CHAPTER 2

GEOLOGY, PETROLOGY AND TECTONIC SETTING OF THE SOUTHEASTERN VOLCANIC ZONE

Introduction

The Southeastern Volcanic Zone (hereafter referred to as the SEVZ) is distinct the other active volcanic zones in Iceland, most noticeably because the rocks of the SEVZ are alkalic to subalkalic (transitional). The SEVZ (the southernmost extension of the Eastern Rift Zone, Figure 1.03) is made up of seven different volcanic systems. These are Hekla, Vatnafjöll, Torfajökull, Tindfjöll, Katla, Eyjafjöll, and Vestmannæyar (Figure 1.18). Each system has its own unique geochemical and tectonic character as briefly summarized below.

Hekla

The following general structural and chemical information for Hekla comes from a compilation of previous investigations, discussed in detail by Jakobsson (1979). The Hekla Volcanic System is 40 km long and 7 km wide. All major eruptions occur in Heklugjá, a 5.5 km long summit fissure extending southwest to northeast. Only high silica rocks are erupted in this central region. Eruptions along the flanks of the system show solely transitional alkali basaltic and andesitic volcanic products. There is no central caldera, and no high-temperature thermal activity. From this information, combined with the positive correlation between length of quiescence and volume of succeeding eruptions, it is believed that Hekla has a large, deep-seated magma chamber. Postglacial extrusive volumes are: 7.7 km^3 basalt, 13.8 km^3 basaltic andesite, 3.7 km^3 andesite, 7.2 km^3 dacite-rhyolite, with a total volume of eruptives of 32.4 km^3 (6.6 km^3 of which was erupted in historic time < A.D. 900).

Baldridge et al. (1973) propose that evolution of primary magmas to the high silica compositions can be explained by crystallization and gravitational separation of olivine, titanomagnetite, plagioclase and possibly augite with no contamination by sialic crust necessary. Water pressure was determined using igneous plagioclase thermometry. By cross-referencing water pressure data with temperature data, water contents can be estimated. Using this relationship, it has been estimated that the basaltic melts would be expected to have water contents between 2.5 to 6 wt%. With such high amounts of water, differentiation of magmas will cause accumulation of highly evolved melts and a separate water phase in the upper parts of the magma chamber. As the water pressure exceeds the strength and weight of overlying rocks an explosive eruption of highly fractionated material results (Gudmundsson, 1986). This can be seen in the plot of SiO2 wt% vs. time of eruption (Figure 2.01) where, after long periods of quiescence, explosive plinian-style eruptions occur with highly silicic material (Williams and McBirney, 1979).

Vatnafjöll

The following information comes from work done by Jakobsson (1979). The Vatnafjöll Volcanic System is 40 km long, 9 km wide. Thirty-one individual eruptive units have been identified, all of transitional alkali basalt composition erupted from fissures 1.8 to 4.4 km long. There have been no historic eruptions from this system, and the total volume of post-glacial basalt is 9.4 km^3.

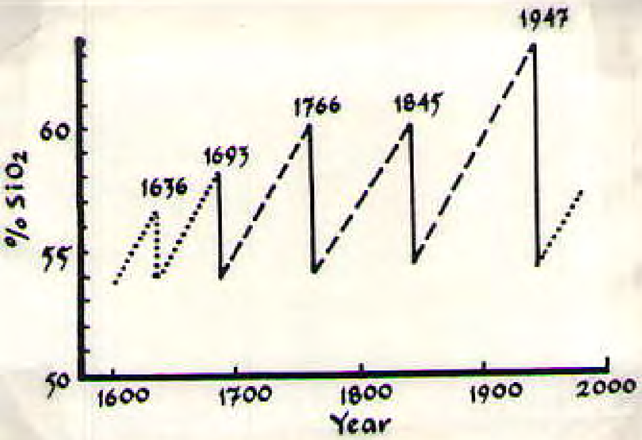

Figure 2.01: The silica contents of the initial gas-rich products of historic eruptions from Hekla tend to be higher than those of the main basaltic magma that follows, and the amount of this difference is directly proportional to the time of repose between eruptions. These relations indicate that silica and volatile components are accumulated at the top of the magma column during the intervals between eruptions (from Williams and McBirney, 1979).

Torfajökull

Unless otherwise stated, work done by McGarvie (1984) on the Torfajökull Volcanic System provides all of the following information. Torfajökull is a central volcanic complex which consists of an elongate rhyolite plateau 450 km^2 in area, with a 30 km long west-northwest, east-southeast axis and an 18 km long northeast-southwest axis. The system is mostly silicic and is the largest silicic center in Iceland. Peralkaline rhyolites are the dominant extrusive composition in the center of the complex, with subalkalic rhyolites erupting during the postglacial period. The eruption rate here has been high, with ten eruptions during the postglacial period, the last one occurring 500 years ago. A large high-temperature geothermal field is present.

Magma mixing appears to have played a significant role in the variety of observed compositions as indicated by inclusions of basalts in rhyolite eruptives and by chemical trends. This fits in with other work showing that magma mixing is indicative of a high magma supply rate (Imsland, 1983). In generation of highly silicic rocks it is believed that basalt magmas are trapped within the crust and evolve, in situ, to develop the more silicic compositions (Macdonald et al., 1990). As these compositions have considerably lower density than the basaltic magmas, they accumulate at the top of the magma chambers, and dominate the material erupted in the center of the complex. For Torfajökull, in particular, it is believed that tholeiitic magma is laterally transported from systems to the north, along the southwards migrating active rift, and is then mixed with the silicic, evolved magmas topping the magma chambers under the complex. The original source material for these silicic compositions, transitional basalt, also plays a role in the mixing, but it seems to be minor.

Total volume of postglacial extrusives is approximately: 0.8 km^3 basaltic lavas, 0.12 km^3 intermediate composition lavas, and 0.87 km^3 acidic lavas: total = 1.8 km^3 (Jakobsson, 1979).

Tindfjöll

All information found on the Tindfjöll Volcanic System comes from work done by Jakobsson (1979). The top of Tindfjöll is covered by a small glacier, with the summit at 1462 m. The lower parts of the complex are dominated by transitional basaltic rocks, while higher in the complex these are interlayered with intermediate and acidic rocks . The caldera is 5 km in diameter. No historic eruptions are known from this system, and the total estimated volume of late glacial to postglacial extrusives is about 0.1 km^3.

Katla

Information on the Katla Volcanic System was compiled by Jakobsson (1979) and is summarized below. Katla is the volcanic system directly east of Eyjafjöll; it extends north past all the other SEVZ systems. In the region between Eyjafjöll and Katla there is a pile of interstratified flows originating presumably from both of the systems. Atop the Katla Volcanic System lies a substantial glacier, Myrdalsjökull, with a summit at 1450 m. The system is 30 km wide (at its broadest point), and 78 km long. Volume calculations of identified lavas indicate 14.8 km^3 from the ice-free portions of the volcano, nearly all of which are basaltic, plus 30 km^3 estimated basalt erupted under the glacier. This gives a total of 45 km^3. The volume of silicic eruptives is unknown, but presumed to be quite low. All basalt compositions are transitional alkali basalts.

