SVERIGES GEOLOGISKA UNDERSÖKNING
GEOLOGICAL SURVEY OF SWEDEN

SUMMARY REPORT OF THE EARTH-MAGNETIC INVESTIGATIONS CARRIED OUT IN THE MAINLAND OF SWEDEN

BY

KURT MOLIN

Summary report of the earth-magnetic investigations carried out in the mainland of Sweden.

By

KURT MOLIN.

Introduction.

As the greater part of Sweden had not yet been magnetically mapped, the Swedish National Committee for Geodesy and Geophysics, in September 1925, presented to the Swedish Government a proposal for a detailed magnetic survey of the mainland of Sweden. After the authorities had expressed their opinion in the matter, means for such magnetic investigations were granted in 1928. The Government entrusted the Geological Survey of Sweden with this magnetic survey and directed the investigations to be carried out, essentially in agreement with the program worked out by the Swedish National Committee for Geodesy and Geophysics.

The field work was begun in June 1928.

The object of the present paper is to give, partly a general view of the position of the earth-magnetic survey of the mainland of Sweden at the beginning of 1928, partly an account of the magnetic investigations which are now being performed under the direction of the Geological Survey of Sweden.

Distribution of the stations.

The net-work of stations which, according to the proposal of the Swedish National Committee was to be surveyed, had been estimated as having an average distance of 18 km. between the observation points, corresponding to 1357 stations for the whole country. The new survey will, therefore, be connected to Molin's[1] measurements of 1915, touching an area which, on the main, is bounded to the north by the line of latitude 62°, or more precisely, by a broken line drawn through Hudiksvall—Sveg—Limedsforsen—Charlottenberg.

The plan also comprises the remeasurement of most of the older observation points, thus obtaining material for augmenting our knowledge of the secular change in the earth-magnetic elements in Sweden. A list of the older measurements, here referred to, has been presented by Carlheim-Gyllensköld[2] who has collected and up to September 1st 1892, reduced the measurements of the horizontal intensity, inclination and declination which, up to the date mentioned, have been carried out and published in Sweden and adjacent parts of Norway and Finland. Carlheim-Gyllensköld's maps extend northwards to about 60° Lat. N.

The number of earlier observations are distributed rather unevenly, partly as regards the elements H, D and I, partly as regards the situation of the stations in the country, as may be seen from the summary in Table 1.

Table 1.

Distribution of earth-magnetic observations made in Sweden before Sept. 1. 1892.

	Surface in km²	H	D	I	Number of obs.
The whole country	440,000	458	359	272	1,089
The southern part to 60° Lat. N.	148,000	336	278	233	847
The northern part above 60° Lat. N.	292,000	122	81	39	242

[1] K. Molin, Bestimmung der erdmagnetischen Elemente einiger Orte im mittleren Schweden, Sommer 1915. Kungl. svenska Vetenskapsakademiens Handlingar, Bd 58. Sthlm 1919.

[2] V. Carlheim-Gyllensköld, Mémoire sur le magnétisme terrestre dans la Suède méridionale. Kungl. svenska Vetenskapsakademiens Handlingar, Bd 27. Sthlm 1895.

On an average one thus obtains for the three elements:

For the whole country	1 observation in		1,210	km^2
For the southern part	1	»	» 524	»
For the northern part	1	»	» 3,610	»

The new net-work, now planned, will give an average of 1 observation point in 324 km^2.

Since 1892 new measurements have been made by Carlheim-Gyllensköld, Granqvist, Grenander, Ljungdahl, Molin, Odelsiö and Rolf. It therefore seems natural to make a survey of the distribution of the observation points at the beginning of 1928. In order to answer this question, it is necessary, when observing the recently attained results, to distinguish between observation points belonging, on one hand, to stretches of coast or to our large navigable lakes and performed on solid ground, so called land stations and, on the other hand, to marine stations. Since 1914 the Hydrographic Service has had measured, by Grenander, Ljungdahl and Odelsiö, the declination, partly at land stations situated along the coast, or on the larger navigable lakes, and partly at marine stations. Refer to the earth-magnetic publications of the Hydrographic Service.

The Hydrographic Service has later on extended its earth-magnetic observations so as to include also H and I. The results of these observations have been published, for the time previous to 1928. In presenting a general view of the position of the earth-magnetic surveys of the mainland of Sweden in the beginning of 1928, it has been thought appropriate to include only those stations of the Hydrographic Service which are situated on solid ground, »land stations». Only these land stations are, therefore, marked out in the maps accompanying this paper.

In connection with the expeditions sent out by the Royal Academy of Science to observe the solar eclipse in 1914, determinations of the earth-magnetic elements were made and registered, during one month, by Granqvist in Åvike ($\varphi = 62° 30',4$ and $\lambda = 17° 45',5$ E fr. Gr.) and by Carlheim-Gyllensköld and Koch in Haparanda.

Through the measurements of Molin, 1915, carried out in an area situated between 59°,5 and 62° Lat. N., 120 new observations have been added to the previous ones which, combined with 42 older measurements, situated in the same area, have all been reduced to the epoch 1915, 67. The distribution of elements, obtained in this way, is seen from Table 2.

Table 2.

Distribution of Molin's observations during 1915.

	Surface in km^2	H	D	I	Number of obs.
Earlier observations in the area	48,000	20	19	3	42
Recently added » » »	—	44	40	36	120
Total » » »	—	64	59	39	162

Thus, as far as this district is concerned, with the stations somewhat distributed, the density of the points in the net-work is as follows:

1 Determination of	D	in	814	km^2.
1 »	» H	»	750	»
1 »	» I	»	1,230	»

Out of Molin's 44 observation points, 8 coincide, on the whole, with earlier observation points where Thalén determined the horizontal intensity.

Finally, it must be mentioned that Rolf in Abisko determined the earth-magnetic elements in connection with the work at the magnetic observatory there, erected, in 1921, by the Meteorological and Hydrographical Service of Sweden.

Respecting the recently taken measurements, the values of the density of the stations, as regards the elements D, H and I, can easily be calculated, but, if the distribution of the stations is looked at according to Maps 1, 2 and 3, it is evident, especially in the case of the declination, that the values of the density of the stations, thus obtained, must be very misleading, as the majority of the recently included points refer to strictly limited areas and are often only concerned with the investigation of anomalies.

Stations, where determinations of declination were carried out previous to the beginning of 1928.

The earliest information we possess in this country concerning declination, goes back to two charts, one of the Baltic Sea and the Belts together and one of the Skagerack, printed in 1694 and 1695 respectively. From 1695 there is a determination of declination, carried out in Torneå by Bilberg and Spole. From the 18th century we have numerous determinations of declination. On Map 1 the rings mark where declination has been determined during the 18th century, and the dots show where new determinations have been made during the 19th and 20th centuries.

The summary below is founded mainly on the above-mentioned work of Carlheim-Gyllensköld. It deals with 59 determinations of declination previous to 1800. It must be observed that, in this number, are also included 4 stations from Norway, 5 from Finland and 2 from Esthonia. As these points offer special interest, the original values of the co-ordinates are stated in Table 3.

Table 3.

Co-ordinates for adjacent, non-Swedish stations where determinations of declination were carried out during the 18th century.

