The Gothenburg Magnetic Excursion

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The Gothenburg Magnetic Excursion

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The Gothenburg Magnetic Excursion in a broad sense ranges from 13,750 to 12,350 years BP and ends with the Gothenburg Magnetic Flip at 12,400–12,350 years BP (= the Fjärås Stadial in southern Scandinavia) with an equatorial VGP position in the central Pacific. The Gothenburg Magnetic Flip is recorded in five closely dated and mutually correlated cores in Sweden. In all five cores, the inclination is completely reversed in the layer representing the Fjärås Stadial dated at 12,400–12,350 years BP. The cores were taken 160 km apart and represent both marine and lacustrine environments. The Gothenburg Magnetic Flip represents the shortest excursion and the most rapid polar change known at present. It is also hitherto the far best-dated paleomagnetic event. The Gothenburg Magnetic Excursion and Flip are proposed as a standard magnetostatigraphic unit.

INTRODUCTION

The short Late Glacial period of reversed polarity known as the Gothenburg "Reversal" (Mörner *et al.*, 1971) or the Gothenburg Magnetic "Flip" (Mörner and Lanser, 1974) was first found in a core from Sweden. The discovery was announced in 1971 (Mörner *et al.*, 1971). The complete results were presented at the INQUA IX Congress in New Zealand in 1973 (Mörner, Ed., 1973, 1976). Additional samples from Sweden, Canada, and the Atlantic were measured and a summary report was given in 1974 (Mörner and Lanser, 1974). The Canadian and Atlantic results are being published separately (Mörner and Lanser, 1975; Mörner, 1976a, d) and a monographic report on the Swedish results is in preparation. In the summary paper (Mörner and Lanser, 1974), 15 localities are listed where "the chronological control indicates that the recorded reversals refer to the same event or excursion" and 11 additional localities where "the dating is not sufficiently precise for direct correlations." Recently, the same magnetic anomaly seems to be well recorded in two Canadian lake sequences (LaSalle, personal communication).

A comprehensive report on the Gothenburg Magnetic Excursion and Flip was given at the XVI IUGG General Assembly in Grenoble, 1975 (Mörner, 1975d). The Gothenburg Magnetic Excursion was reported to consist of two parts: (1) a period of irregular magnetism from 13,750–12,400 years BP, including at least one Canadian record of fully reversed polarity (the Port Dover Excursion), and (2) the Gothenburg Magnetic Flip from 12,400–12,350 years BP (= the Fjärås Stadial), repeatedly recorded in Swedish cores as fully reversed inclination with a corresponding VGP center in the central equatorial Pacific.

The Gothenburg Flip is so short and changes so rapidly that it can only be recorded in detailed analyses of sediments with a high sedimentation rate. For reliable mutual correlations, the dating control must be unusually accurate. Sweden offers good possibilities of establishing a very good dating control, thanks to the glacial stadial/interstadial chronology, the varve chronology, the pollen zonation, and the accessable uplifted marine deposits, besides normal radiocarbon dating (Fig. 1).

METHODS

All cores were taken with the Swedish foil piston corer giving undisturbed (Fig. 2)

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1	2	3	4	5	6	7	8	9
HOLOCENE	Postglacial	Subatlantic	SA	X IX			Vendsysselian Form IV	Littorina Sea
					2200	2200		
		Subboreal	SB	VIII			Kattegattian Formation III	
					5000	5800		
		Atlantic	AT	VII				
					7750	8000		
		Boreal	BO	VI V			Varbergian Form	Ancylus Lake
					9700	9700		
		Preboreal	PB	IV			Gothenburgian Form I	Yoldia Sea
					10 000	10 000		
PLEISTOCENE	Late Glacial	Younger Dryas	YD	III			Falkenbergian Formation B	Baltic Ice Lake (complex)
					10 950	10 950		
		Allerod	AL	II				
					11 750	11 750		
		Older Dryas	OD	Ic				
					11 900	11 900		
		Bölling	BO	Ib				
					12 350	(12 350)		
		Fjärås	Fj	Oldest Dryas, Ia				
					12 400	(12 400)		
		Ågård	ÅG					
					12 700	(12 900)		
		Low Baltic	LB				Lönstrupian Formation A	ice cover
					13 100	(13 250)		
		Vintapper	Vi					
					13 700	(13 700)		