Eyjafjöll Volcanic System

The Eyjafjöll Volcanic system lies at the front of the propagating rift segment of the SEVZ, just behind the Vestmannæyar Volcanic System and near the intersection of the Eastern Rift Zone with the South Iceland Seismic Zone. Eyjafjöll is a large composite volcano consisting of both a fissure swarm, 5 km wide and 30 km long, and a central volcano (Figure 2.02) (Jakobsson, 1979). The summit of Eyjafjöll, at 1668 m, is covered by a glacier, Eyjafjölljökull, which is presently retreating. An inferred central caldera, thought to be located beneath the glacier, is 2.5-3 km wide (Jakobsson, 1979). Unlike the rest of the systems along the SEVZ which show linear features parallel or subparallel to the rift axis, the fissures of the Eyjafjöll system are perpendicular to the axis, along an east-west trend. This suggests a unique tectonic environment for this system relative to the rest of the SEVZ.

The volcano is composed of a pile of lava flows and hyaloclastites formed during subaerial and subglacial or subaqueous conditions, respectively. Previous work suggests at least nine cycles of transition between these conditions recorded in the studied cross-sectional sequences (Kristjánsson et al., 1988). The oldest rocks are exposed on the southern side of the volcano in cliff walls cut during the transgressive stage of the present glacier, and by wave activity when sea level was higher. These are reversely magnetized lava flows of the Matuyama magnetic period, and are interlayered with hyaloclastites. They are visible at the base of the Steinafjall section and have been dated independently by Ian McDougall and Robert Duncan using K-Ar dating at 0.78±0.30 and 0.81±0.50 Ma respectively (Kristjánsson et al., 1988; present investigation). These lowermost, reversed flows are overlain by normally magnetized rocks of the Brunhes magnetic period. Known postglacial activity of Eyjafjöll consists of two separate Holocene lava flows,

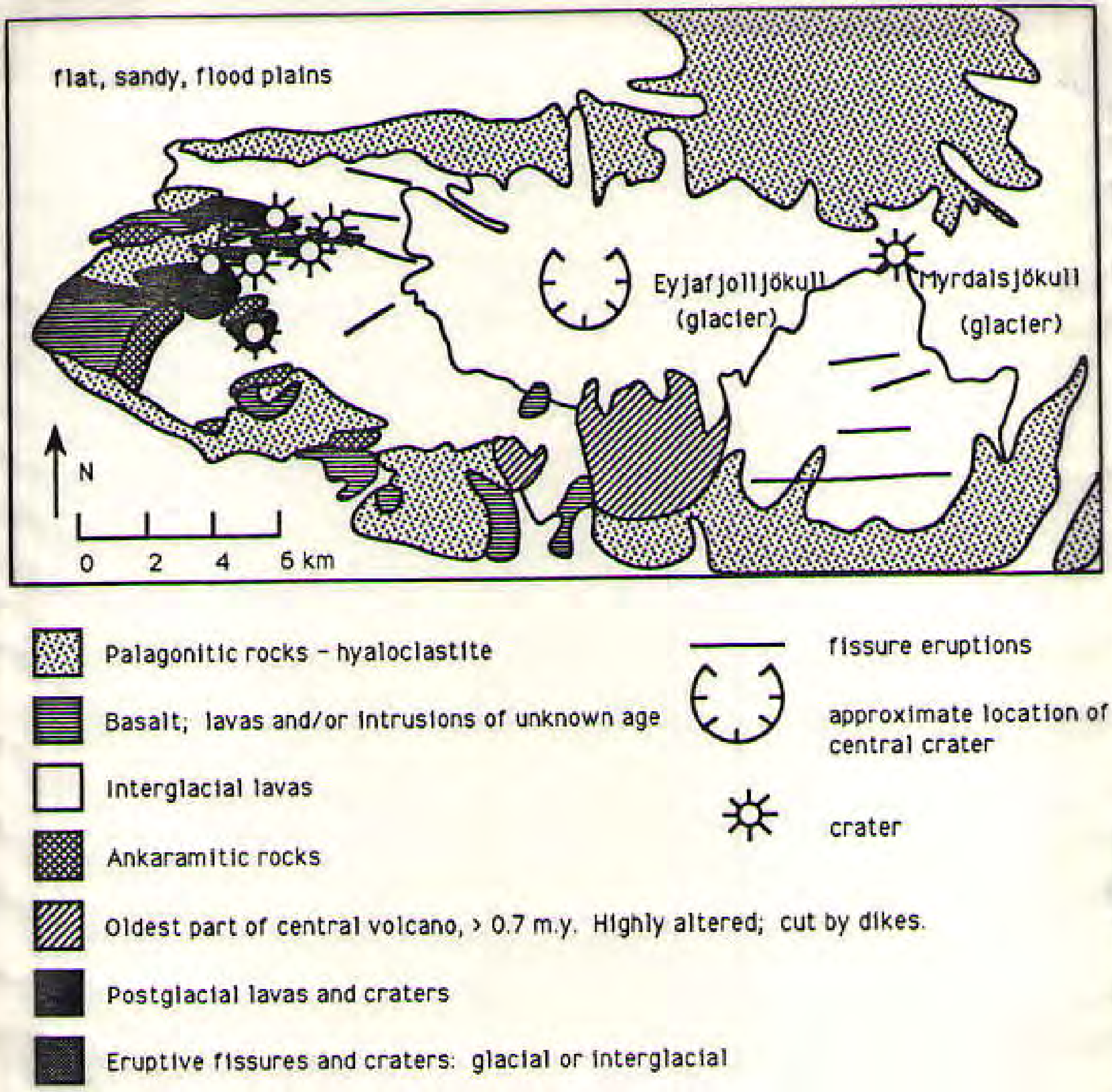

Figure 2.02: Eyjafjöll Volcanic System - Geology (modified from Jakobsson, 1979, and Jón Jónsson, 1988). Summit is at 1668 meters; base is at sea level.

both from fissure eruptions, and one historic phreatic eruption,1821-1823 A.D., from the central caldera, producing tephra of intermediate composition (Jakobsson, 1979). Total volume of postglacial extrusives is estimated at 0.6 km^3, which includes: 0.4 km^3 basalt, 0.24 km^3 basaltic andesite, and 0.01 km^3 acidic material (Ibid).

Vestmannæyar

The Vestmannæyar Volcanic System consists of about 18 islands and a few submarine volcanic eruptions. Submarine data come from dredge hauls of four submarine hills on the shelf around Vestmannæyar (Jakobsson, 1979). This shelf consists of depths from 50 to 140 m, and lies just off the coast from Eyjafjöll. Heimæy (13.4 km^2) and Surtsey (2.5 km^2) are the largest islands, the latter created during a phreatomagmatic (now called Surtseyan) eruption from 1963 to 1965 (Williams and McBirney, 1979). This is the southern tip of the SEVZ, and the propagating rift. Jakobsson (1979) discusses the general structure and composition of this system, and this is summarized below. A 1565 m hole was drilled on Heimæy showing alkalic basalts and tuffs of the present Vestmannæyar system down to 180 m. Below this are marine tuffaceous sediments to 740 m depth, followed by altered basalt lavas, transitional in composition, similar to Hekla. No published data have been found further describing the altered basalts at depth, and for purposes of this thesis they are considered basement.

The area of Vestmannæyar Volcanic System has been outlined at 38 km long, 29 km wide. The main center of volcanic activity is in the Heimæy region, which itself forms the topographic high for the region. The only known occurrences of intermediate rocks (no high silica rocks are found) are on Heimæy, suggesting that this island is developing into a central volcano.

