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Aeromagnetic survey of SW Iceland

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ABSTRACT

The paper describes an aeromagnetic survey carried out in 1968 and 1969. It contains total field intensity profiles flown at 900 m above sea level with a spacing of 4 km and an aeromagnetic contour map of SW Iceland.

INTRODUCTION

During the last decade various instruments using the proton precession principle have been built at the University of Iceland for measuring and recording the earth's magnetic field (Sigurgeirsson, 1970). Some of these instruments have been developed for airborne use in order to carry out an aeromagnetic survey of Iceland. Measurements began in 1965 from a helicopter, using the same proton precession magnetometer and recording equipment as has been employed in Leirvogur Magnetic Observatory since 1962 for measuring and recording on film the geomagnetic field intensity at intervals of 10 minutes (Saemundsson, 1969). When used in the air a reading was automatically taken every 3 seconds. To avoid magnetic field disturbances from the helicopter the sensor was suspended in a 20 m long cable.

This equipment was used for an aeromagnetic survey of the island of Surtsey (Sigurgeirsson, 1968). Photographs taken with a camera pointing straight down were used for positioning.

The regular survey started in 1968 with new measuring equipment giving out a continuous proton precession signal. This equipment was operated from a four-seater, single-engined aeroplane (Cessna 172). All measurements reported in this paper are made with this equipment.

Aeromagnetic surveys of Iceland have been carried out by Canadian and United States expeditions (Sigurgeirsson, 1967). In 1959 a Canadian prospecting plane made a detailed survey of an area of 300 km^2 around Reykjavík (Saemundsson, 1969). In 1964 and 1966 the U.S. Oceanographic Office made a detailed survey of the surroundings of Surtsey and in 1968 surveyed parts of western Iceland.

In 1965 a group from Dominion Observatory in Canada under the direction of Dr. Paul H. Serson carried out an extensive aeromagnetic survey covering all Iceland. (Serson et al., 1968; Hannaford and Haines, 1969). All components of the geomagnetic field were measured at an altitude of about 3000 m on tracks spaced at 20 nautical miles or 37 km.

MEASURING EQUIPMENT

The magnetic field detector is a continuous signal proton precession magnetometer (Sigurgeirsson, 1970) contained in a "bird", consisting of a 2.3 m long aluminium pipe 10 cm in diameter with stabilizing fins on the rear end. The "bird" is suspended from one wing of the aeroplane as seen in Fig. 1.

During measurements the "bird" hangs in a 20 m long nylon string which goes over a pulley fixed to the wing, and from there into the cabin through a small hole in the window. An electric cable leads directly from the "bird" through the same hole into the cabin. Before landing the "bird" is pulled up under the wing by the nylon string, while the cable is used to damp any oscillations. In lowered position the "bird" is quite stable but when it is a few meters under the wing it may start oscillating. For safe handling it is therefore preferable to have it hanging in two cords.

The electric cable contains a shielded signal cable and power leads for the pump motor carrying 1 A, 24 V, D.C. The proton-spin oscillator electronics, including batteries, are all inside the "bird" and the output is an AC signal with a frequency of 2000–2500 Hz directly proportional to the magnetic field intensity.

Fig. 1. The survey plane with the magnetometer hanging from its wing.

Magnetic field disturbance from the aeroplane is considered to be less than 10 γ and this is also true for field disturbances caused by the electric motor and the permanent magnet inside the "bird".

In the plane the signal is fed into one channel on a magnetic tape recorder, as schematically shown in Fig. 2. Another channel records a 1000 Hz reference signal from a crystal controlled oscillator. Every 10 seconds a third channel records time pulses from a clock controlled by the same oscillator. This channel also records pulses of opposite polarity produced manually by pressing the marker key. The positioning is obtained by looking straight down through a sighting telescope installed in the floor of the plane. When known landmarks appear in the telescope the marker key is pressed down and the point marked on a map. At the same time a verbal description is recorded on the voice channel.