FIG. 1. Chronostratigraphy of southern Scandinavia. (1) global Epochs; (2) local north European periods; (3) subdivision of the Postglacial and Late Glacial with (4) corresponding zonation according to Nilsson (1961) and Mörner (1971a), respectively; (5) pollen zonation according to Jessen (1935); (6) radiocarbon dates (Nilsson, 1964; Mörner, 1969); (7) varve dates (Mörner 1969, 1975a, 1976b); (8) subdivision of the Kattegatt sediments (Mörner 1971c, 1975e); and (9) main Baltic stages.

and continuous cores of up to 11 mm in length. The corer and cores were carefully oriented. The 11 m cores, after a brief field examination, were cut up in 1.5 m lengths, wrapped up in plastic foils, put into plastic tubes, and transported to the laboratory, where they were subjected to a careful stratigraphic analysis and finally cut up in 3.6 cm pieces that were sucked into plastic containers without affecting the sediment structures. The samples were measured by Dr. J. Lanser on astetic magnetometers at the Paleomagnetic Laboratory of Utrecht University. All samples were treated with progressive demagnetization in alternating fields of up to 2000 Oe peak values (50 Hz). A detailed report on the magnetic properties and the various analyses applied is in preparation by Lanser. In general, demagnetization in 200 Oe does not change the results to any significant degree. All VGP calculations were made on the Digico magnetometer system of the Stockholm Paleomagnetic Laboratory.

DISCUSSION

Stratigraphically, the Gothenburg Magnetic Flip falls in the Fjärås Stadial or zone Fj in Mörner's climatic zone system (Mörner, 1971a), dated at 12,400–12,350 years BP (Mörner, 1969, 1971b). The ice marginal position during the Fjärås Stadial is well established (Fig. 3), at least for the west coast of Sweden (Mörner, 1969). The Fjärås Stadial represents the end of the classical Oldest Dryas biozone (Mörner, 1969, 1971a, b). The radiocarbon-dated malacological changes on the west coast can be correlated with the ice marginal fluctuations and the climatic zones (Mörner, 1969, p. 167). Figure 1 illustrates the chronostratigraphical control of south Scandinavian sediments. The Gothenburg Magnetic Excursion in a broad sense embraces zones Vi, LB, ÅG and Fj, i.e., the time 13,750–12,350 years BP.

In southern Sweden, several sections (Fig. 3) have been analyzed paleomagnetically specifically for the study of the