Seventeen postglacial eruptions have been identified above surface throughout the system, three of which are on Heimæy (including the Eldfell eruption of 1973). No hydrothermal activity is found anywhere in the area, and the geothermal gradient is quite low, 60 °C/km at the 1565 m deep drill hole, suggesting no high-level magma chambers. Estimated volumes for the postglacial extrusives are: ≥ 3.7 km^3 alkali olivine basalts, 0.25 km^3 hawaiite to mugearite (one eruption), totalling 3.9 km^3. Much work has been done on the Vestmannæyar Volcanic System recently by Thy (1991a,b), and Furman et al. (1991) involving high-pressure crystallization modeling. It will be discussed in Chapter 5.

Chemical, Petrologic, and Geophysical Data for the SEVZ

Isotopic Compositions

$^{3}He/^{4}He$ values for the SEVZ are higher than anywhere else in Iceland (Figure 2.03, Kurz et al., 1985). They are in the range of 18-26 x atmospheric. The value of 26.2 x atmospheric, for a sample from the western edge of the Tindfjöll Volcanic System, is the highest found throughout Iceland. High values of $^{3}He/^{4}He$ are attributed to hotspot signatures, while low values ≤8 x atmospheric, are more typical of MORB, as described in Chapter 1. The one exception to the SEVZ range is a sample from the Hekla region which falls within the range of values of the Western Rift Zone, at 13.9 x atmospheric.

Work done by Meyer et al. (1985), also shows that La/Sm values are higher for the SEVZ (Hekla - Katla) than anywhere else in Iceland (Figure 2.04). This is also where the highest $^{87}Sr/^{86}Sr$ ratios, highest ^{207}Pb and ^{206}Pb values and the lowest $^{143}Nd/^{144}Nd$ are found (Figures 2.05, 2.06, 2.097). In Vestmannæyar the La/Sm, Sr and Pb isotope ratios decrease,

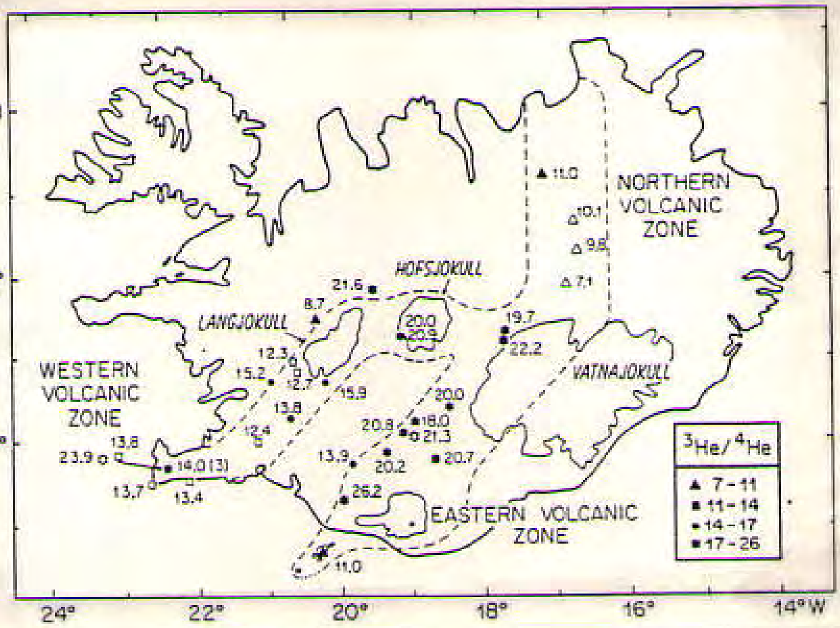

Figure 2.03: $^3He/^4He$ values for different regions within Iceland. Symbols indicate different ranges in $^3He/^4He$. The numbers give actual values of $^3He/^4He$ (in units of R/R_{atm}). Hollow symbols indicate data from Condomines et al. (1983), others are from Kurz et al. (1985).

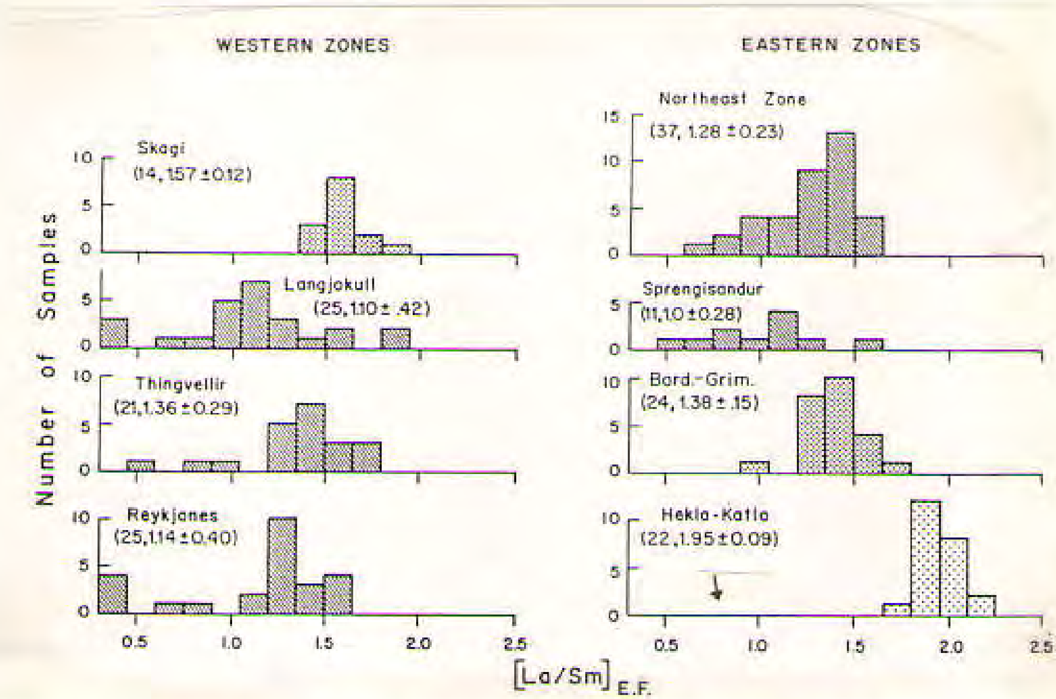

Figure 2.04: La/Sm histograms for different volcanic regions. Numbers beneath each region name indicate the number of samples, the mean, and the standard deviation. The arrow indicates the average for two alkali basalts from Vestmannæyar (from Meyer et al., 1985).

