PALEOMAGNETISM AND MAGNETIC SURVEYS IN ICELAND

Leo KRISTJANSSON

Science Institute, University of Iceland, Reykjavik, Iceland *

Received 13 February 1970

Results from paleomagnetic measurements on Icelandic rocks are presented and discussed, with special reference to the interpretation of local aeromagnetic anomalies. From the available data it is concluded that linear anomalies extending along the central Neo-volcanic zone can be explained by the large and uniform magnetization of Quaternary basalt formations. For Tertiary regions of Iceland it is demonstrated that large magnetic anomalies recently observed are due to highly magnetic gabbro intrusions or to sub-basaltic material, rather than to basalt lavas or dykes.

1. Introduction

In the last few years, several aeromagnetic surveys have been carried out in and around Iceland [1, 2]. If the results from such surveys are to be properly interpreted in terms of geologic structure, the magnetization of local rocks, both in surface and sub-surface strata, must be known. The present communication reviews some relevant aspects of available data on remanent, induced and viscous magnetization in Icelandic basic rocks such as lavas, dykes and gabbro intrusives.

2. Remanent and induced magnetization

Iceland is predominantly built up of Miocene to Lower Quaternary basalt lavas: in the central Neo-volcanic zone these are overlain by the Upper Quaternary to Recent Palagonite Formation (fig. 1). This formation consists of a mixture of pyroclastic rocks and lavas, and it is believed to be produced chiefly by sub-glacial or sub-aquatic volcanism. It rarely exceeds one km in thickness, according to geological and seismic evidence [3].

It is difficult to obtain a magnetically representa-

tive collection of Icelandic rocks, as for example the intensity of natural remanence may vary by a factor of fifty through a single lava [4] and there are many different types of lava in any one mountain. However, table 1 below, which summarizes some recent measurements on the magnetic properties of Icelandic basic rocks by the author and others, is partly made up by combining the results of smaller surveys, which agreed reasonably among themselves where overlapping. Each entry in the table represents an area between 10 and 200 km in linear dimension.

Samples were mostly collected by a portable drill as described by Watkins [16]. The number of samples collected at a site (i.e. at a lava, dyke, etc.) varied between one and six in most cases. In those surveys where only one or two samples were collected per site, the sample measurements have been averaged directly: these are distinguished by the number 1 in the sampling column of table 1. In other cases results from two or more samples per site may have been averaged logarithmically prior to averaging over all sites, and these surveys are numbered 2 in the sampling column.

Measurements in Iceland were carried out using an astatic magnetometer designed by Th. Sigurgeirsson and others, and a 1000 cps susceptibility bridge designed by the author and Ó.Gardarsson. The distributions of both remanence (J) and initial volume susceptibility (k) values were found to be better approxi-
Table 1
Average magnetic properties of some Icelandic basic rocks.