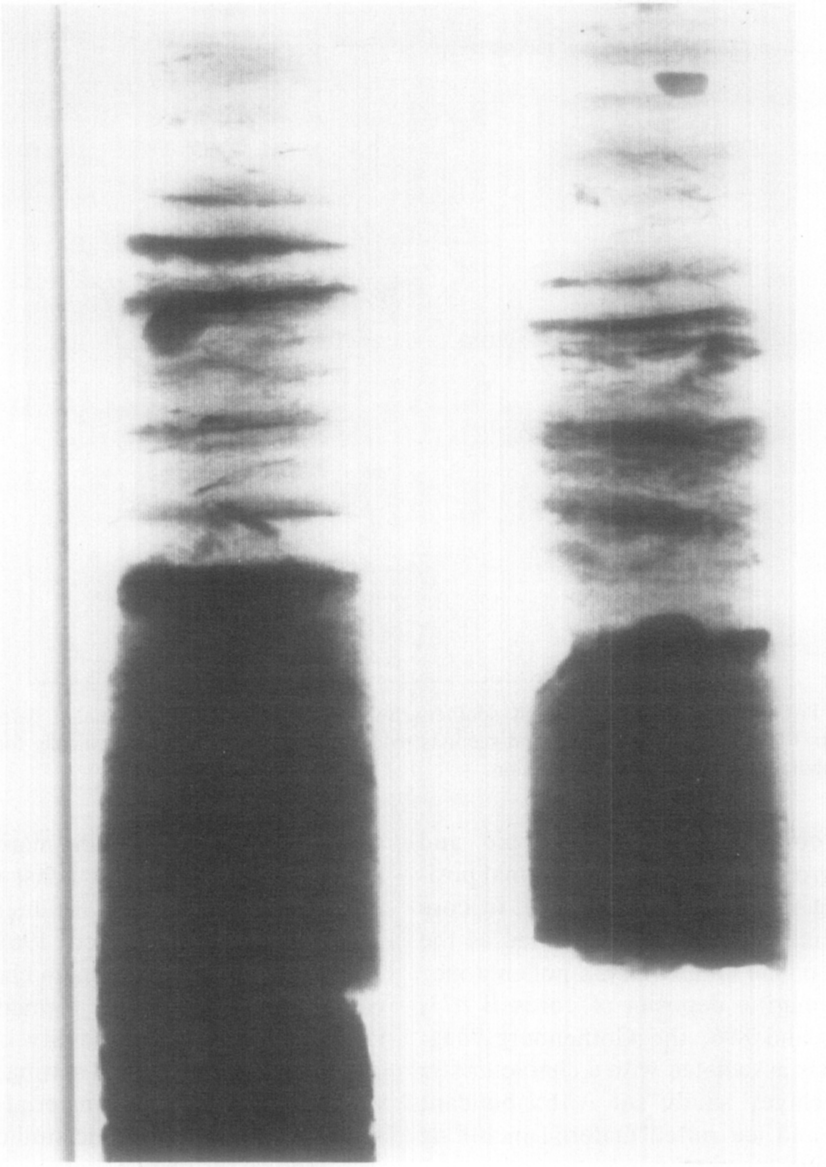


FIG. 2. X-ray photography of parts of cores B 911 and 913 taken when the cores were still in the plastic tubes. Sampling with the Swedish foil piston corer gives quite undisturbed samples and continuous cores of up to 11 m long.

Gothenburg Magnetic Excursion and Flip. Cores B 890, 891, and 893 are discussed separately (Mörner, 1975b, c, e). B 664 refers to clays at the interlobate moraine of the Ängelholm Phase (Mörner, 1969) and represents the base of the Vintapper Interstadial (13,750 BP). The other cores are the important ones for the discussion of the Gothenburg Magnetic Excursion and Flip.

Cores B 873, 901, 897, 896, and 892 all have a well-established chronology that enables close correlations on grounds other than the magnetic results. They all include deposits of the Fjärås Stadial: in cores B 873, 901, 897, and 986, these beds are