The magnetic tape recorder is a Philips ANALOG 7 instrument tape recorder using 0.5 inch wide tape in lengths of 480 m. Recording speed is either 3½ or ⅞ inches per second. Power for the tape recorder, crystal clock and magnetometer pump is supplied by a 24 V, 80 Ah Ni-Fe accumulator. Electric current requirements are 9–10 A.

On the first flight (on March 30, 1968) only a two channel tape recorder was available. Then the proton precession signal together with a 360 Hz reference signal was recorded on one channel. Time pulses, positioning pulses and speech were recorded on the other.

PLANNING OF THE SURVEY

This survey was planned as a first step in an aeromagnetic survey covering all Iceland. Distance between flight lines is 4 km and the

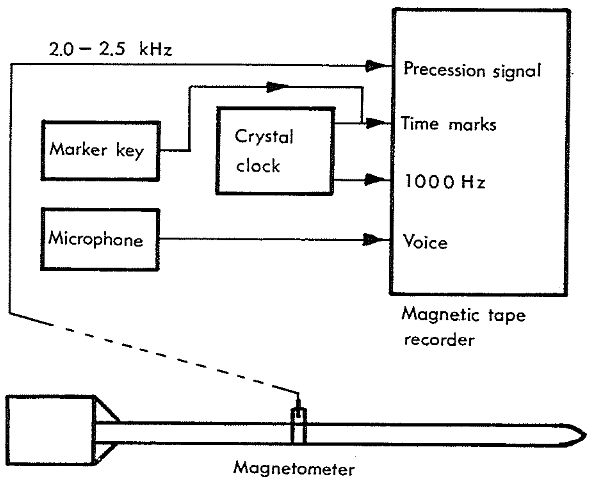

Fig. 2. Recording equipment for the aeromagnetic survey.

flying altitude is normally 900 m above sea level except where high mountains make it necessary to go to a higher level. The airspeed is 160–180 km/h, but in some cases the groundspeed may vary from 100 to 240 km/h due to the wind.

Before each flight the planned flight lines are drawn on a map in scale 1:50 000, and landmarks along the route are studied carefully by the pilot and the observer. In general the distance between fixpoints is about 5 km, deviations from the planned track less than 500 m and the accuracy in positioning better than 300 m. In a few places the distance between fixpoints is as long as 15 km and the actual route may deviate as much as 1 km from the planned track. Under such circumstances the inaccuracy in positioning may be as high as 600 m. The altitude is measured by a barometic altimeter and is normally kept within 100 m off the planned level.

The results reported here contain 1200 km of survey lines representing a total survey flight-time of 8 hours. In a survey covering all Iceland about 200 survey hours are needed when flights to and from the survey area are excluded.

TREATMENT OF RESULTS

After the flight the magnetic tape is played back from the recorder. The proton precession signal is fed into a counter which counts the number of oscillations. The counter is connected to a paper-tape punch controlled by the time pulses on channel no. 2. The counter runs continuously, but every 10 seconds its reading is punched on the paper tape. The recording of time pulses on the magnetic tape, together with the proton precession signal, eliminates any frequency errors caused by a change in speed of the magnetic tape.

The time pulses and positioning pulses from channel 3 are recorded on paper by a pen recorder and at the same time all information from the speech channel is written on the paper record. The read-out process is schematically shown in Fig. 3.

The punched paper tape record is transferred to IBM cards for introduction into an IBM-1620 computer. Here signal frequency is calculated as one tenth of the stepwise increase in counter reading, and converted to magnetic field strength in gamma units by multiplying with $2\pi/0.267513$ (Sigurgeirsson, 1970).