<table>
<thead>
<tr>
<th>Description</th>
<th>No. of samples</th>
<th>Sampling, see text</th>
<th>a.c. demagnetization, peak (Oe)</th>
<th>$J_{ar}$ (10^-3 G)</th>
<th>$J_{log}$ (10^-3 G)</th>
<th>$k_{log}$ (10^-3 G/Oe)</th>
<th>Ref.</th>
</tr>
</thead>
<tbody>
<tr>
<td>66 Miocene lavas, NW-Iceland</td>
<td>240</td>
<td>2</td>
<td>85</td>
<td>2.9</td>
<td>2.2</td>
<td>1.25</td>
<td>[5]</td>
</tr>
<tr>
<td>Some 1000 Miocene to L. Quaternary lavas, E-Iceland (anomalous samples excluded from $J_{log}$)</td>
<td>~2000</td>
<td>1</td>
<td>150</td>
<td>2.4</td>
<td>2.0</td>
<td></td>
<td>[6]</td>
</tr>
<tr>
<td>110 L. Quaternary lavas from the preceding collection, E-Iceland</td>
<td>160</td>
<td>1</td>
<td>0</td>
<td>6</td>
<td>4.2</td>
<td></td>
<td>[9]</td>
</tr>
<tr>
<td>270 Pliocene lavas, SW-Iceland (mainly from Hvalfjörður area)</td>
<td>400</td>
<td>1.2</td>
<td>0</td>
<td>4.2</td>
<td>2.6</td>
<td></td>
<td>[8]</td>
</tr>
<tr>
<td>30 Pliocene-L. Quaternary lavas, Reykjavik-Stardalur (excluding very altered samples)</td>
<td>40</td>
<td>2</td>
<td>0</td>
<td>8</td>
<td>5.4</td>
<td>1.8</td>
<td></td>
</tr>
<tr>
<td>17 Pliocene-L. Quaternary elastic beds (from boreholes), Reykjavik</td>
<td>18</td>
<td>1</td>
<td>3.4</td>
<td>1.5</td>
<td>0.6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>20 Interglacial light-gray lavas (formerly called dolerites), Reykjavik</td>
<td>27</td>
<td>2</td>
<td>0</td>
<td>3.5</td>
<td>2.5</td>
<td>0.36</td>
<td></td>
</tr>
<tr>
<td>13 Upper Quaternary palagonite tuffs, SW-Iceland</td>
<td>17</td>
<td>1</td>
<td>0</td>
<td>0.1</td>
<td>0.04</td>
<td>0.08</td>
<td></td>
</tr>
<tr>
<td>Lavas, pillows, breccia fragments and dykes from 45 sites in the U. Quaternary Palagonite Formation</td>
<td>63</td>
<td>2</td>
<td>0</td>
<td>16</td>
<td>11</td>
<td>0.9</td>
<td>[7]</td>
</tr>
<tr>
<td>10 Miocene dykes, NW- and E-Iceland</td>
<td>126</td>
<td>2</td>
<td>0</td>
<td>4.2</td>
<td>3.5</td>
<td>1.4</td>
<td>[7]</td>
</tr>
<tr>
<td>10 Pliocene dykes, SW-Iceland</td>
<td>20</td>
<td>2</td>
<td>0</td>
<td>7.5</td>
<td>5.8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>U. Tertiary-Quaternary gabbros from 10 widely scattered sites, S- and W-Iceland: see figs. 1 and 2</td>
<td>21</td>
<td>2</td>
<td>0</td>
<td>6.5</td>
<td>6</td>
<td>5</td>
<td></td>
</tr>
</tbody>
</table>

$J_{ar}, J_{log}$: arithmetic and logarithmic (geometric) average values of remanence. $k_{log}$: logarithmic average value of initial volume susceptibility.

Magnetized by lognormal curves than by ordinary normal curves, but the arithmetic averages $J_{ar}$ have been included in Table 1 because of their application to the interpretation of magnetic surveys. Between-site log_{10} standard deviations were usually around 0.4, and systematic errors, mainly in instrument calibration, may total 10%. From Table 1 (when allowance has been made for the reduction of $J$ on a.c. demagnetization, but disregarding minor effects such as the presence of interbasaltic sediments), it is estimated that a suite of one-polarity Tertiary Icelandic lavas has an arithmetic average natural remanence of $(3.5 \pm 1) \times 10^{-3}$ gauss. Lower Quaternary (1–3 my old) lavas similarly have an estimated mean remanent magnetization of $(6.5 \pm 2) \times 10^{-3}$ gauss, and it must be noted that they may include unusually thick series of reversely magnetized lavas [1, 2].

The most highly magnetized basalts are found in the Palagonite Formation, but this formation largely consists of the almost non-magnetic palagonite tuffs (Table 1) and contains breccias and dolerite lavas of low net magnetization. In Table 1, no dolerite samples...
are included in the results from the Palagonite Formation, but a few postglacial lavas are included. For 25 postglacial lavas Brynjolfsson [15] has found an (arithmetic?) average remanence of about $14 \times 10^{-3}$ G. Using geologists' estimates of the proportions of the various rock types within the Palagonite Formation, one obtains a weighted average remanence of $(6.5 \pm 2.5) \times 10^{-3}$ G for its surface rocks.

From susceptibility values for Icelandic dykes and lavas, where known, it may be seen that induced magnetization in 0.5 Oe field is generally small compared to the remanence $J$ and may be neglected in magnetic surveys. The high value of $k_{\log} = 3.5 \times 10^{-3}$ G/Oe, reported in an earlier publication [10] is now believed to contain an error in averaging.

3. Viscous magnetization (VRM)

According to Table 1, the older basalts in Iceland may be on the average less magnetized than Quaternary ones by a factor of two to four. One reason for this difference could be viscous decay of TRM with time [11], in the basalts. The oldest Tertiary basalts of NW-Iceland, however, are of similar magnetic intensity as much younger (Pliocene) lavas of SW-Iceland, and they also contain appreciable primary magnetization components acquired at quite low temperatures [5]. It therefore appears more probable that the difference in remanence between Tertiary and Quaternary lavas, if real, is caused by differences in composition or in environment at the time of eruption [14].