		φ	λ E. fr. Gr.
Vardhus	Norway	70° 24′	31° 3′.5
Vadsön	»	70 4	29 43.5
Utsjocki	Finland	69 45	26 56.5
Sodankylä	»	67 24	26 38.5
Torneå	»	65 53	24 10.5
Kusamo	»	65 51	29 4.5
Qvedlie	Norway	64 32	13 41.5
Skaal	»	64 9	13 52.5
Utön	Finland	59 46	21 15.5
Dagerort	Esthonia	58 56	22 4.5
Svalferort	»	57 54	22 2.5

Table 4 gives the names of the observers and the numbers of stations measured by each. At 4 of the 59 stations, the determinations of declination have been made by 2 or more observers. For one station the name of the observer is not given in the above-mentioned work of Carlheim-Gyllensköld.

Table 4.

The number of determinations of declination carried out during the 18th century, assigned to the respective observers.

	Number of stations	Observation-year
Bützow	1	—
Celsius	2	1737, 1740
Elvius	2	1718, 1748
Hedin	1	—
Hellant	7	1748, 1767—1776
Hiorter	6	1740
Marelius	24	1753—1765
af Schultén	20	1798 (1800, 1803—1804)

During the 19th century, the number of stations where determination of declination was carried out reached 324. Out of these, 10 stations in this country coincide with older ones, namely those included in Table 5.

Table 5.

Places where determinations of declination where carried out during the 18th as well as the 19th century.

	φ	λ E. fr. Gr.
Haparanda	65° 50′	24° 9′.2
Falun	60 36	15 38.5
Upsala	59 51.2	17 37.9
Stockholm	59 20.5	18 3.5
Strömstad	58 56.3	11 10.0
Landsort	58 44.4	17 52.1
Hållö (Sälö)	58 20.4	11 13.4
Göteborg	57 42.1	11 58.0
Vinga	57 38.1	11 36.4
Karlskrona	56 9.8	15 36.1

During the 19th century, determinations of declination have been made, at the number of stations below, by the following observers (Table 6).

Table 6.

The number of declination-stations, measured during the 19th century, distributed among the respective observers.

	Number of stations	Observation-year
Arwidsson	67	1860—1861
Carlheim-Gyllensköld	186	1886, 1889, 1892
Grönn	3	1842
Göransson	1	1854
Hansteen	5	1828—1830
Hovgaard	1	1878
af Klint	54	—
Lilliehöök	1	1845
Petterssou	15	—
Rosén	7	1878
Sefström	17	1838—1844
Wegelin	6	1843—1844

The number of determinations of declination, performed at 320 localities by the observers mentioned above, reaches a total of 363, to which are to be added observations from Haparanda, Stockholm, Oslo and Copenhagen. Besides these 4 places, declination has been determined at altogether 31 places, at separate times, by two or more observes: at 20 stations by 2 observers, at 10 stations by 3 observers and at 1 station by 4 observers.

At Haparanda, 10 older determinations of declination were executed between 1695,5 and 1878,65, and at Stockholm, 61 such determinations from 1718,5 to 1892,67, from which Carlheim-Gyllensköld, in his abovementioned work, has compute formulas for the changes of declination with the time in these places. These series of observation, so very important to our knowledge of the secular change of declination, were made at Haparanda by: Bilberg and Spole 1695, Celsius 1736, Hellant 1748, 1767, 1777, Hansteen 1825, Gaimard 1840, Lilliehöök 1845, Arwidsson 1854, 1860, and at Stockholm by: Elvius 1718, Wilcke 1763—1777, Cronstrand 1786—1815, Hansteen 1828—1830, Rudberg and Selander 1833, 1835, Sefström 1840, Selander 1841—1844, Lilliehöök 1845, A. J. Ångström 1850, 1853, Lemström 1858, Arwidsson 1860, Carlheim-Gyllensköld 1892.

To the declination-series at Haparanda must be added the measurements of Carlheim-Gyllensköld and Koch in 1914 and those of Ljungdahl in 1921, and for Stockholm, the measurements of Ljungdahl from 1913 to 1928.

Further, there are Granqvist's determination carried out at Åvike and Rolf's at Abisko. From the lastmentioned place there is also a determination of declination by Ljungdahl in 1921.

During 1915, through the measurements of Molin, 40 new determinations of declination were made in the area between 59,°5 and 62° Lat. N.

Regarding the determinations of declination, made by the Hydrographic Service, the following summarization has been made in Table 7. If, at one and the same place, the declination has been determined at two or more adjacent points, these determinations have not been looked upon as separate. In the endeavour to bring forward only the number of new stations, the frequently appearing remeasurements — valuable as they may be in themselves to the study of the secular change — have not been taken further into account.

Table 7.

Survey of the determinations of declination made, from 1913 and onwards, by the Hydrograhic Service with regard to the new land-stations, according to publications available in 1928.

		Number of stations	
1913	Ljungdahl	3	Järnhällen. Publ. No. 4.[1]
1914	Odelsiö	4	The coast of Blekinge. Publ. No. 3.
1914	Ljungdahl	59	Kristinehamn—Karlstad and Kållandsö—Värmlandsnäset. Publ. No. 2.
1914	Ljungdahl	8	Boden—Finnish boundary, Sollefteå, Långsele and Östersund. Publ. No. 4.
1915	Odelsiö	25	The coast of Blekinge. Publ. No. 2.
1916	Ljungdahl	30	Among the anomalies at Lake Wener. Publ. No. 2.
1917	Ljungdahl	31	South and East Scania and West Blekinge. Publ. No. 3.
1917	Ljungdahl	2	Singö, as completion of the measurements of 1913. Publ. No. 4.
1917	Ljungdahl	8	Among the anomalies of Lake Wener. Publ. No. 2.
1919	Ljungdahl	17	Arholma—Sandhamn. Kungl. Nautisk-Meteorologiska byrån. Jordmagnetism. N:r 1.
1919	Ljungdahl	60	Gothland. Publ. No. 1.
1920	Ljungdahl	114	Lake Mälar and the coast-line Arholma—Ulvöarna. Publ. No. 4.
1921	Ljungdahl	79	The coast-line Örnsköldsvik—Haparanda. Publ. No. 4.
1924	Ljungdahl	5	South Kvarken. Publ. No. 5.
1925	Odelsiö	10	South Kvarken. Publ. No. 5.
1926	Odelsiö	11	South Kvarken. Publ. No. 6.

The lack of extension in the maps, used here, has not permitted us to include 7 places shown in Carlheim-Gyllensköld's list, with determinations of declination from the 18th century. The map contains 872 stations, belonging to Sweden and neighbouring countries. In this number are not included points on Åland and its archipelago which were measured from the Finnish side by Keränen, Hintikka and Vaisälä[2].

Stations where determinations of inclination have been carried out, up to the beginning of 1928.

The earliest determinations of inclination, carried out in this country, are made at Haparanda, Upsala and Stockholm.

During 1737,5—1921,5, 9 determinations were carried out at Haparanda. To give an idea of the intervals of time between the determinations, the names of the 10 observers are given in Table 8, together with the observation-year.

Of Ljungdahl's determination at Haparanda, in 1921,5, only the result reduced to the epoch of 1922,5 is published.

From Upsala, the series comprises the period of 1743,7—1916, and contains determinations made by the observers mentioned in Table 8.

[1] Kungl. Sjökarteverket. Jordmagnetiska publikationer. Sthlm.
[2] See Kungl. Sjökarteverket. Jordmagnetiska publikationer. N:r 5 and N:r 6. Stockholm and Helsingfors 1926 and 1927.

†—302296.

Presumably, Granqvist has also carried out determinations of inclination at Upsala, though I have not been able to find any statements by him to this effect.

