially worn hummocky outcrops that rise an average of two to four meters above the grassy surface.

A thick series of monoclinally folded lava flows lies immediately to the south of the lens. This neighboring structure is the focus of other research (Ackerly, this volume).

PETROGRAPHY AND GEOCHEMISTRY

Lens Rocks

Nine samples collected vertically through the lens are included in this study. Overall, the lens samples are remarkably similar in mineralogy, texture, grain size, and chemistry, including trace element distribution (Fig. 3). All plot as tholeiitic basalts on an AFM diagram and as sub-alkaline basalts according to Winchester and Floyd (1977) (Fig. 4). In each thin section, the groundmass is intergranular and is composed of roughly equal amounts of plagioclase and clinopyroxene. Ilmenite and other opaque minerals constitute a significant portion (more than 15%) of the groundmass. The only other minerals found are spinel and olivine, both of which occur rarely. In the three thin sections in which it is found, olivine occurs in small (0.3–0.5 mm), isolated, subhedral to euhedral orthorhombic grains that have been highly altered to iddingsite. Thin, very fine-grained haloes surround many of the olivine grains. These haloes are composed of groundmass material and appear to form a chilled zone around the grains, suggesting that the olivine may be xenocrystic.

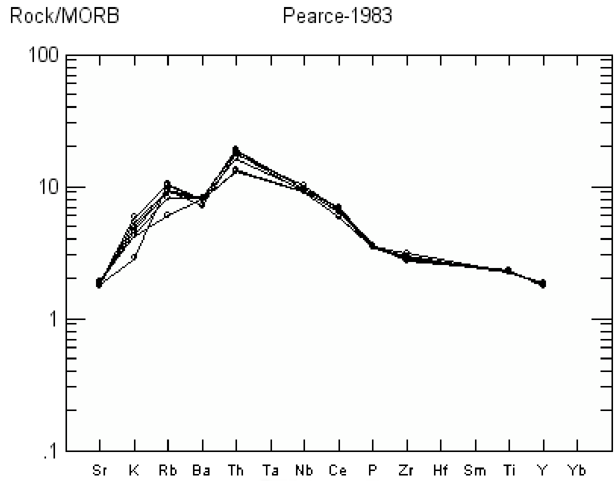

Fig. 3. Trace element distribution of all nine samples from the lens, normalized against a MORB (Pearce, 1983).

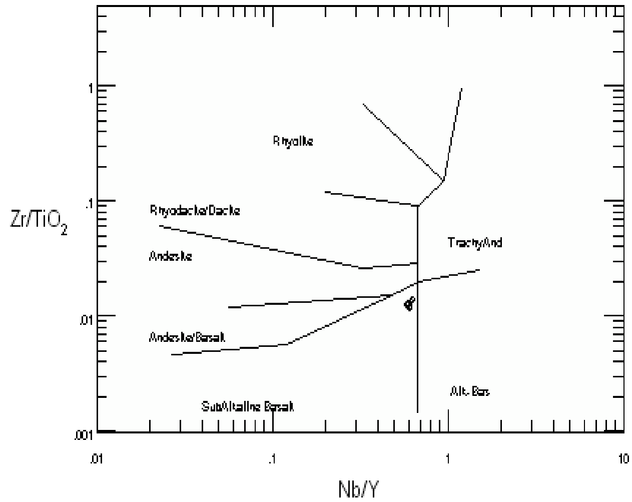

Fig. 4. Nine lens samples plot as almost a single point within the field of subalkaline basalts (Winchester and Floyd, 1977).

Grain size of the groundmass material ranges from microcrystalline to fine. The finest grains occur in the samples taken closest to the margins of the lens. All of the thin sections display a weakly porphyritic texture, with fine- to medium-grained phenocrysts of plagioclase and, less frequently, clinopyroxene embedded in the aphanitic groundmass. In each of the samples, phenocrysts account for less than 5% of the section.

Plagioclase phenocrysts are euhedral to anhedral, while clinopyroxene phenocrysts are subhedral to anhedral. Any loss of definition of the grain boundary is due to partial resorption of the crystal into the groundmass. Only one small vesicle is present in the nine thin sections from the lens.