The possibility that one type of rock contains a higher viscous remanence than others, to an extent affecting magnetic surveys, has also been suggested [5] as many lava samples from Iceland contain appreciable amounts of VRM [5, 15].

Irving and Roy [6] have proposed a method for estimating in rocks the amount of VRM having time constant $1-10^5$ yr (named by them $S$). This method employs results of a.c. demagnetizations of groups of normally and reversely magnetized rock samples. These groups must be large and of very similar chemical and physical properties, and samples showing weak or unstable magnetization, transitional (anomalous) directions of remanence or other suspect features must be rejected. The VRM-component having time constant less than 1 yr may be estimated by measuring the NRM of specimens that have been left standing in the laboratory for weeks to months; this component is named $T$.

The author has applied these methods to collections of Icelandic rock samples, with the following results:

1. From Sigurgeirsson's measurements [8b] on a.c. demagnetized samples from 110 basalt lavas from SW-Iceland, 36 samples were rejected. In the remainder, the average intensity of magnetization in the 35 reverse samples increased by 11% on 40 Oe demagnetization. However, these being on the average less magnetized than the normal ones after 110 Oe treatment, it can only be concluded that the average $S$ in all these samples amounted to somewhere between 12-20% of their mean primary magnetization $P$. An estimated value of $T = 10-15\%$ of $P$ was obtained from duplicate NRM measurements on 60 lava samples from SW-Iceland [8a], the arithmetic average angle between the two sets of directions being $7^\circ$ and the time between measurements being 3-4 yr.

2. In 200 lava samples from E-Iceland [9], $S$ was by the above methods found to be of the order of 3%
of $P$ (by demagnetization in 50 Oe a.c. field only). $T$ was not measured directly but was probably also of the order of 3% of $P$.

3. In 43 lava samples from NW-Iceland [5], the average drop in remanent intensity between 0 and 85 Oe demagnetizations was about 15%, mainly due to soft $P$. As $T$, from repeat measurements 100 days apart, also amounted to some 15% of $P$, the effect of $S$ could not be discerned.

4. In 8 samples of highly magnetized basalts from the Palagonite Formation, and also in 10 samples of Tertiary gabbros, the average $S + T$ was by similar methods found to be less than 15% of their average $P$-values. The accuracy of these results is limited by the fact that the former samples were all of normal, and most of the latter of unknown, polarity.

The amount of VRM present in Icelandic basic rocks is thus seen to be quite variable, and attempts to correlate its intensity with other parameters between lavas, e.g. with $P$ using the data of [8b], have not provided any basis for predicting where VRM occurs. This makes its effect on magnetic anomalies difficult to assess, but in high-altitude surveys any regional variations in VRM probably need not be considered.

4. Dispersion of paleomagnetic directions

In considering the magnetic effect of a suite of one-polarity lavas one should, ideally, take into account the dispersion of magnetic directions between the lavas, as well as their mean direction and intensity of magnetization. As a first-order correction in work with a vertical-component magnetometer, one should thus multiply the mean intensity of NRM, as derived from paleomagnetic measurements, by a correction factor \( \cos \delta \sin I \), where $I$ is the inclination of the mean paleomagnetic field direction and $\delta$ the between-lava dispersion angle \( \cos^{-1}(R/N) \) for paleofield directions. Then, the lavas may be treated as if they were all vertically magnetized, provided within-lava dispersion is small.

In order to obtain a value of $\delta$ applicable to this problem in Iceland, all measurements of paleo-field directions from surveys spanning at least several geomagnetic epochs must be analysed. In particular, transitional directions of remanence must be included in the analysis.

The experimental value of $\delta = 22.5^\circ$ was previously reported by the author [5] from NW-Iceland, and a value of $\delta = 20.1^\circ$ has been obtained by a similar analysis of paleomagnetic directions in 123 stable Pliocene-Quaternary lavas from E-Iceland [9]. These results are believed to be a good approximation to the dispersion of paleo-geomagnetic field. The angle $I$ being approximately $73^\circ$ [5], the above mentioned factor $\cos \delta \sin I$ is found to be very nearly 0.9 for Tertiary flat-lying lavas in Iceland. Hence their magnetization may, for the interpretation of magnetic anomalies, be assumed to be vertical.