The series at Stockholm comprises 22 determinations, made between 1767,5—1892,67, by the 12 observers given in Table 8.

Table 8.

Determinations of inclination carried out at:

Haparanda		Upsala		Stockholm	
Celsius	1737	Celsius	1743	Wilcke	1767
Hansteen	1825	A. J. Ångström	1852—1855 1870—1872	Hansteen	1820, 1825 1842, 1859
Lottin	1839	Hansteen	1859	Rudberg	1832, 1833
Lilliehöök	1845	Arwidsson	1860	Lottin	1839
Kämtz	1847	Lundqvist	1869	Lilliehöök	1845
Arwidsson	1860	Forsman	1871	A. J. Ångström	1849 1853, 1855
Forsman	1871	Solander	1882, 1884 1888	Arwidsson	1860
Carlheim-Gyllensköld and Koch	1914	Carlheim-Gyllensköld	1886, 1889, 1892	Lemström and Lindhagen	1869
Ljungdahl	1921	Molin	1915, 1916	Lundqvist	1869
				Siljeström	1888
				Solander	1888
				Carlheim-Gyllensköld	1892

Besides series from Haparanda, Upsala and Stockholm — which are of great importance to our knowledge of the secular change of inclination in Sweden — the following observers have carried out determinations of inclination (Table 9).

Table 9.

Determinations of inclination, with the exception of those from Haparanda, Upsala and Stockholm, performed by the following observers.

	Number of obs.	Observation-year
Arwidsson	38	1860—1861
Carlheim-Gyllensköld	188	1886, 1889, 1892
Ekelund	1	1854
Forsman	26	1871
Göransson	1	1864
Granqvist	1	1914
Hansteen	24	1819—1820, 1842, 1859
Hovgaard	1	1878
af Klint	1	—
Keränen	6	1924—1926
Lilliehöök	1	1846
Ljungdahl	91	1921—1924
Lundqvist	36	1869
Molin	36	1915
Odelsiö	32	1924—1926
Rolf	1	1926
Wijkander	1	1876

Of these observations which amount to 485, some are repeated at different times by different observers: at 37 stations by 2 observers, at 2 stations by 5 observers and at 1 station by 6 observers. Also in this way, further material has been collected about the secular change of inclination in this country.

With regard to literature, I must refer the reader to the above work of Carlheim-Gyllensköld. The results of Granqvist, Koch and Rolf have not yet been published. Molin's determinations of inclination are to be found in the above work and those of Ljungdahl, Keränen and Odelsiö in the publications of the Hydrographic Service, Kungl. Sjökarteverket. Jordmagnetiska publikationer, Nos. 3, 4, 5 and 6.

The places at which determinations of inclination have been carried out amount to 278 during the 19th century and 151 during the 20th; 113 of them being the work of the Hydrographic Service. Out of these places 3 are situated along the coastline of Norrland.

Map 2 shows 429 stations belonging to Sweden and neighbouring countries, besides which are given 26 Finnish stations from Åland and its archipelago.

Distribution of stations where determinations of the horizontal intensity have been made earlier than 1928.

As regards a knowledge of the secular change of the horizontal intensity, Sweden possesses series of measurements from 4 stations, viz. Haparanda, Upsala, Stockholm and Gothenburg, as is evident from Table 10.

Table 10.

Chronological list of those observers who determined the horizontal intensity of the four following stations until the beginning of 1928.

Haparanda 1825—1921,5	Upsala 1869—1927	Stockholm 1825—1928	Gothenburg 1827—1882
Hansteen	A. J. Ångström	Hansteen	Hansteen
Boeck and Meyer	Lundqvist	Rudberg	Segelcke
Lilliehöök	Thalén	Lilliehöök	Hagerup
Kämtz	Carlheim-Gyllensköld	Arwidsson	Johansson
Arwidsson	Solander	Lemström	Arwidsson
Carlheim-Gyllensköld and Koch	Koch	Lundqvist	Thalén
Ljungdahl	Granqvist	Thalén	Solander
	Molin	Forsman	
		Carlheim-Gyllensköld	
		Ljungdahl	

Besides at the above-mentioned places, determinations of the horizontal intensity have been performed to the extent seen from Table 11.

Table 11.

Determinations of horizontal intensity, with the exception of those from Haparanda, Upsala, Stockholm and Gothenburg, performed by the following observers up to the beginning of 1928.

	Number of obs.	Observation-year
Arwidsson	39	1860—1861
Boeck and Meyer	12	1838
Carlheim-Gyllensköld	192	1886, 1889, 1892
Faernley	1	1886
Forsman	29	1871
Granqvist	1	1914
Hansteen	84	1825, 1828—1830
Keilhau	2	—
Keränen	5	1925—1926
Ljungdahl	136	1921—1924
Lundqvist	36	1869
Molin	44	1915
Odelsiö	32	1924—1926
Rolf	1	1926—1927
Solander	6	1882
Thalén	135	1869—1882

In several cases there may, from these 755 observations, be drawn conclusions concerning the secular change of the horizontal intensity, the observations having been repeated at different times: at 68 stations twice by 2 observers, at 12 stations 3 times by 3 observers and at 3 stations 4 times by 4 observers.

The number of observation places were, until the beginning of 1928, 660. On map 3 these stations are marked. Moreover, on the same map have been inserted 26 Finnish stations belonging to Åland and its archipelago, where the horizontal intensity was determined by the Finnish observers Keränen, Hintikka and Vaisälä, during mutual work for the connecting of the Finnish and Swedish net-work of marine stations at South Kvarken. This work was established, in the years 1924—1926, by the Central Meteorological Institute of Finland, the Nautical-Meteorological Service and the Hydrographic Service of Sweden.

As to the observations of horizontal intensity, the literature referred to regarding the determination of inclination is applicable here.

The base-station of the new net-work of land-stations.

For several reasons, the magnet-house of the Upsala Physical Institution ($\varphi = 59° 51',2$; $\lambda = 17° 37',7$ E. fr. Gr.) was chosen as base-station of the new net-work of land-stations which, at the beginning of the summer of 1928, were to be surveyed under the direction and inspection of the Geological Survey of Sweden. In this way, a tradition, connected with Swedish earth-magnetic investigation, was preserved. The determinations of the horisontal intensity, made by A. J. Ångström, Lundqvist and Thalén in Upsala, are there followed up by Solander's careful, absolute determinations, 1889—1890, a detailed account of which is given in his work »Konstantenbestimmung mit einem Lamontschen Theodolit»[1]. The angles of deviation were determined with the great Lamont theodolite, belonging to the Physical Institution at Upsala[2]. The apparatus which Solander used for his determinations of oscillation is made of wood and has the following dimensions: oscillation-box 28 cm. long, 27 cm. wide, with a glass-tube of 120 cm's height, including the fittings. The total height is 145 cm. At the top of the glass tube, there are a tortion-head and an arrangement for adjusting the length of the suspension thread. Two gables, placed opposite each other and provided with plane pannels of glass, can be screwed off. The observations were performed with telescope and scale, the latter at a distance of about 170 cm.