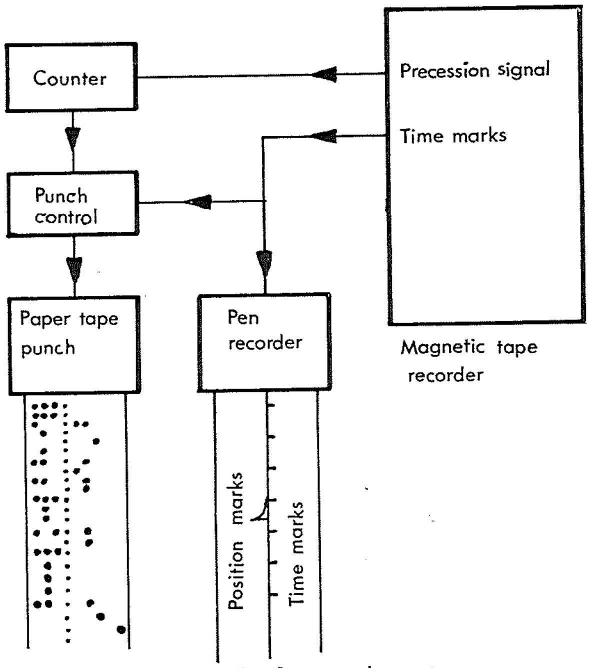

Fig. 3. Read-out equipment.

The geomagnetic field intensity varies with time. In extreme cases fluctuations around the mean value may amount to several thousand gammas. Besides, the mean value undergoes a slow secular variation which during the last few years has amounted to a yearly increase of 40 gammas at Leirvogur Observatory. Although measurements have not been made on magnetically disturbed days, it is considered desirable to correct the measured values for time variations. Therefore, during aeromagnetic surveys the magnetic field intensity at Leirvogur Magnetic Observatory $F_{Leirv.}$ is recorded on punched paper tape every minute by the proton precession magnetometer, which normally is used to record hourly mean values for field intensity (Saemundsson, 1969). This record is also processed by the computer and used to correct the aeromagnetic measurements for time variations in the geomagnetic field by subtracting

$$\triangle F = F_{Leirv.} - 51070\ \gamma.$$

The corrected field values then correspond to a field of 51070 gammas at Leirvogur Observatory. This was the mean field in late 1967. The corrected results are punched on cards, each card containing 12 field values or two minutes measurements together with time and