For comparison, the author has obtained values of $\delta$ from those paleomagnetic surveys in other latitudes, which span at least a few Upper Cenozoic magnetic epochs and employ stable demagnetized lavas. For each of these surveys, which were carried out in Oregon and Washington [16], the Cap Verde Islands [17], Réunion [18] and the Canary Islands [19], the $\delta$-values obtained by combining all data are found to lie between $21^\circ$ and $24^\circ$. Simple dipole-wobble models of the geomagnetic field [20, fig. 8], on the other hand, predict a drop in $\delta$ from equator towards the poles by a factor of about 3, so the experimental results above may be connected with the frequent reversals and near-reversals of the field in the Upper Cenozoic [23].

5. Dykes and magnetic anomalies

It has been concluded that in Iceland Quaternary basalts happen to have larger values of remanence than Tertiary ones and to consist of up to 1 km thick series of essentially single-polarity rocks over large areas. By simple calculations of fields from rectangular-block bodies it appears that these results can explain a significant part of linear magnetic anomalies observed in and near the central volcanic zone shown in fig. 1. However, anomalies reaching hundreds of gammas are also found at 3–4 km altitude over the Tertiary areas of Iceland [1, fig. 1] where lavas generally form flat-lying series with polarity inversions occurring once every 150 m thickness or so. In spite of the considerable uncertainties quoted above with the average remanence of the lavas, other phenomena
must probably be invoked to explain these anomalies. It has also been noted by Sigurgeirsson [2], that magnetic anomalies in the Neo-volcanic zone do not always correlate with topography.

One possible explanation of such anomalous anomalies could be the existence of major dyke swarms having uniform direction of remanence in large areas [1]. However, there is little geological or geophysical evidence for such swarms in Iceland, the actual volume of dykes being generally of the order of 5% of the country at sea level [11]. Being mostly the feeder dykes of the Tertiary lava flows, one would not expect them to be distributed in such a fashion as to produce any large-area magnetic anomalies.

The following experimental results further indicate the actual magnetic effects of dykes:

1. The average remanent magnetization of 20 Tertiary dykes sampled near sea level in Iceland (table 1) was around \(6 \times 10^{-3}\) gauss, rather than \(25 \times 10^{-3}\) G as suggested by Serson et al. [1]. During the measurements of this property, no major systematic variation of remanent intensity through the dykes was observed, nor was there any correlation between dyke thickness and intensity. As remarked in section 2 above, the \(Q\)-ratio of the dykes usually exceeds 1, and in general within-dyke variations in magnetic properties are smaller than corresponding within-lava variations [22].

It is concluded that dykes exposed above the present sea level produce by themselves no appreciable regional magnetic anomalies in Iceland.

2. The possibility of widespread remagnetization of the lava pile by dyke heating, suggested by [1], may be investigated by measuring the remanence of lava samples collected at varying distances, say 0.1–10 m, from dyke contacts. This has been done at nine of the dykes sampled for table 1, and they have not been found to cause any systematic changes in intensity of remanence of the lavas. Such effects are perhaps not to be expected, because of the marked non-uniformity of magnetic properties within the lavas [4, 22].

In five cases the dyke and the lava, where sampled, had very different but stable directions of remanence. It was found that each dyke had altered the direction in an adjacent volume of lava equal to only a fraction of its own volume. The average value of this fraction is probably one-fifth or less: uncertainties in this average reflect the fact that lava-dyke contacts are seldom plane or distinct, and also the fact that the lava samples were collected about 0.5 m apart, the average dyke thickness being similar to the Iceland average of 4 m [11].

The value one-fifth is in good agreement with thermal conduction calculations, assuming the validity of Thellier's law of partial TRM and using the thermal properties for lavas quoted in [1]. It must also be assumed, to account for the results, that any eruption through the dykes lasted only for a day or two, and that the dyke rock subsequently solidified gradually from the sides inwards rather than all at the same time. Furthermore, it must be assumed that at the time of dyke intrusion the local temperatures in the lava pile were about 150°C or less: this assumption is consistent with a maximum-temperature estimate of 120°C arrived at in [5], and also with similar results by Wilson and Smith [21, p. 379], although the latter incorrectly attribute a temperature estimate of 200°C or more to Walker [11].

The intrusive heating model of [1] thus seems to require values of dyke concentration and of paleo-heat flow much higher than is observed so far in the exposed strata.