In spite of all exactitude, Solander found that, with the instruments mentioned, the horizontal intensity could not be absolutely determined with an exactitude of only a few γ. As, on the contrary, by using an apparatus with known fundamental constants, relative values, with a corresponding degree of accuracy, could easily be obtained, Solander made a journey to the magnetic observatories of Pawlowsk, Vienna, Potsdam, Göttingen, Strassburg, Parc St. Mour, Utrecht, Wilhelmshafen, Hamburg and Copenhagen, in order to connect, by one and the same instrument, the Upsala value of horizontal intensity with the international ones. Solander gives an account of the results of his journey in his article »Vergleich der Bestimmungen der Horizontalintensität an verschiedenen magnetischen Observatorien».[3] By means of the same great Lamont theodolite, the apparatus for oscillation described above, and Solander's constants for magnet No. 1, the horizontal intensity has, since then, been determined in Upsala by Granqvist, Koch and Molin. After 1909, these determinations have taken place on the central pillar of the present magnethouse of the Physical Institution. In this magnet-house are also placed variometers for direct reading of declination, as well as horizontal and vertical intensities. The variometers for declination and horizontal intensity, placed in the east and north corners respectively of the magnet-house, are of Lamont's construction. These instruments are exhaustively described by Lamont in the above-mentioned work. On the south pillar of the magnet-house is placed the vertical variometer. It is a modified Lloyd's[4] balance constructed by Solander. The variometers have always functioned satisfactorily.

Previously was used as mere a lightning-rod on the Epidemic Hospital but, owing to the hospital's being rebuilt, this mere was lost. In the early summer of 1928, a window was made in the north-east gable of the magnet-house to gain a free view towards the Cathedral, which offers several good mires. At the same time, a collimation-mere was fitted to the magnethouse in order to facilitate nightly observations.

[1] E. Solander. Nova acta reg. sc. Ups. Ser. III, 1891.
[2] I. Lamont. Ann. d. Münchener Sternwarte, Supplement Vol. IV, 1863.
[3] E. Solander. Nova acta reg. soc. sc. Ups. Ser. III, 1893.
[4] E. Solander. Nova acta reg. soc. sc. Ups. Ser. III, 1890.

In this connection should be emphasized the great practical importance to the present survey of an access to the Upsala magnet-house. Thus, it is of the greatest value to be able, day after day and at any time, to compare field instruments and to train field observers for their work.

In order to form an idea, based on objective foundations, of the magnitude of the local, accidental magnetic disturbances in the Upsala magnet-house, the necessary space was detached, by means of the wooden wall in the south-western part of the magnethouse, and a complete set of registering variometers of Toepfer's construction, belonging to the Academy of Science, were fitted up there by Molin in June 1928. By means of comparison between the registrations of adjacent magnetic observatories should be found out the extent of risk from local, accidental disturbances in the Upsala magnet-house to the purpose for which the same is now to be used.

During 1928, Molin has made comparisons in the magnetic observatory at Lovö mentioned below, in order to find out the connection between the measurements of the Geological Survey and those of the Hydrographic Service.

The magnetic observatory at Näs, Jämtland.

For the correction of field-measurements for variations in the earth-magnetic field, Sweden had, in the beginning of 1928, two magnetic observatories for registering. These were the one established in Abisko ($\varphi = 68° 21',1$; $\lambda = 18° 49',3$ E. fr. Gr.), by the Meteorological-Hydrographic Service under direction of Dr. A. Wallen and inspection and leadership of Dr. Rolf, and the one on Lovön, outside Stockholm ($\varphi = 59° 20',7$; $\lambda = 17° 49',6$ E. fr. Gr.), by the Hydrographic Service under inspection of Commodore G. Reinius and leadership of Dr. Ljungdahl and Mr. S. Åslund, B. A. A detailed account of the activity of this latter, during its first year, 1928, has now been presented in a publication[1] by the Hydrographic Service, printed 1930 and treating the declination and horizontal intensity.

Further, we might reckon with registrations from neighbouring observatories, viz. that of Finland at Sodankylä, of Norway at Tromsö and of Denmark at Rude Skov.

As the Swedish observatories at Abisko and Lovö (Stockholm) are situated at a distance of 1000 km. from each other, it was found desirable, in consideration of the earthmagnetic survey of Norrland, by the Geological Survey to establish a magnetic observatory of registration in the Silurian tract of Jämtland which was to be kept going during the summer months as long as required by the field-measurements.

The new observatory was erected in the summer of 1928, at Näs, ($\varphi = 62° 58',4$; $\lambda = 14° 34',5$ E. fr. Gr.), ground being kindly placed at its disposal by Mr. and Mrs. Behm.

The magnet-house which is the property of the Academy of Science, is a wooden pavilion with double walls and a wide, protecting roof, specially constructed for the circulation of air. The house is 5 m. long and 2,7 m. wide, and situated in the direction north to south, having the entrance and a photographic dark-room towards the south. It lies on lime-stone rock, and the registering apparatus, as well as the variometers, have been standing, from June 1929, on cement-pillars, cast from the rocky foundation through holes cut in the floor.

These variometers are similar to those of Upsala, fitted up in 1928. They were supplied by Toepfer & Sohn, Potsdam, and belong to the Academy of Science. The registering apparatus is placed towards the south and, counted from the same towards the north, stand in the following order the variometers for H., D. and V. The variometers for H. and V. are equipped with an arrangement for the registering of the temperature. The needles of the D. and H. are suspended from quartz filaments. That of the H. instrument is deviated, by means of a torsion-head, to the position of a right angle from the magnetic meridian. The moveable system of Lloyd's balance consists of a body with two magnets which, after adjustment, lies horizontally, resting with agate knife-edges against agate cups. The system is freely moveable round a horizontal axis and, by means of 4 vertically placed field-magnets — 2 to the west and 2 to the east of the instrument — the temperature coefficient and one part of the vertical component is compensated. The interior of the instruments is kept dry by means of a glasstube containing P_2O_5. The instruments are placed, according to the registering-box, as shown on a plan from Toepfer & Sohn.

[1] Kungl. Sjökarteverket, Ergebnisse der Beobachtungen des Magnetischen Observatoriums zu Lovö (Stockholm) im Jahre 1928, Stockholm 1930.

The determinations of sensibility are carried out with a little deviation-magnet belonging to the instrument. These deviations were read off ocularly on the metal scale of the registering-box, and also registered photographically.

The temperature coefficients of the horizontal and vertical variometers have been determined at Upsala, 1915—1916, by Molin, in connection with the registrations carried out in Sweden in 1914.

In order to determine the base-values of the variometers, the field instruments were placed, in the summer of 1928, above a point marked by a bore-hole in the rock, about 10 m. south of the magnet-house. During June 1929, a cement pillar of suitable height was erected over the bore-hole in order to facilitate, by different determinations of base-values, the centrating of the field-instruments. This pillar was also used at that comparison of field-instruments which was, later on, carried out at Näs.

During 1928, 1929 och 1930, base-values were repeatedly determined every year by Molin. Determinations of sensibility were made three times every summer by Molin and Mrs. Karin Molin.

The Näs observatory was managed by Mrs. Molin during the summers of 1928—1930. In order to control the registering clock-work, Mrs. Molin takes up the time-signals of 12h 58m—13h 0m which are sent out by the broad-casting station at Östersund.

In consideration of the importance which the magnetic observatory at Näs has to our measurements, the magnetic character of the neighbourhood has been examined. For this purpose, magnetic elements were determined, not only at the cement pillar (the »bore-hole») near the magnetic observatory, but also at 4 points situated on the high plateau which, in a south-eastern direction, runs from the magnetic observatory down towards Lake Näkten. Of these points, one from 1928 — marked S. G. U. 43 — can no longer be used for remeasurements, as a newly set-up telephone-wire has been drawn over the point. From 1928 there remains another point and, during June 1929, two new ones, with studs bearing S. G. U. 33 and S. G. U. 34, were marked as compensation for the lost point 43. Not far from Näs there is one of Hansteen's old points, Ålsta ($\varphi = 62°$ $58', 9$; $\lambda = 14° 35', 2$ E. fr. Gr.) at which Molin, in 1928, carried out determinations which might be considered an estimation of the magnetic character of the tract chosen for the observatory. From the above-mentioned observations may be seen that the magnetic character of the area around the observatory is assumingly homogeneous.