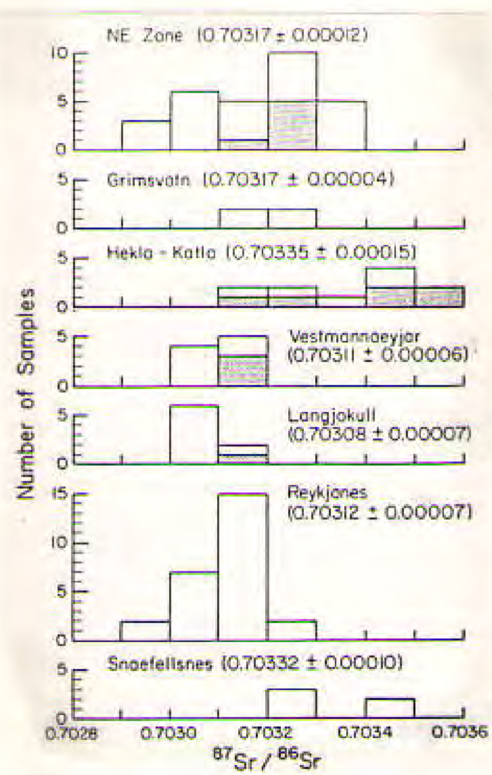

Figure 2.05: $^{87}Sr/^{86}Sr$ histograms for different regions within Iceland. Shaded areas indicate acid and intermediate volcanics. Means and standard deviations are reported beneath or along side the region names. All data have been normalized to a value of 0.70800 for the Eimer and Amend standard (from Meyer et al., 1985).

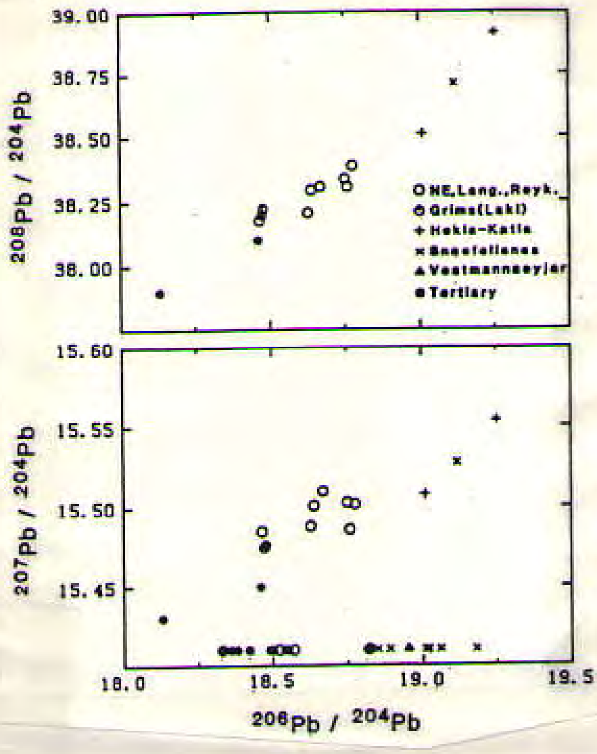

Figure 2.06: Pb-Pb diagrams for Recent and Tertiary volcanics from Iceland. Data plotted at base of lower diagram are unreliable due to outdated analytical techniques (from Meyer et al., 1985).

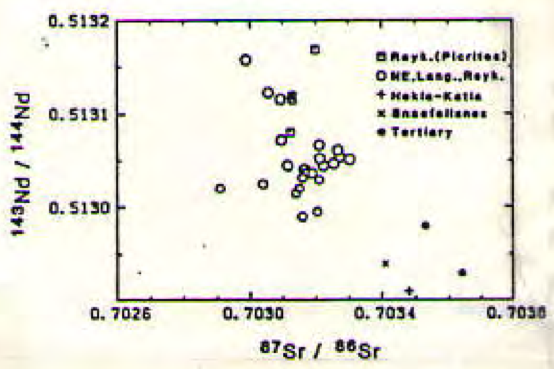

Figure 2.07: Nd ratios versus Sr ratios for both Recent and Tertiary volcanics from Iceland (from Meyer et al., 1985).

whereas Nd isotope ratios increase. $^3He/^4He$ also decreases in Vestmannæyar to a value of 11.0 x atmospheric.

Petrology

Meyer et al. (1985) did work on the petrology of Iceland basalts and discovered the following information. Examination of plagioclase morphology and zoning for phenocrysts in transitional basalts from the Hekla-Katla area shows skeletal and resorption textures while phenocrysts in the tholeiites of the active rift zones are more tabular and euhedral. The phenocryst morphology of the SEVZ is suggestive of mixing of materials of different compositions. Furthermore, forsterite content in olivine and anorthite content in plagioclase both show greater compositional variety in the SEVZ rocks than in material from the parallel Western Rift Zone, (Figure 2.08). This can be explained by the existence of a large range of magma compositions (suggestive of prevalent fractional crystallization).

Geochemistry

Meyer et al. (1985) collected the following geochemical data for all neovolcanic regions of Iceland. Al_2O_3 shows enrichment for whole rock data, indicating plagioclase accumulation, especially where some of the rocks contain up to 45% plagioclase phenocrysts. Fractional crystallization models were run for several separate volcanic regions, in order to compare with major element variations; all variations are found accountable through 55-75% fractional crystallization of variable proportions of chromian spinel, olivine, plagioclase, clinopyroxene and titanomagnetite.

Differing from the rest of Iceland, the SEVZ has a higher alkaline (Na + K) content, grading from the tholeiites of the Eastern Rift Zone to the alkalic basalts of Vestmannæyar, passing through a transitional zone in the Hekla-Katla region. Using the aforementioned fractional crystallization models, the

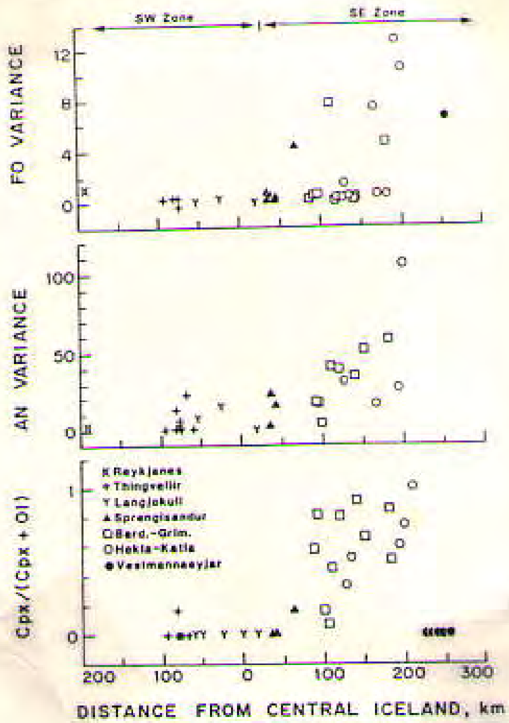

Figure 2.08: Mineralogical variations along the southern neovolcanic zones. Fo variance and An variance refer respectively to the variance in olivine and plagioclase phenocryst compositions observed in individual samples. Cpx/(Cpx+Ol) is the modal ratio of clinopyroxene to clinopyroxene + olivine phenocrysts. Sample locations have been projected normally to the axes of the volcanic zones (see figure 2.01), (from Meyer et al., 1985).

alkalic basalts of Vestmannæyar show greater proportions of olivine fractionation with olivine: plagioclase : clinopyroxene = 34.4 : 34.6 : 30.0 compared to the tholeiitic basalts, 15.0 : 49.6 : 35.4.

Rare earth element patterns for the SEVZ are all uniformly LREE enriched as opposed to the rift zones where it is variable. This uniformity can only occur if melting conditions of the underlying mantle are uniform, or the magmas homogenize in melt accumulation zones prior to eruption. Mg numbers are slightly lower for the SEVZ than elsewhere in Iceland despite the high MgO values. This suggests Fe enrichment. Accompanied by high Ti, these transitional rocks are referred to as Fe-Ti basalts.