3. The properties of basalts buried at depth remain largely unknown, but the following observations may be relevant: (a) Samples of small (Tertiary basalt?) drill chippings from 800–2200 m depths in two Reykjavik boreholes were found to have susceptibilities clustering around \(3 \times 10^{-3}\) G/\(Oe\), and to acquire considerable remanence when cooled in air from a temperature of 600°C. In fact this remanence, averaging \(13 \times 10^{-3}\) G at an ambient field of 0.5 Oe (logarithmic average of 11 samples) was similar to those obtained by subjecting 21 typical samples of Pliocene and Lower Quaternary lavas from SW-Iceland to the same treatment. (b) Approximately five times lower values of susceptibility and artificial TRM intensity were obtained with chippings of highly altered material from 300–1100 m depths in a high-temperature (>250°C) borehole in the Neo-volcanic zone. (c) It is known that in high-temperature areas the magnetic material in rocks has frequently been dissolved or altered to pyrites by ground water. Intrusion of a large number of dykes could produce such temperatures.
On the available data it is therefore concluded that the presence of dykes in Iceland does not cause any major aeromagnetic anomalies, but much more work on dykes and their geological setting is required. It is not known, for instance, whether they in Iceland represent in general tensional fissures having their present dimensions, or incidental cracks later enlarged by the abrasive action of erupting magma.

6. Gabbro and magnetic anomalies

If lavas and dykes be excluded, one must look for other phenomena capable of causing magnetic anomalies over the Tertiary areas of Iceland.

Seismic reflection results [3] show that the Tertiary basalts only reach to 2-4 km depth in most of the country. Where the lower part of these is exposed, it is characterized by the occurrence of large basic and acid intrusions, and similar intrusive complexes also appear higher up in the lava pile. In a low-altitude aeromagnetic survey in progress in W-Iceland (flight altitude 3000 ft), large anomalies have been found not only above or near many of these (Th. Sigurgeirsson, personal communication) but also over areas where the presence of highly magnetized rock had not been expected (see sect. 7). Being 3-6 km in extent and reaching a few thousand gammas in total field, these anomalies are much more conspicuous than anomalies occurring over volcanoes within the Palagonite Formation (such as Surtsey).

Judging from inshore navigators' reports, many more such anomalies may be expected to be found in Tertiary areas in and around Iceland as Sigurgeirsson's survey is extended.

In connection with Sigurgeirsson's work, the author has measured the magnetic properties of gabbro and related rocks from some Icelandic intrusions (figs. 1 and 2). It is found that gabbro, also including olivine gabbro and pyroxenite, has in general considerably higher values of remanence and susceptibility than, say, Tertiary lavas: see fig. 2 and table 1. Most of the samples obtained were unoriented, but at two localities of large negative anomalies (the Videy and Hafnarfjall areas) the magnetization of gabbro outcrops was found to be reverse. From the results of a.c. demagnetization of 10 samples it is concluded that the remanence of Icelandic gabbro is predominantly a stable to very stable TRM, and it is presumably due to the presence of abundant titanomagnetite grains. The size of these grains is in many samples of the order of 0.2-2 mm, as compared to about 0.015 mm in some Tertiary Icelandic basalts [5], but reversible thermomagnetic curves yield Curie points near 560°C for both the basalts and the gabbrons. The intensity of NRM in the latter is positively correlated with their susceptibility (fig. 2) and with their stability of remanence, whereas no obvious between-site correlations of these properties have been noted in the basalts sampled for table 1, and within-lava correlations follow a different pattern [22].

Gabbroic nodules occur widely in Icelandic basalts, both outside and inside the Neo-volcanic zone, and Jónsson [12] has suggested that an extensive layer of gabbro underlies the Tertiary basalts. Such nodules, however, have a low percentage of opaque minerals.

![Fig. 2. Distribution of NRM intensity and susceptibility values for samples of Icelandic gabbro (filled circles), diabase, ankaruramite and pyrite-altered gabbro (open circles) and gabbroic nodules in basalt (circles with cross). Dotted lines indicate log-average values of NRM intensity and susceptibility for 66 Tertiary lavas from NW-Iceland [5]].
around 6.2–6.5 km/sec and is believed to be basic in composition [3]. At one locality in Iceland, this layer is known to approach the surface to within 1 km over an area of some 6 km extent (G.Pálmason, personal communication), centred near the Stardalur farm 24 km ENE of Reykjavik city (fig. 2). From seismic and gravity results, Pálmason estimates the density excess of the underlying material there to be 0.2 g/cm$^3$ relative to the surrounding basalts.