Field observers.

For the organization of the present magnetic survey of the mainland of Sweden, it is important to secure interested and energetic surveyors.

During 1928, which year was, to a large extent, occupied by tasks of a preparatory nature, only Dr. Molin and Mr. T. Johansson took a part in the field-work. At Molin's expedition, Mr. I. Sahlberg acted as assistant. During 1929, there were three expeditions, and the work was carried out by Dr. Molin, with Mr. Mueller as assistant, by Mr. K. Rothstein, B. A. and by Mr. Werner. Also during 1930, three expeditions have been at work. Besides Rothstein and Werner, Captain A. Edwards is taking part in the survey, with Mr. A. Söderlind as assistant.

Field works and instruments.

When planning the instrumental equipment of the field expeditions for the first part of the work, viz. the magnetic survey of Norrland, the means of communication in the district have had a decisive influence. In the mountainous districts of Härjedalen, Jämtland and Lapland, only an expedition with light instrumental equipment has a possibility of fulfilling its work, in a short time and without too great extra expense. The so-called mountain-expedition has, therefore, been equipped with the light magnetic theodolite, Chasselon No. 83, which allows a determination of the azimuth, a complete determination of declination with torsion-correction and a determination of the horizontal intensity, by means of deviations and oscillations. A similar instrument has been used by Hintikka and Keränen at earth-magnetic measurements in Finland. The instrument in its case weighs 4 kg. To this comes a dip circle which, as to principle, is of excellent construction, but, the inclination-needles having a length of only 6,5 cm., the instrument acts less accurately than desirable. The weight of this instrument with case is 2 kg. The instruments belong to the Academy of Science and are described by Th. Moareaux in his work »Détermination des éléments magnétiques en France».[1] For the field-theodolite and the dip circle a strong leather bag has been made which also holds the note-books and maps. Besides, there is a tripod which can be used for both instruments. Hitherto, the position of the chronometer has been determined by broad-casting signals, obtained with the apparatus of the inhabitants. Whether this equipment must be increased by a wire-less time-receiver, when more thinly populated areas are visited, still has to be seen.

In order to protect the instruments from the sun, a simple sun-protection was used, in 1928. During 1929, such a protection which could also be used against the rain, was carried along and, for the surveys of 1930, the same has been considerably improved.

The changeable weather in the mountainous districts makes it necessary to carry a substantial personal equipment as well as some reserve provisions. Thus, the total weight of the packing is about 35 kg. Therefore, a bearer is required or, better still, a pack-horse with leader. The chronometer is carried by hand.

The transport-possibilities offered by our water-ways have also been used, and will become of great importance to mountain-expeditions during the coming years, as well as during 1930.

In order to make use of the cheap means of communication, offered by the railways, an expedition was equipped, in 1929, to which was allotted the task of determining the magnetic elements of the net-work of points formed by the Norrland railway stations. In many cases, these stations can only be reached by means of the railway. In this connection, however, there is one inconvenience which increases the farther north one travels, viz. that most of the railways up here only run one train daily in each direction. As, thus, one may not be able to make the best use of the short time of the year during which the survey can be suitably performed so far north, the net-work of bus-lines, fairly well developed in the above-mentioned area, has lately, to a large extent, been combined with the railway net-work. The instrumental equipment of this expedition consists of a magnetic theodolite by Bamberg, No. 2312. By this instrument the azimuth is determined. Besides, the declination is found by using two magnetic needles, suspended on a pivot. As to the horizontal intensity, only the deflection angles can be measured. A dip circle, Dover No. 72, completes the equipment. Both instruments can be mounted of the same tripod. They belong to the Hydrographic Service and have kindly been placed at the disposal of the Geological Survey of Sweden by its Chief, Commodore G. Reinius. With the receivers of the inhabitants is also determined, by wire-less time-signals, the position of the chronometer. At all transports. the surveyor is responsible for the safety of the instruments which may not be registered as luggage.

In order to make the best use of that net-work of highroads in Norrland, where motor-traffic is allowed, a motor expedition has been at work since 1928. The instrumental equipment is rather heavy. The chief instrument is a theodolite from the Askania Works, with a detachable universal instrument for astronomical determinations. The azimuth can also be obtained by using the theodolite with its little telescope and a mirror. The declination is determined by a magnetic system, suspended on a pivot. The deflection angles are always found by each of the two deviation-magnets belonging to the instrument, and at the shortest of the two distances possible from the magnometer. Sometimes, complete determinations of deviation are carried out by both magnets for both distances. The instrument also possesses an oscillation-box in which the deviation-magnets are suspended from a phosphor-bronze filament. The oscillations are determined by means of telescope, scale and chronometer in the usual way.

The earth-inductor, belonging to the instrument, is built into the above-mentioned universal instrument and is to be used in connection with a string-galvanometer as zero instrument. This galvanometer, however, did not answer the expectations; therefore, until a suitable galvanometer has been procured, the inclination is determined by the dip circle, Dover No. 60, belonging to the Academy of Science. If the time-signal cannot be conveniently obtained with the receivers of the inhabitants, the position of the chronometer can be fixed by means of a receiver belonging to the expedition. During the measurements, the instruments are protected against sun and rain by a tent.

In case determinations of base-values should be required unexpectedly, a Bamberg theodolite was stationed, in 1930, as reserve-instrument, at the magnetic observatory of Näs. Through the courtesy of the Stockholm Navigation School, this instrument has been placed at the disposal of the Geological Survey of Sweden. For 1930, two base-value determinations are already carried out at Näs with the Askania Works theodolite and the dip circle, Dover No. 60.

[1] Annales du Bureau Central Météorologique de France. Paris 1886. p. 57.

Field works 1928—1930.

Out of the 224 stations, surveyed during the years 1928 and 1929 by the Geological Survey, 223 are marked on Map 4. The contributions made by the different observers are seen in Table 12.

Table 12.

	No. of stations	Time of survey	Average No. of stations a day
Molin	38	1928 $^{13}/_{7}$—$^{15}/_{8}$	1.2
Johansson	29	1928 $^{5}/_{7}$—$^{22}/_{8}$	0.6
Molin	36	1929 $^{2}/_{7}$—$^{13}/_{7}$ and $^{19}/_{7}$—$^{30}/_{7}$	1.5
Rothstein	52	1929 $^{18}/_{6}$—$^{15}/_{8}$	0.9
Werner	69	1929 $^{25}/_{6}$—$^{28}/_{8}$	1.1

The number of older, identified and remeasured observation stations which are included in the above total, is 20.

The working-plan for 1930 is to be seen on map 5. In order to utilize the journeys of the motor expedition to and from the working field, a number of stations have been chosen on the lines Örebro—Bräcke and Sundsvall—Upsala.

When making out the working-plan of the year, the communications of the districts are taken into consideration, with an endeavour to obtain approximately 1 observation-point for every 324 km^2. From a geological point of view, this plan is subsequently examined so that, for the survey are chosen stations free from disturbances and, as a whole, characteristic of the geology of the district. From various causes, the surveyor may, however, be unable to follow the plan in all its details. He will then choose new points in the field which, later on, have to be examined from a geological point of view.