Geophysical data

The geothermal gradient is lower in the SEVZ than elsewhere along rift zones (Figure 2.09, 2.10, from Pálmason and Sæmundsson, 1979). This region also has the thickest crust, 10 to 30 km, the latter number referring to the crust under Vestmannæyar (RRISP 77, 1980; Meyer et al., 1985). The melt accumulation zone beneath the crust has been discussed by Meyer et al. (1985) and found (by magnetotelluric data) to decrease in thickness southwards along the zone.

Geochemical Models and Trends for the Propagating Rift

Kurz et al. (1985) made the following conclusions from the isotope data. Areas with high $^{3}He/^{4}He$ ratios are young (due to absence of radiogenic ^{4}He formed during uranium decay) and supplied by hotspot derived magmas (due to high values for primordial ^{3}He, from an undegassed source) . The high $^{3}He/^{4}He$ values of the SEVZ, which as the tip of a propagating rift is a very young region of volcanism, indicate that this region must get much of its magma supply from the hotspot. The ratios drop significantly at the tip of the SEVZ,

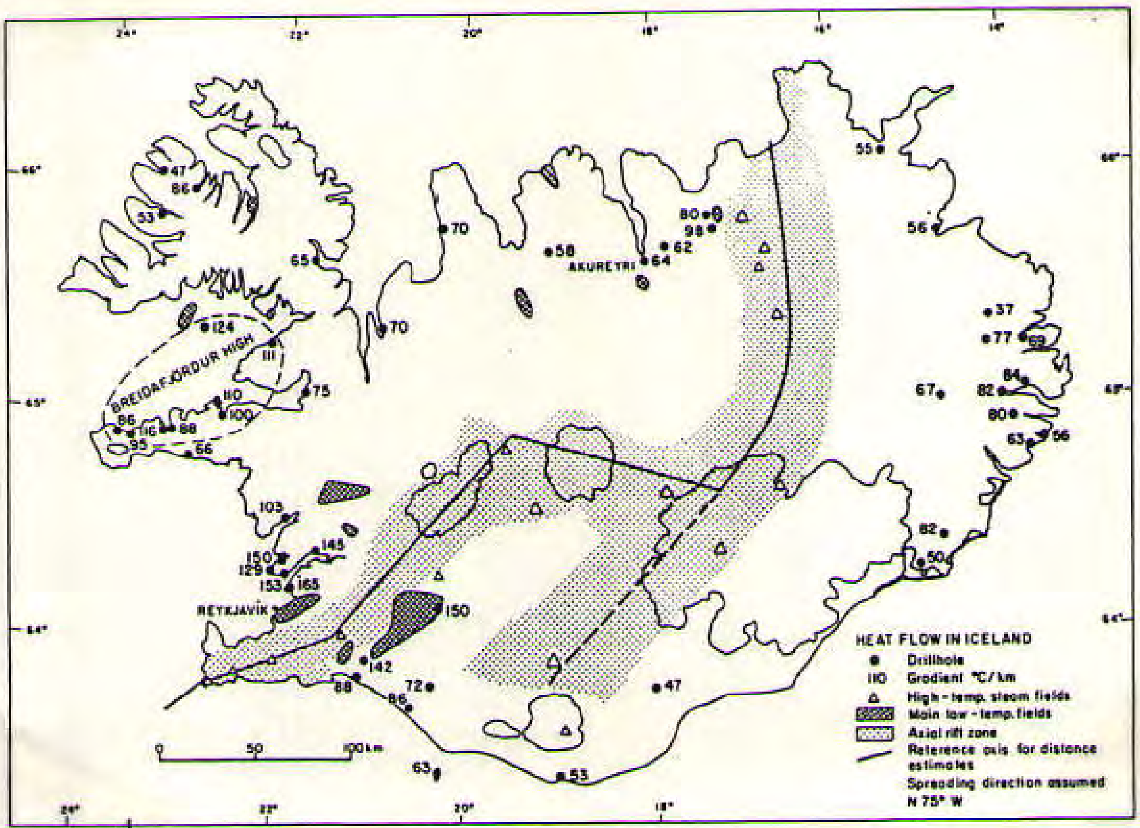

Figure 2.09: The location of drillholes used to determine thermal gradients in Iceland. The main centers of geothermal activity are shown on the map (from Pálmason and Sæmundsson, 1979).

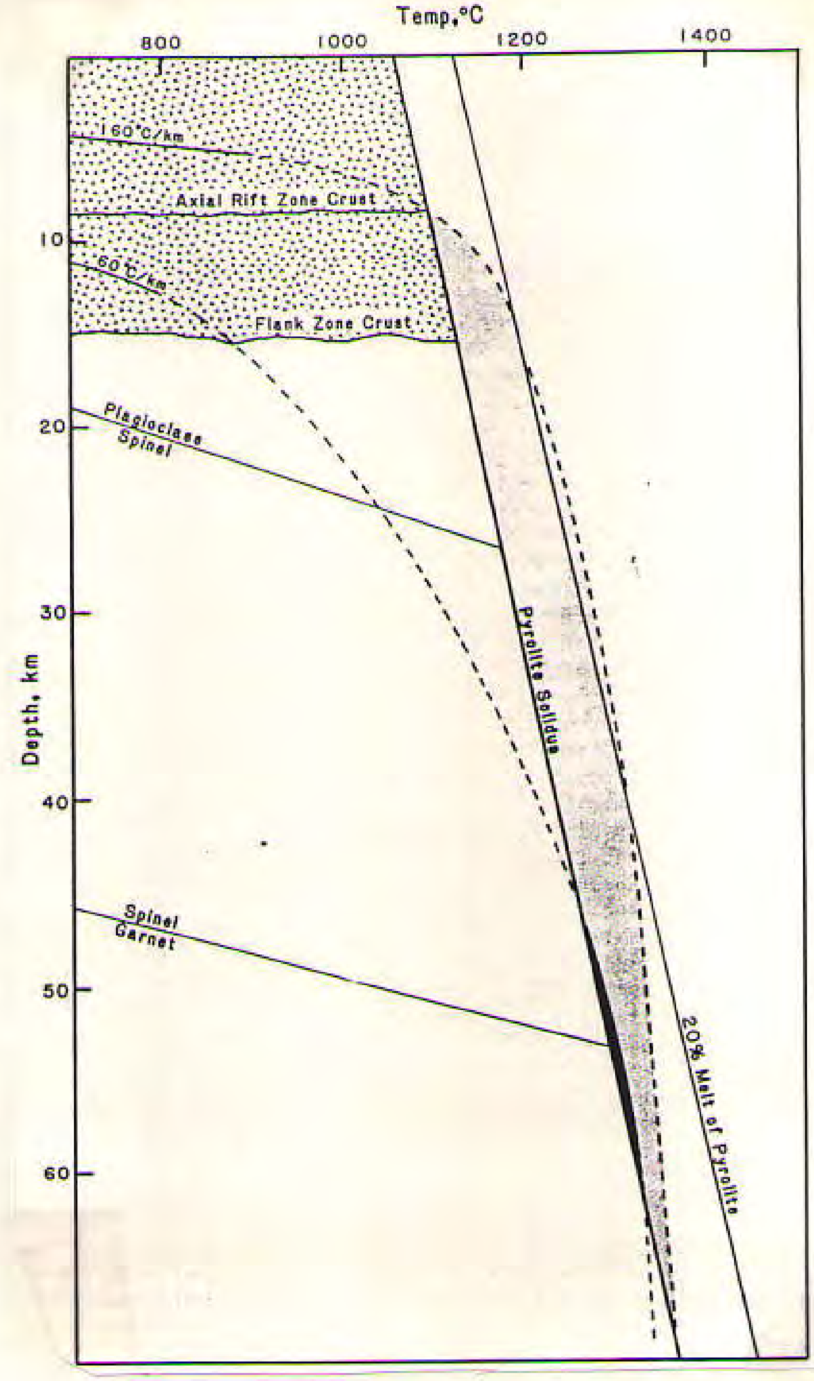

Figure 2.10: Geothermal gradients in Iceland and their relationship to the pyrolite solidus. Shaded areas indicate zones of partial melting. Geothermal gradients at shallow levels are based on temperature gradients in drill holes (Figure 2.11), (from Meyer et al, 1985).