The plagioclase phenocrysts typically occur in clusters of three or more rectangular laths. Albite and pericline twinning is found frequently in the plagioclase throughout all of the sections. In addition, many of the plagioclase grains display strong concentric zoning (calcic interior grading into a narrow sodic rim). SEM/EDS analysis indicated that the plagioclase ranges in composition from $Na_{0.42}Ca_{0.54}Al_{1.52}Si_{2.46}O_8$ to $Na_{0.46}Ca_{0.50}Al_{1.49}Si_{2.49}O_8$. Extinction angle measurements in thin section point to a labradorite composition overall. Numerous small apatite inclusions occur in plagioclase phenocrysts in each of the thin sections; they also occur with less frequency in clinopyroxene phenocrysts. The inclusions, which are rounded and weakly birefringent, can be found in the interior of the grains as well as at their margins.

Further SEM analysis indicated that groundmass clinopyroxene compositions range from $Ca_{0.63}(Mg_{0.77},Fe_{0.55})\ Si_{1.93}O_6$ to $(Ca_{0.17}(Mg_{1.09},Fe_{0.72})\ Si_{1.97}O_6)$.

Underlying Units

A layer of rhyolitic ash flow tuff lies directly below the lens (Fig. 2). Four samples of this material were collected and made into thin sections. Each of the samples has a predominantly glassy groundmass with a eutaxitic fabric. Small plagioclase phenocrysts scattered in the groundmass account for between 5% and 10% of material in the section. Basalt pebbles of varying compositions account for as much as 40%, while opaque minerals constitute another 1%-2%. A very fine-grained, tan-colored (under uncrossed polars) halo surrounds the basalt pebbles. Compaction structures in the vitric groundmass surrounding the fragments are further indication of the exogenous source of the pebbles.

Numerous small spherulites are present in one rhyolitic sample. This thin section also displays a banding pattern of alternating lighter and darker material. Many of the plagioclase phenocrysts are aligned with the orientation of the banding.

AGE DATA

Ar^{40}/Ar^{39} dating indicates an age of 6.98 +/- 0.18 Ma (2-sigma error) for the lens. A topographically, but not necessarily stratigraphically, higher basalt unit located 1 km ENE of the lens was dated at 7.35 +/- 0.19 Ma (Auerbach, this volume). A basalt from the monocline beneath the lens has an age of 7.62 +/- 0.32 Ma (Ackerly, this volume). These data allow the lens basalt to be intrusive or extrusive. The latter interpretation is dependent on paleo-topography, which is an important factor in the determination of the stratigraphy of volcanic areas.

DISCUSSION AND CONCLUSIONS

The striking uniformity of grain size and chemical composition throughout the Hjallin Lens indicates that the entire body must have cooled very rapidly. Thus, it seems most likely that the lens is an extrusive feature. Had the lens been emplaced as a shallow-level laccolith, as maintained by Annells (1968), a slower cooling rate would have given rise to fractional crystallization of the melt and a layering of grain sizes. However, the remarkable homogeneity of texture, mineralogy, and chemical composition precludes any significant differentiation within the lens.

Furthermore, the units immediately beneath the lens are surficial units: ash flow tuffs and a poorly consolidated sedimentary unit with well-preserved carbonized and silicified wood. The Hjallin Lens thus appears to be an abnormally thick extrusive unit related to the basalt flows that cover the majority of the Skagi Peninsula. Its thickness could be due to its unique position immediately adjacent to a large monoclinal fold structure (Ackerly, this volume). Extension-related down-dropping, which was reinforced by crustal loading from accumulating lavas, resulted in the creation of the monocline and the formation of a topographic low. As it erupted, the lava flowed down into this valley, where it pooled and subsequently cooled very rapidly.

While the data set presented here is a strong one, it is not complete. The entire upper part of the lens (where vesicles might once have been abundant) has been eroded and scoured away by glacial activity and its eastern margin is almost totally covered in pasture. Better exposure along these boundaries would have allowed for a more comprehensive interpretation of the origin of the lens.

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