For 1930, rather a large number of stations have been planned, as may be seen from Map 5. The scarcity of stations on the map, above 68° Lat. N., is caused by the impracticable character of the country. Those stations which are not surveyed in 1930, will be taken up in the work of next year.

The hope of obtaining good results from the survey of 1930 is due, partly to the circumstance that the expeditions were ready to start considerably earlier than last year, and partly to the fact that the work should continue until October, weather permitting.

Description of points.

Arrived at the place in question, the surveyor has to choose the point for his observations. This task demands special care and is of the greatest importance for a good survey work. To give detailed instructions to the surveyor would probably be of little value, as it is impossible to anticipate the complex of factors offered by the local conditions and which must influence the surveyor in his choice of point. Only in the main, it has been possible to point out the desirability of proceeding along certain lines. Except that the surveyor must first examine, by ocular inspection, that the nearest surroundings of the station are free from magnetic disturbances and that the area, from a geological point of view, is as nearly homogeneous as possible, his choice must be influenced by the necessity of a clear sight for azimuth determinations and by the desirability of obtaining good, distant mires. Besides these primary points, there are a number of others, of secondary nature, of which only the following should be mentioned. There should be a prospect of the station remaining undisturbed by an increasing colonization, thus rendering possible a future remeasurement. The position of the station ought to be fixed in relation to objects of a permanent nature.

The surveyor marks the point on the map in order to determine its co-ordinates, and further makes, on the spot, a description of the station with a sketch on a large scale, taking up the essential features of the environment and the requisite distances determined by pacing. The text of this description is framed according to a given disposition, with the purpose of showing the way to anyone who tries to find the point and enabling him to identify the station.

In places, where this is possible, the point is marked by a bore-hole and, in many places, auxiliary marks are used, with arrow-heads cut in stone pointing towards the station, at certain measured distances from it. In some cases, brass studs, marked with the initials S. G. U. and the number, are placed at suitable points, about equally distributed over that part of the country. The stud is firmly cemented. In some cases, the surveyors have taken a photo of their observation points.

For the description of each station has been used a sheet of paper, which sheets are arranged according to a cardsystem. The description of each station includes all data concerning the observation-point, its geology, the measurements carried out there and information regarding earlier surveys, in case the point has been surveyed before. The sketches appended to the descriptions have been redrawn in the proper proportions. To this effect, an extensive work has been done by Mrs. Molin. Further, this description comprises cuttings from the map, with the observation-point marked.

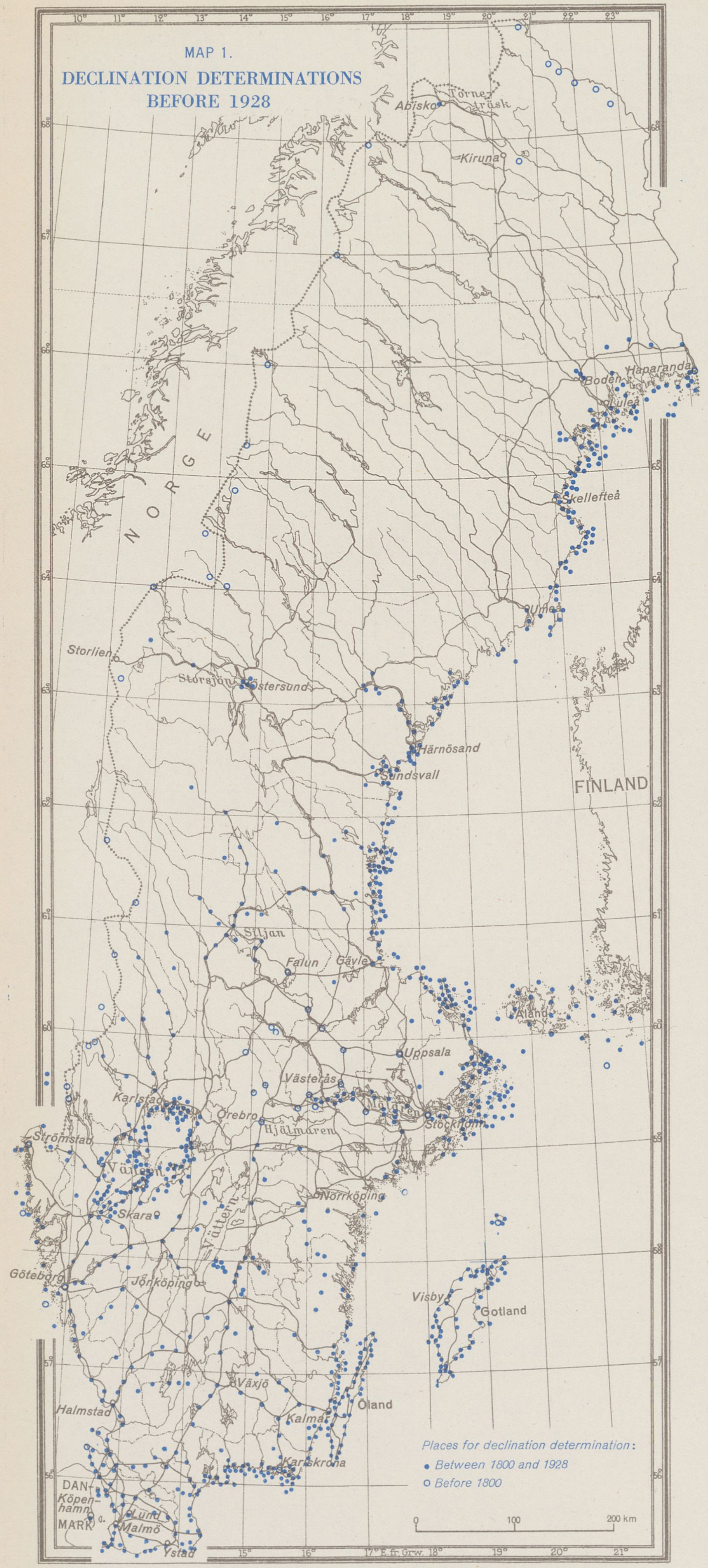
The preparation of the primary measurements is the work of the field observers. For the computation of the azimuth, printed forms have been used. The primary material has been controlled by Molin. The further calculation of the measurements as to the constants of the instruments, the corrections for disturbances and the reduction to epoch with regard to secular change is to be done by Molin. All determinations of the constants have been carried out by Molin himself, or under his direction.