Vestmannæyar, accompanied by a decrease in $^{87}Sr/^{86}Sr$ values, radiogenic Pb values, and La/Sm ratios, and an increase in Nd isotopic ratios. This change is indicative of increased influence of MORB component in source composition. Undepleted (plume source) material dominates at the northern end of the SEVZ while depleted (MORB source) material dominates the southern portion. An alternative process which would lower the $^{3}He/^{4}He$ values is crustal assimilation (because ^{4}He is greater in older crust than in young basalts). But in order to produce the range seen throughout Iceland (from 26 x atmospheric to 10 x atmospheric) over 66% crustal assimilation must be taking place. This doesn't correspond with major, trace and other isotopic data and therefore cannot be the cause for lowering of the $^{3}He/^{4}He$ values. Therefore, it must be variable amounts of depleted and undepleted source components that create the trends seen in Iceland. This has been modeled (Meyer et al., 1985; Kurz et al., 1985) as blobs of plume material (tens of km in diameter) rising and mixing with MORB source - depleted, upper mantle. In the northern parts of the SEVZ plume material is of the greatest proportion while in Vestmannæyar the proportion drops.

Combining the information for postglacial volcanism from individual volcanic systems within the SEVZ, it is apparent that the volume of extrusives is least in the south and increases towards the north. In particular, Hekla, Vatnafjöll, and Katla are the largest volume systems in the SEVZ, and also the furthest north. Torfajökull lies between these three and has significantly less volume but is dominantly silicic. If the silicic magmatism is a result of fractional crystallization as mentioned earlier in this chapter, then that would suggest an even larger volume of mafic material involved at depth (possible intruded material). The lowest volume systems are Tindfjöll and Eyjafjöll in the south. Vestmannæyar has only slightly more volume than these two. The systems further north along the Eastern Rift Zone are even larger than Katla (the largest in the SEVZ), with volumes of 54 km^3 for the system just north of Katla.

There is a progressive compositional trend from the alkalic province of Vestmannæyar in the south to the transitional systems of the middle regions and finally to the tholeiites of the Eastern Rift Zone (furthest north). Silicic magmatism, indicative of long residence time in magma chambers (so that fractional crystallization can occur), also increases northward, with Torfajökull as the maximum. This silicic magmatism is always localized in the central or summit regions of the individual volcanic systems.

The existence of silicic and alkalic lavas in the SEVZ has caused previous investigators to propose the occurrence of crustal assimilation. The basis for these past arguments comes from the idea that if amphibolite facies rocks at the base of the crust are melted, then a nepheline normative component will result after amphibole breakdown (Oskarsson et al., 1982, 1983; Steinthórsson et al., 1985; Condomines et al., 1983; Hemond et al., 1988). However, more recent work has been done by Beard and Lofgren (1991) which shows that dehydration-melting of amphibolites actually creates granodioritic to trondhjemitic melts which are low in K. Water-saturated melts are strongly peraluminous, rich in Ca and poor in Fe, Mg, Ti, and K. None of these conditions produced nepheline normative components or alkalic material. This is by far the most compelling reason to look for an alternative mechanism to explain production of alkalic basalts.

However, it is still possible that crustal assimilation may be occurring in regions of Iceland, perhaps even along the SEVZ. But what exactly would the effects be of this assimilation? Furman et al. (1991) use isotope and trace element data to describe the chemical changes expected from crustal assimilation, and how this appears to be negligible for the Vestmannæyar system in particular and the SEVZ as a whole. This is summarized as follows. Crustal material would be higher in $^{87}Sr/^{86}Sr$ (0.70370 - 0.70432 for a silicic xenolith found in a Surtsey basalt) than what is found in the the SEVZ (0.70312) and should vary with different amounts of assimilation. As it turns out, all the systems of the SEVZ are internally uniform in isotope content for Sr, Nd, Pb and He (not including the highly silicic rocks of the Torfajökull volcano). If crustal assimilation occurs, then it must be occurring to the same degree in all melts within a single system. Oxygen isotope ratios are +5.5 to +5.7 for all Vestmannæyar lavas, while Icelandic material which has seen interaction with meteoric waters (hydrothermally altered crust) has values between +4.6 and -10.0. Finally, Ba, Rb, La and Nb, which are mobile elements during hydrothermal alteration, would be variable in crustal material, and upon addition to melts should impart different signatures. These elements show uniform signatures, however, for the SEVZ, similar to undepleted mantle signatures. None of the geochemical data reviewed by these authors (Furman et al., 1985) indicates crustal assimilation is occurring in any detectable amount in the SEVZ, most especially in Vestmannæyar, the most alkalic system of the SEVZ.

The geochemical signatures discussed above are all indicative of a hotspot dominated source. A heterogeneous source, such as a mixture of plume material and MORB source material as mentioned in Chapter 1 and modeled by Kurz et al. (1985), Meyer et al., (1985) and Hilton et al. (1990), would explain why the isotopes are uniform within volcanic systems, and why trends are present along them (more depleted mantle component in the south). Whether crustal assimilation is happening in small amounts among the systems in the SEVZ must be studied in more detail to decide, but it is apparent that the alkaline nature of the SEVZ is not a result of crustal assimilation. It becomes necessary therefore to formulate another method.

Alkaline magmas can be generated by melting of mantle material at greater depths and lower percentages than what typically occurs along the Mid-Atlantic Ridge and the Rift Zones within Iceland (Jaques and Green, 1980; Stolper, 1980; Kushiro et al., 1968, 1972; Green 1973; Thy, 1991a). High pressure work by Jaques and Green (1980) shows that alkali olivine basalts and alkali picrites can form in a very narrow P-T field, at high pressures and low partial melts (Figure 2.11). As mentioned earlier, the crust under the SEVZ is quite thick (10 to 30 km compared to 4-8 km along the rift zones). As the thickness decreases (northwards along the SEVZ), so does the melt depth, and thus the alkalinity (Meyer et al., 1985, Thy, 1991b). The volume of eruptives decreases to the south as does the geothermal gradient, ≈60 °C/km for Vestmannæyar, as opposed to ≈200 °C/km along the rift zones (Hilton et al., 1990; Sleep, 1990; Pálmason and Sæmundsson, 1979). With lower percentage melts of source material at higher pressure, alkaline magmas could form along the SEVZ while tholeiites dominate the rift zones.