Recently, Th. Sigurgeirsson has found a steep aeromagnetic anomaly of roughly 6 km extent at Stardalur, reaching some 4000 $\gamma$ in total field at 3000 ft and dwarfing any nearby anomalies due to lavas, including a broad negative anomaly that runs NE through the Videy and Stardalur areas (Th. Sigurgeirsson, personal communication; see also fig. 1 of [1]). Assuming it to be mainly due to material lying between depths of 0.5 km and 2.5 km in the area, the author has estimated the mean remanent plus induced magnetization of this material as about $12 \times 10^{-3}$ gauss.

In a ground magnetic survey of the Stardalur anomaly area, several maxima in the total magnetic field intensity were discovered (fig. 3), by far the highest of these reaching 79 000 $\gamma$, the regional field in SW-Iceland being around 51 000 $\gamma$. This maximum seems to be due to a ridge extending from or through the sub-basaltic material up to a depth of 50–70 m below the surface. The depth estimate was obtained by the method of characteristic curves [24] which also gives the horizontal dimensions of the ridge as approximately 200 m by 600 m and its total magnetization as $(50–60) \times 10^{-3}$ G, if uniform. It must be noted that of all measured Tertiary and Lower Quaternary basic rocks in Iceland, only a few percent have NRM intensities in excess of $20 \times 10^{-3}$ gauss.

The surface rocks in the Videy and Stardalur areas include fresh and hydrothermally altered basalts, breccias and diabase intrusives (all overlain in parts by interglacial dolerite lavas), in general having normal magnetic directions in the Stardalur area and reverse in the Videy area. These directions are stable but scattered and do therefore not appear to have been acquired during any regional heating or during intense volcanic activity. Drillings in progress at Stardalur farm at the time of writing are yielding peculiar basaltic material of NRM $\approx 0.07$ gauss below 40 m depth; detailed measurements on these rocks will be reported elsewhere.

7. Stardalur anomaly

One possibility in anomaly interpretation in Iceland, not hitherto considered, is that material underlying the Tertiary basalts contributes to magnetic anomalies. This layer 3, usually found below 2–4 km depth from sea level, has seismic $P$-wave velocities

(\leq 2\%$, according to Jónsson) and low susceptibilities, and they have not been included in the average of table 1. Neither have samples of diabase, ankaramite, anorthosite or pyrite-altered gabbro, obtained from one or two localities in Iceland each, been included in table 1, as these had somewhat lower susceptibilities than average Tertiary basalts.

Gravity anomalies accompany some of the localized aeromagnetic anomalies found in W-Iceland, and they are usually of the order of 10 mgal positive [13]. The densities of the gabbro samples included in table 1 cluster around 2.9–2.95 g/cm$^3$, whereas a suite of lavas may be expected to have a mean density of 2.7 g/cm$^3$ [13].

It is concluded that relatively magnetite-rich gabbro or similar rock types, occurring widely in plutonic intrusions in Iceland, are responsible for a major part of aeromagnetic and gravity anomalies observed in at least the Tertiary areas of the country.

Fig. 3. Simplified features of a total-field ground magnetic survey at Stardalur farm, S.W. Iceland, showing the central part of the 6 km wide Stardalur magnetic anomaly. Hills of diabase, some 150 m in relief, extend from the top of the map towards North and West.
8. Discussion

The above results define and estimate some of the major factors relevant to the interpretation of aeromagnetic anomalies in Iceland. It must be stressed, however, that a great deal of the above data is extracted from preliminary research work on few rock samples or in limited areas. The geological and paleomagnetic information available from Central and Northern Iceland, for instance, is almost negligible. Further work on the geology and magnetic properties of gabbro intrusions and of dykes is particularly needed, as the relative importance of dykes in structural models of Iceland may have been exaggerated by previous investigators.

It appears plausible that Icelandic gabbro and/or sub-basaltic material resembles the 6-7 km/sec seismic-velocity layer found widely in ocean areas away from mid-ocean ridges. This layer could then, by the results of sections 6 and 7 above, be expected to contribute significantly to observed oceanic magnetic anomalies.

Acknowledgements

The original results presented in this communication were chiefly obtained at the University Science Institute in Reykjavik [25] and the author is very grateful to Professors M.Magnússon and Th. Sigurðsson for providing facilities and for suggesting interesting research projects. Thanks are also due to Th. Bússon, O.Ágústsson and geologists in Iceland for technical assistance and fruitful discussions. Professor N.D.Watkins kindly provided unpublished data on Eastern Iceland dykes, and Professor E.R. Deutsch suggested various improvements in the paper.

References