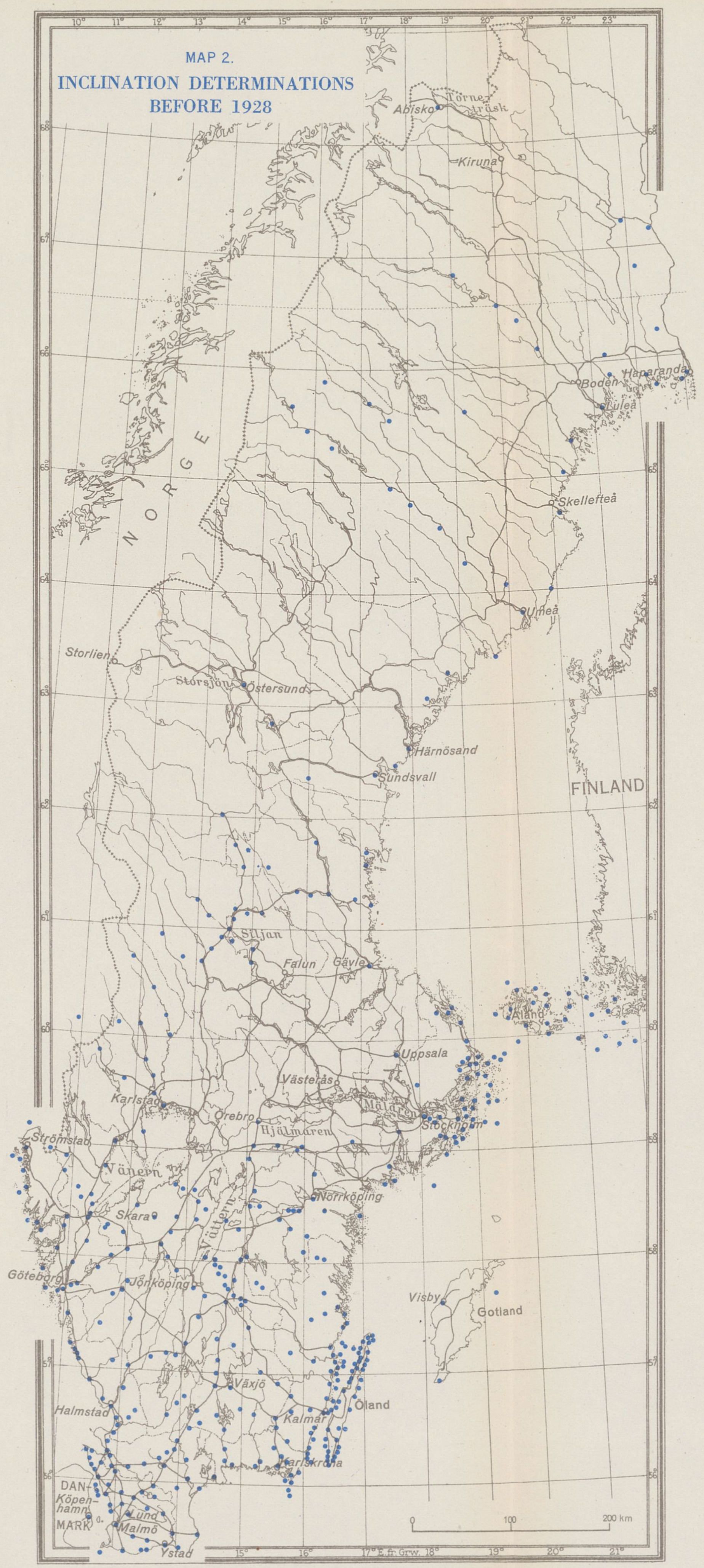
Summary of the program.

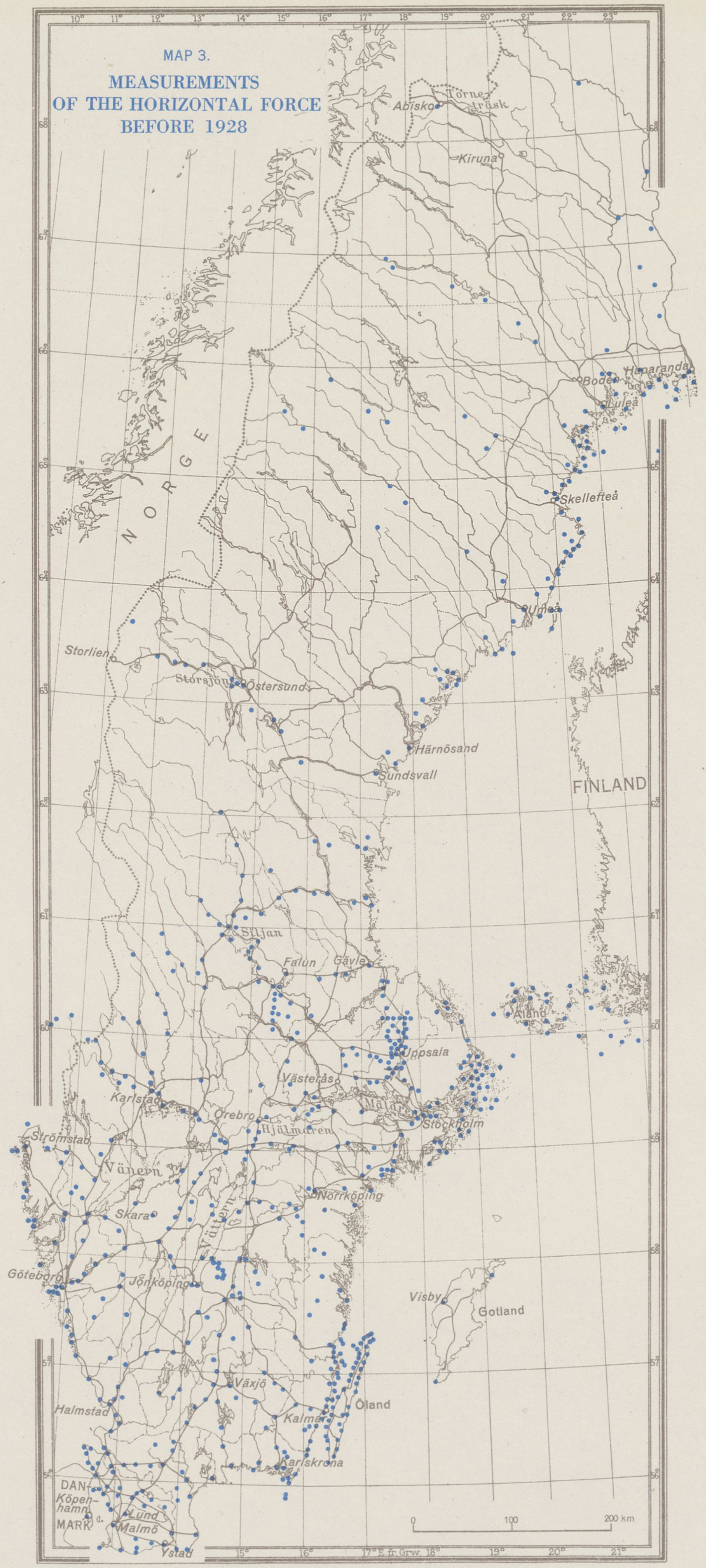
The present task of carrying out the magnetic survey of the main-land of Sweden with, on an average, 1 point on 324 km², the Geological Survey has planned to get finished by the end of 1933. In view of the small amount of field-work which it was possible to perform during 1928, also the year of 1934 will eventually have to be used. After the hitherto most unknown part of the country has been surveyed, the work will be concentrated to the central and southern parts of Sweden where, particularly, the questions of the remeasurement of older stations and the planning of complementary surveys must be carefully considered. In order to reduce the field-measurements to a suitable epoch, a number of remeasurements should be performed, during the last year, at certain points marked by a stud or a bore-hole, in order to obtain the requisite knowledge of the secular change for the respective elements. As a contribution towards a knowledge, during the interval in question, of the secular changes in different parts of the country, the Geological Survey hopes that they may utilize the results of the work started, in 1929, in the main-land of Sweden, by the Hydrographic Service, for the purpose of following, by means of recurring measurements, the secular variations of a certain number of marked points chosen by the Hydrographic Service.