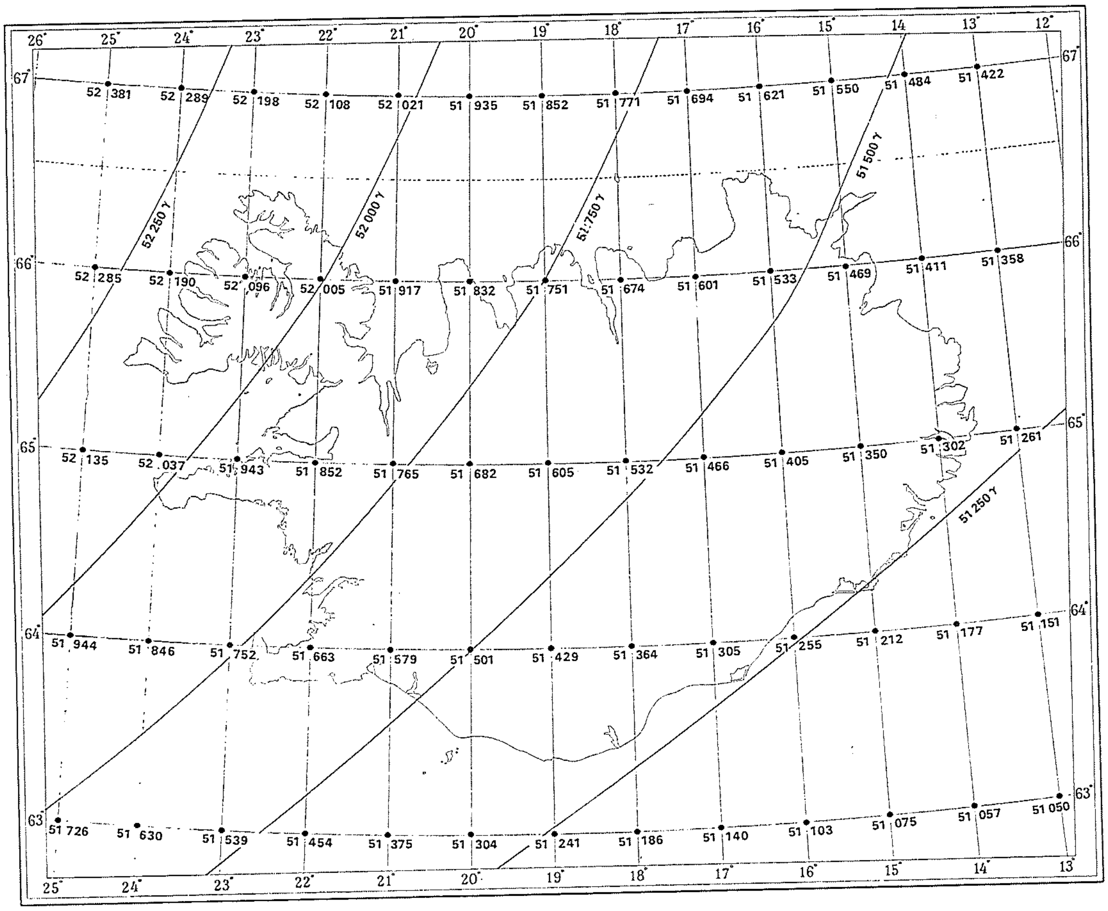

Fig. 4. Regional Field from Serson's survey.

day for the end of the last 10 seconds measuring period on the card. In addition, the computer turns out the results as a printed table and in the form of a diagram.

A quick way to produce a graph of the measured field is to play the recorded frequency signals into a frequency recorder. Here the 1000 Hz reference frequency on channel 2 is put through a frequency doubler and mixed with the proton precession signal. The difference frequency is sent to a frequency meter with a pen recorder. As the magnetic field is directly proportional to the frequency, it is easy to scale the frequency curve to give the field directly. This field is not corrected for time variations and is normally used as a control for the results from the computer. Only in cases where the field varies too fast to be faithfully given by the 10 s averages is the frequency graph used in the final plotting.

AEROMAGNETIC MAPS

The actual route is drawn on a map in scale 1:50000 by joining points marked on the map during the flight. The time is marked on the line in accordance with the time and location pulses on the paper record of channel 3. Next the table from the computer is used to plot the magnetic field at right angles out from the flight line (route) for each 10 s interval. A scale of 200 γ / cm is used for the magnetic profile with a base value of 52000 γ centered on the route line.

The mean regional value of the geomagnetic field is plotted as a broken line along the route. It has not been calculated from the present survey but is taken from the Canadian aeromagnetic survey of 1965. Fig. 4 gives regional values of total field intensity for every intersection of integral degrees of latitude and longitude. This is a part of a table, supplied by Dr. Serson, which is based on the best fitting third degree poly-