Combining major trend information from the SEVZ it is seen that moving northwards from the tip of the propagator there is a decrease in crustal thickness, an increase in magma supply, a change in composition (from alkalic material in the south to the tholeiites of the north), and an increase in more silicic eruptives. This has been attributed to the tectonic character of this region as a propagating rift. Figure 2.12 shows a schematic comparison of magmas generated along the SEVZ (alkalic and transitional basalts) and those generated along the parallel Western Rift Zone (tholeiites) (Meyer et al., 1985). As mentioned in the last chapter regarding propagating rifts, the magma supply of the older, dying rift (Western Rift Zone) is hypothesized to be

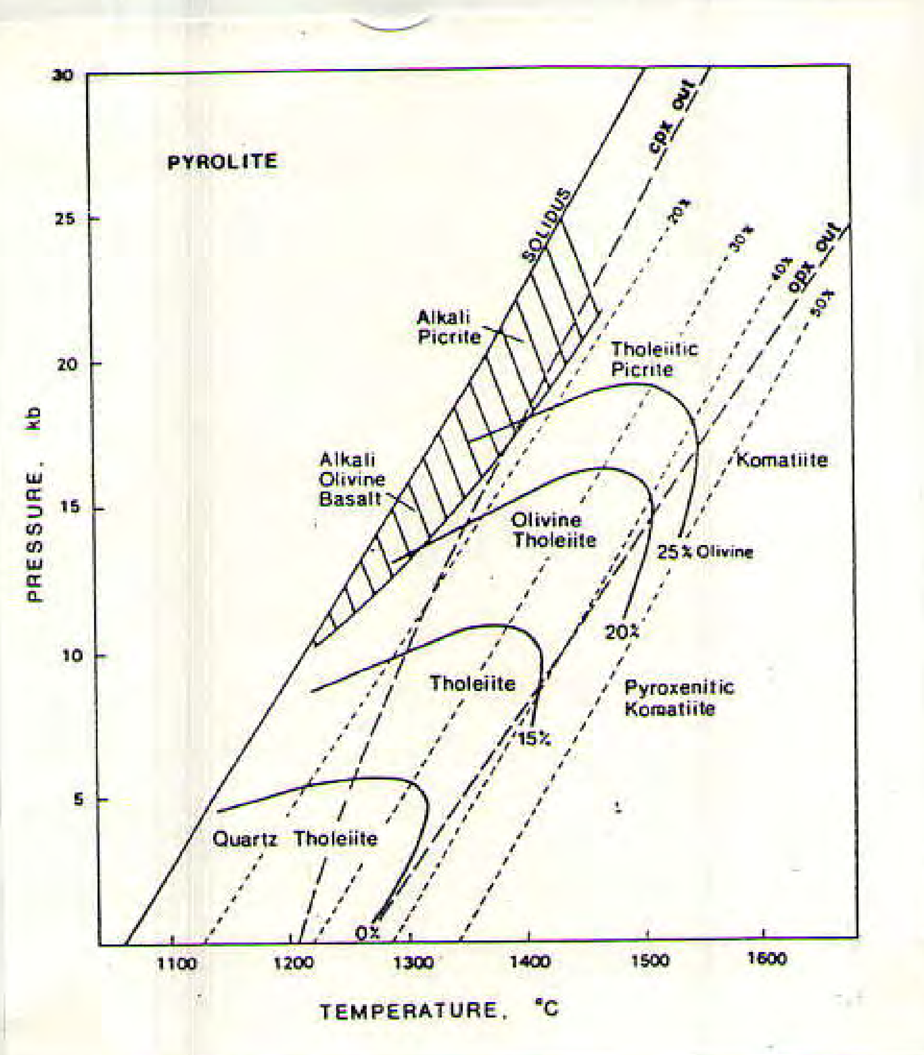

Figure 2.11: P-T diagram for partial melting of pyrolite, indicating compositions of liquids generated. Long-dashed lines indicate disappearance of residual phases; short-dashed lines indicate percentage melting; solid-dashed lines indicate percent normative olivine in the melt (from Jaques and Green, 1980).

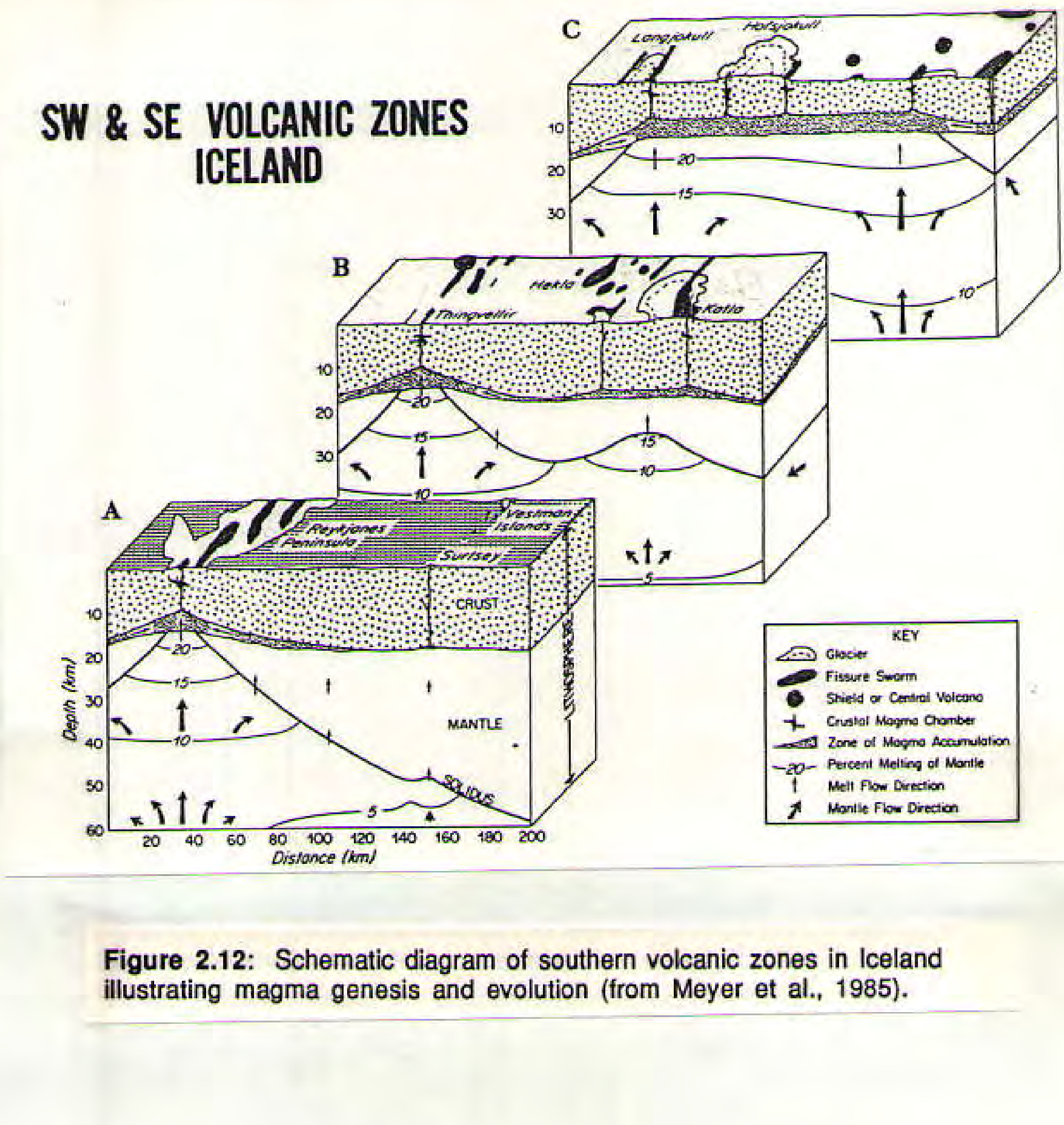

Figure 2.12: Schematic diagram of southern volcanic zones in Iceland illustrating magma genesis and evolution (from Meyer et al., 1985).

diverted to the propagator (SEVZ).