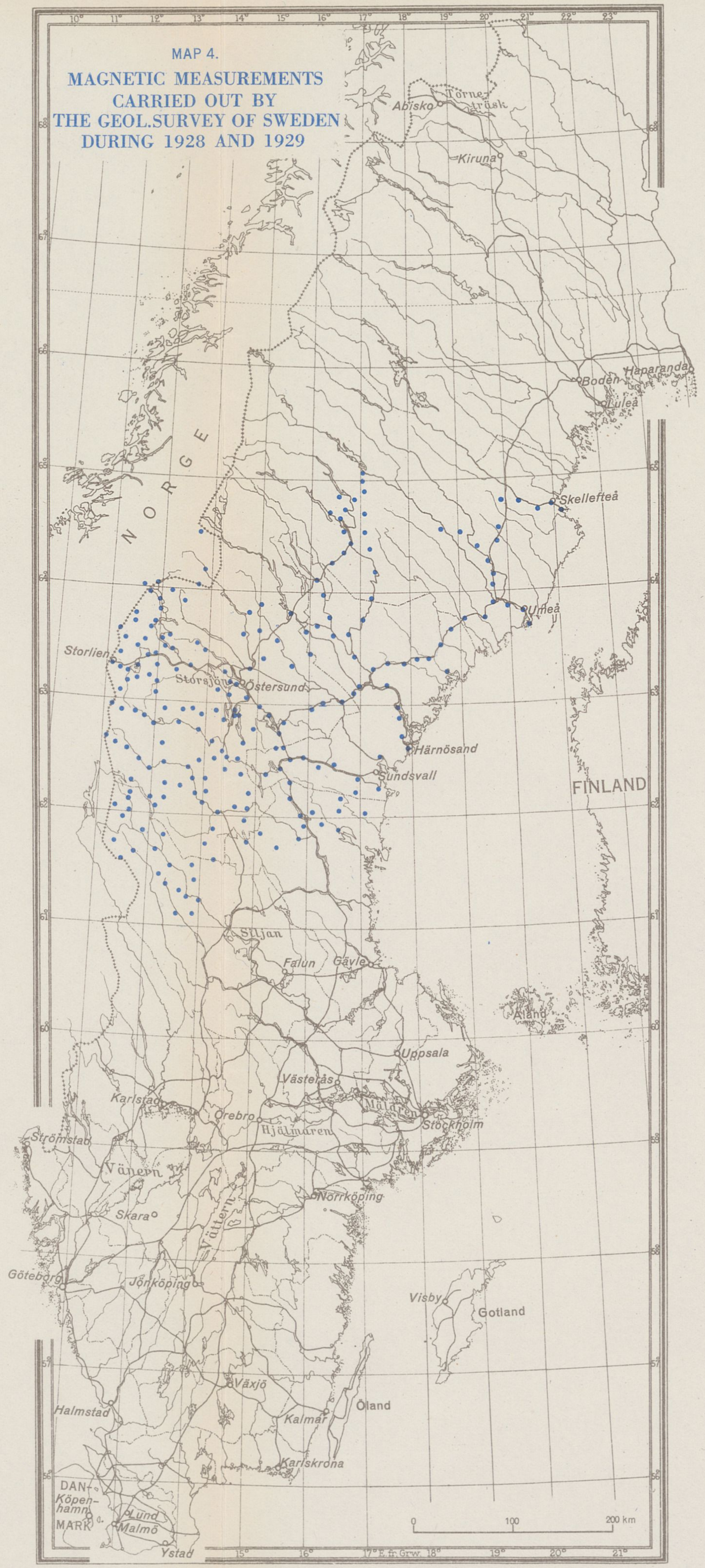
Upsala, in July 1930.

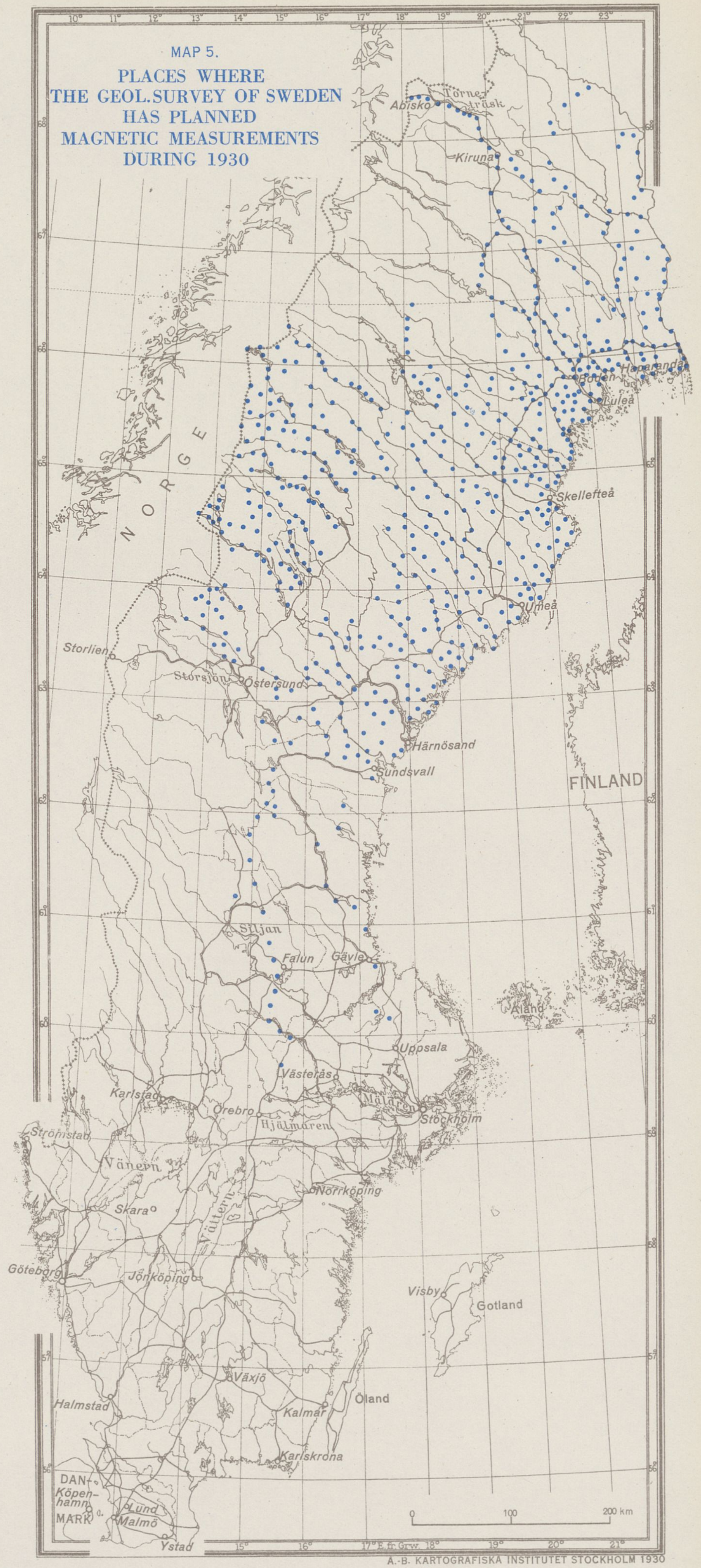
Stockholm 1930. Kungl. Boktryckeriet 302296











A.-B. KARTOGRAFISKA INSTITUTET STOCKHOLM 1930

STOCKHOLM 1930. KUNGL. BOKTRYCKERIET. P. A. NORSTEDT & SÖNER 302296