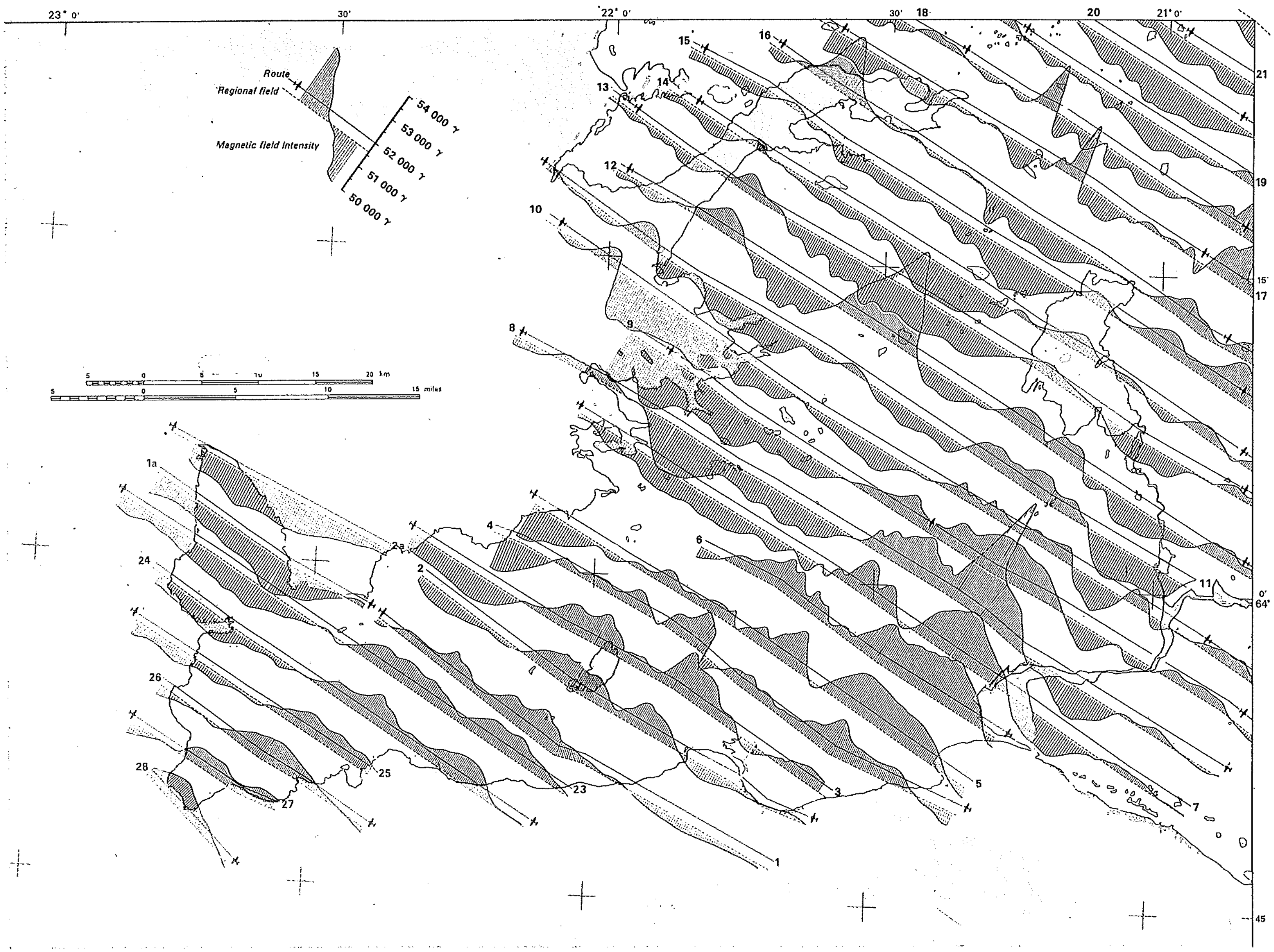

Fig. 5. Aeromagnetic profiles in SW Iceland. Total field intensity 900 m above sea level.

nomial for F in the survey area covering Iceland and the sea SW of Iceland.

In Serson's survey no correction was made for time variation of the geomagnetic field. During the time of the survey on Oct. 17, 22, 24 and 25, 1965 the hourly mean values of magnetic field intensity at Leirvogur Magnetic Observatory varied between 50 980 and 51 100 γ, the average being about 51 010 which is close to the mean value for the geomagnetic field at the time of the measurement. Therefore 60 γ have to be added to Serson's values to bring them up to the same reference level as was used in the present survey (51 070 γ).

On the average F decreases with altitude as r^{-3}, r being the distance from the earth's centre. The regional value of F is therefore about 20 γ lower at 900 m altitude than at sea level. Altogether we therefore have to add 40 γ to Serson's values, which refer to sea level, to get regional field intensities suitable for our survey at 900 m altitude.

The map containing the magnetic profiles is reduced in size photographically, redrawn and printed in scale 1:250 000. Fig. 5 is a reduced reproduction of this map. It contains all the information from the aeromagnetic measurements and should be used for all critical studies to draw conclusions from these measurements.