On the basis of the resorbed and skeletal textures and wide range of compositions for the phenocrysts from the SEVZ lavas, Meyer et al. (1985) suggested that they could be produced by mixing of primitive and evolved basalts. They further conclude that there are fundamental differences in magma evolution and supply rate between the SEVZ and the rift zones. The SEVZ magmas have longer residence time in magma chambers, greater degrees of fractionation, and longer time intervals between magma chamber replenishment. The uniformly LREE enriched character of the SEVZ suggests uniform melting conditions or homogenization of mantle melts in large magma reservoirs. Modeling was done for batch melting of possible mantle sources (Meyer et al., 1985) in the attempt to produce the observed LREE enriched trends of the SEVZ. The results show that it is only possible if melting is done at a great enough depth that garnet replaces spinel as the stable aluminum-rich phase. In this case, with a garnet lherzolite mineralogy, 1-3% batch melting will yield the Hekla-Katla basalts. This is dependent upon good knowledge of partition coefficients for the REE relative to temperature, and composition. More will be discussed on this in Chapter 5.

All of the observations of Meyer et al. (1985) are shown in Figure 2.13, a schematic cross-section through the SEVZ. It is proposed that the formation of the SEVZ propagating rift began by ascension of a mantle blob at about 2-3 Ma which spread out laterally beneath the eastern Iceland lithosphere and triggered the southward propagation of the Eastern Rift Zone. The blob comes as a pulse of material from the mantle plume. Evidence for an undegassed, undepleted mantle beneath the SEVZ is supported by isotope data and La/Sm ratios. Vestmannæyar taps into mantle just beyond the tip of the undepleted mantle blob, and therefore has a signature closer to MORB material. This is

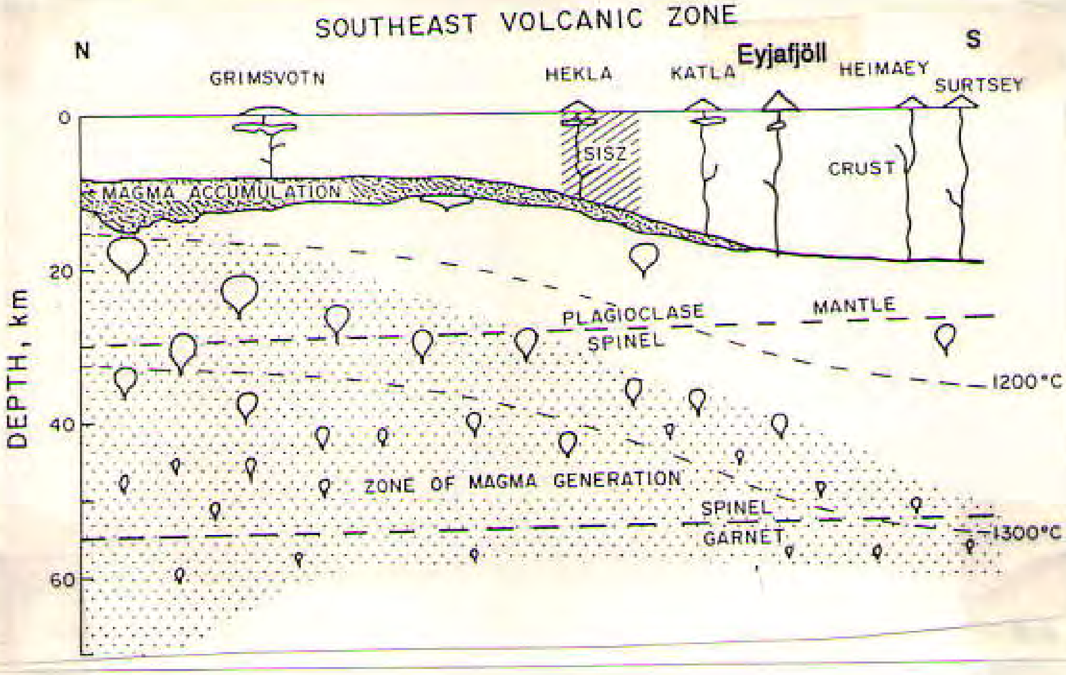

Figure 2.13: Model of magma generation and accumulation along the SEVZ. Crustal thickness is based on seismic data. The lens of magma accumulation is based on magnetotelluric data and contains 10-20% melt. Isotherms are based on geothermal gradients (from Meyer et al., 1985).

accompanied by increased depth of melting and smaller percentages of melt, and hence more alkalic lavas.

Prior to this investigation the only available data for the SEVZ consisted of alkalic rocks from Vestmannæyar, and transitional and tholeiitic rocks from the rest of the rest of the volcanic systems. If, in fact, the depth of melting is becoming gradually deeper (southwards) along strike of the rift, then the geochemical changes should make a regular transition. In other words, there should be history in each of the systems of initial alkalic volcanism followed by transitional and finally tholeiitic magmas. In fact, few alkalic rocks are known from any of the other volcanic systems. Eyjafjöll, however, which lies geographically along strike between Vestmannæyar (where all samples are alkalic) and the rest of the SEVZ (where all samples are transitional or tholeiitic), consists mainly of alkalic and transitional rocks. This is the subject of the rest of the thesis.

Research Objectives

The major objective of my research is to use geochemical and geochronological data to characterize the magmatic and tectonic processes of the Eyjafjöll Volcanic System, and to ultimately relate this information to the position of Eyjafjöll relative to the rest of the SEVZ. The major problems are:

1) What is the timescale of volcanic activity at the southern end of the SEVZ propagating rift (maximum to minimum ages)?

2) How have the compositions and eruption rates of magmas at the tip of the propagator varied through time?

3) Is there evidence for multiple cycles of recharge, fractionation, assimilation and eruption, and if so on what timescale?

4) How closely related are magma supply and tectonism?

5) How does the geochemistry of Eyjafjöll magmatism differ from the magmatism elsewhere along the SEVZ, and Eastern Rift Zone, and how can this be explained?

The applications of my research are significant for the following reasons:

1) It is the first, focussed application of K-Ar age determination to young (< 1 Ma) basalts from the neovolcanic zones in Iceland.

2) This volcano-tectonic zone can be used as a subaerial analog for a mature spreading ridge, in particular a ridge segment - transform fault intersection. This can provide time constraints to previously studied petrologic and tectonic processes of mid-ocean rifts.

3) It will bring a clearer understanding of the neovolcanic zones of Iceland, in particular regarding the effects of crustal assimilation, magma mixing, and fractionation, with the potential of adding time constraints to the modeling of magma processes.