On the map the direction of flight is shown by aeroplane signatures. The time of measurement in each track is given in Table I. During the time of these measurements the field intensity in Leirvogur deviates less than 100 γ from the mean intensity for the time in question. As the distance from the magnetic observatory does not exceed 50 km, corrections for time variations are not expected to introduce appreciable inaccuracies.

Fig. 6 is a contour map of the magnetic field based on the magnetic profiles. The contours are drawn at intervals of 500 gammas. The measured areas are darkened in three different shades of grey tone, darkest where the field strength is higher than the regional average value and lighter where the field is lower than average. The lightest shade indicates that no measurements are available. To faciliate comparison with the landscape the elevation is shown with white 100 m contour lines.

TABLE I.

Track No	Time of survey year	day	hour
1	1968	30/3	17:10 — 17:23
2	,,	,,	17:25 — 17:48
3	,,	,,	17:50 — 18:03
4	,,	,,	18:08 — 18:33
5	,,	,,	18:35 — 18:49
6	,,	,,	18:52 — 19:07
7	,,	,,	19:16 — 19:38
8	,,	,,	19:39 — 20:13
9	1968	19/6	11:22 — 11:51
10	,,	,,	11:58 — 12:25
11	,,	,,	12:28 — 12:58
12	,,	,,	13:10 — 13:33
13	1968	3/7	11:48 — 12:13
14	,,	,,	12:25 — 12:49
15	,,	,,	12:52 — 13:16
19	,,	,,	19:19 — 19:29
20	,,	,,	19:55 — 20:01
21	,,	,,	20:20 — 20:23
18	1968	9/7	16:33 — 16:46
17	1968	23/8	16:30 — 16:49
16	,,	,,	16:51 — 17:10
2a	1969	12/4	18:30 — 18:38
1a	,,	,,	18:43 — 18:50
23	,,	,,	18:52 — 19:08
24	,,	,,	19:10 — 19:24
25	,,	,,	19:25 — 19:34
26	,,	,,	19:36 — 19:43
27	,,	,,	19:45 — 19:50
28	,,	,,	19:52 — 19:56

In certain places some information in addition to the magnetic profiles in Fig. 5 has been used to draw the magnetic contours. Such places are the SE and NW corners of the map, the Kleifarvatn area, a line between Keflavík and Reykjavík and the anomalous areas at Stardalur and Ferstikla.

The aeromagnetic map shows that the zone of recent volcanism is accompanied by high magnetic field intensities.

Three prominent positive field anomalies are seen on the map: 1. Skálafell, 2. Stardalur and 3. Ferstikla. Recent measurements in Borgarfjörður have revealed a fourth anomaly at Hvanneyri, lying on the same line as the three others.

The aeromagnetic maps, both profiles and countour maps, in scale 1:250 000 are available from the Icelandic Survey Department, Reykjavík.

ACKNOWLEDGEMENTS

The aeromagnetic survey has been prepared and carried out by many individuals. A large

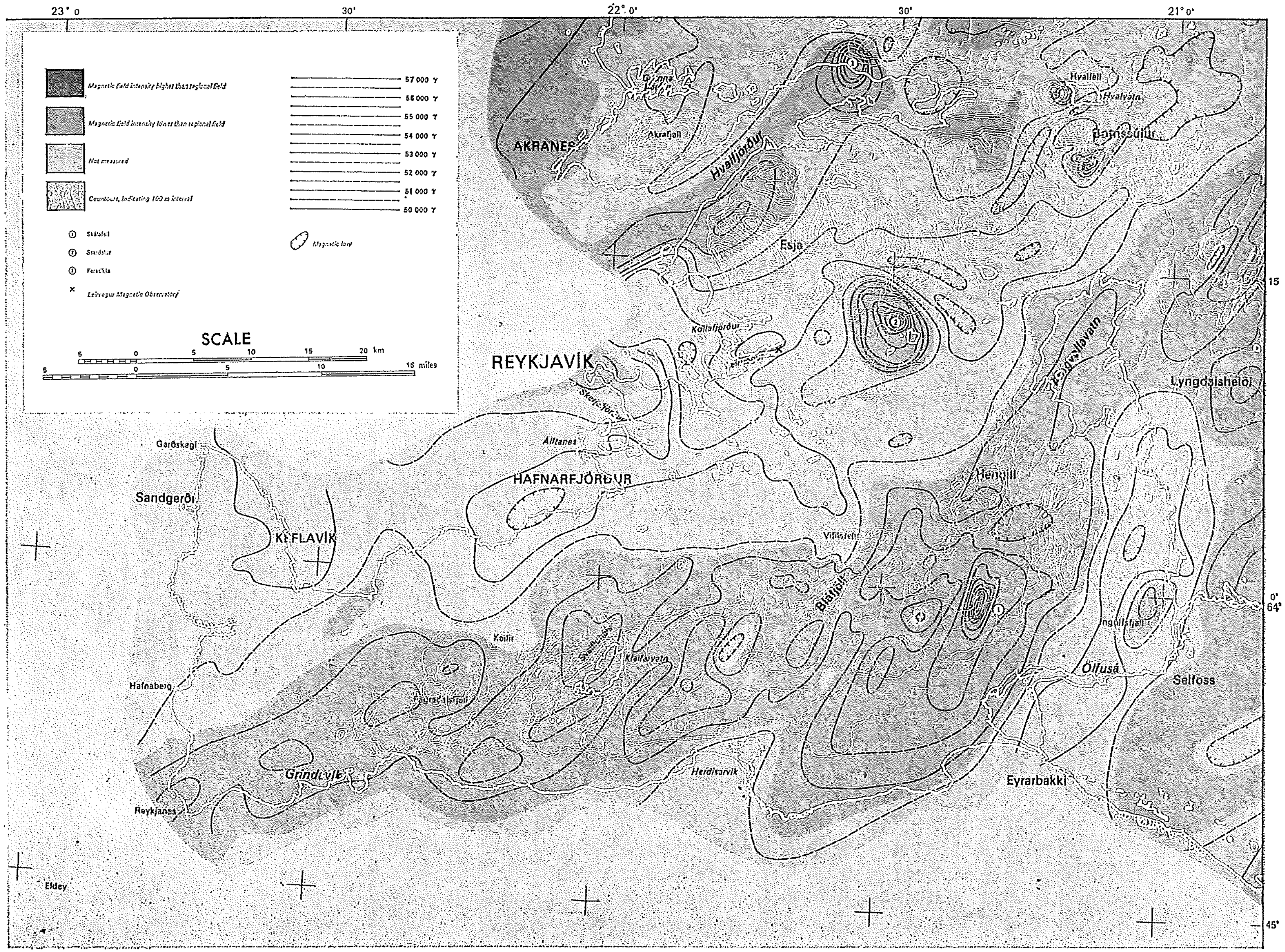

Fig. 6. Aeromagnetic map of SW Iceland. Total field intensity 900 m above sea level.

part of the staff of the Science Institue has made some contribution to this project.

In 1968 Kristján Benediktsson and Stefán Briem participated in the measurements. Magnetic profiles and maps were drawn by Stefán Briem. In the 1969 flight Leó Kristjánsson was responsible for the positioning, but the map was drawn by Jón Pétursson. The final drawing of maps for publication was done by Jón Rafn Jóhannsson of the Icelandic Survey Department.

Thanks are due to the pilot Þórólfur Magnússon for skilful operation of his plane during test-flights with the "bird" and to Dr. Þorsteinn Sæmundsson for making available necessary data from Leirvogur Magnetic Observatory and permitting the use of equipment at the observatory. I should also like to thank Dr. Sæmundsson for valuable suggestions regarding presentation of the results and for reading the manuscript.

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