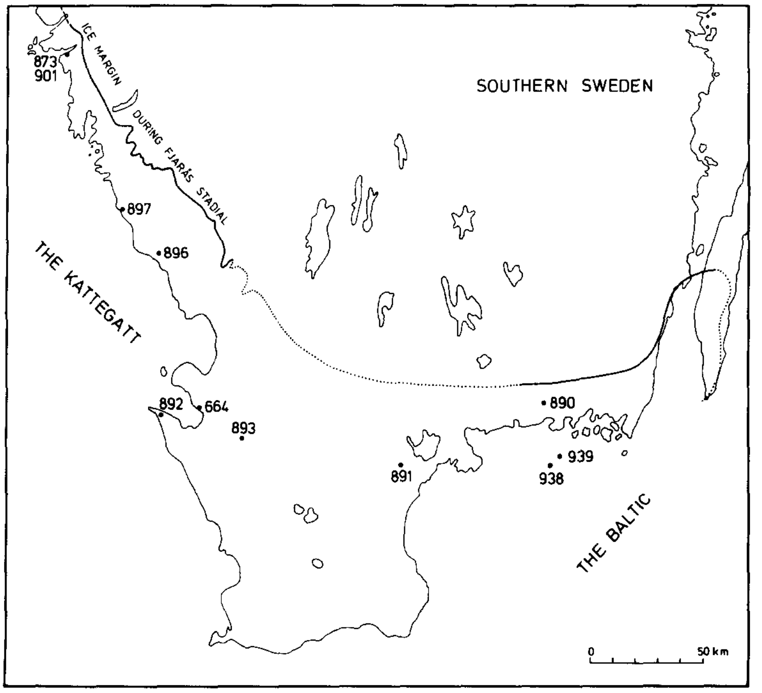
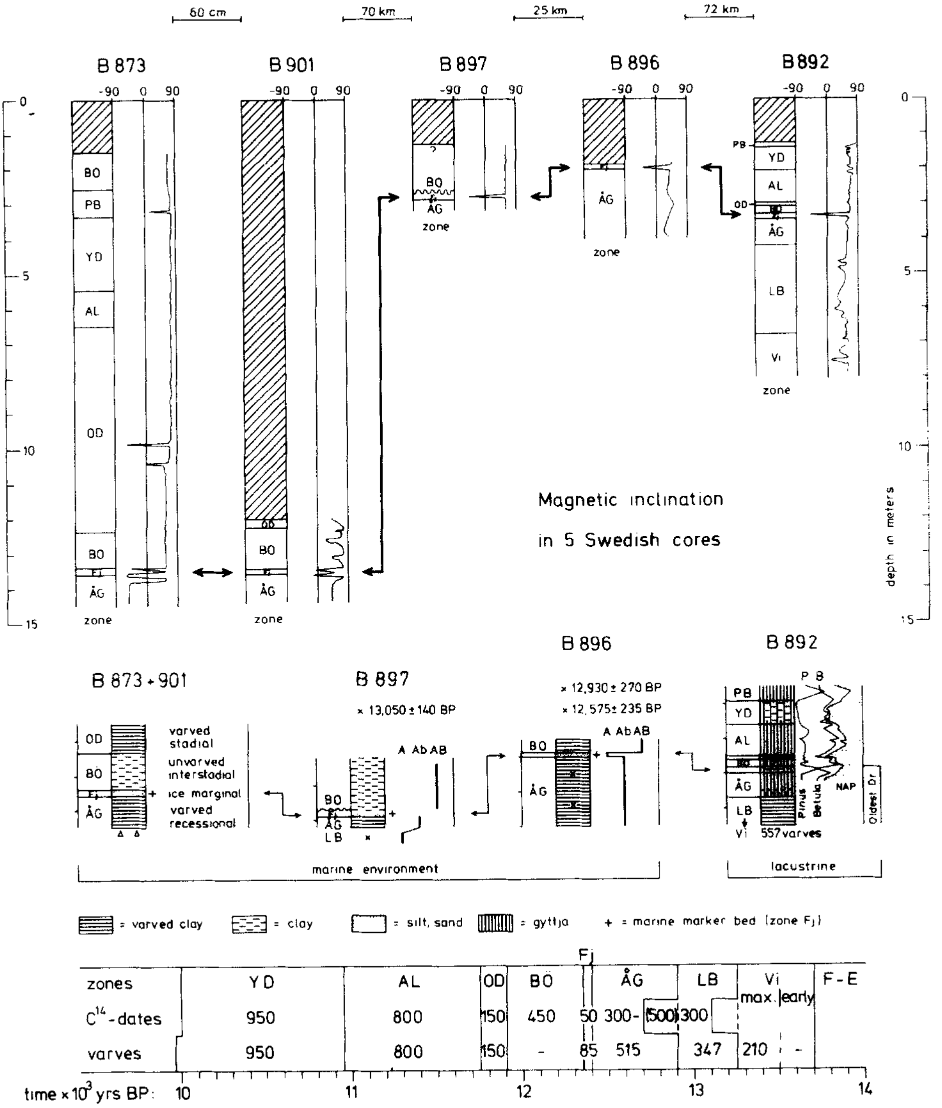


FIG. 3. Position of the ice margin in southern Sweden during the Fjärås Stadial dated at 12,400–12,350 years BP, and location of cores and sections paleomagnetically analyzed specifically for the study of the Gothenburg Magnetic Flip and Excursion.

directly correlated on stratigraphic and climatic grounds with the ice marginal position along the Fjärås line (Fig. 3); in core B 892, this layer is easily identified as the top layer of the Oldest Dryas pollen zone.

In the marine deposits of cores B 873, 901, 897, and 896, the Gothenburg Magnetic Flip is associated with a characteristic layer of clayey sandy silt with abundant molluscs and ice rafted material including pebbles with attached barnacles and pieces of Cretaceous chalk and chert from Skåne–Denmark (suddenly appearing in this layer and not being found on the Swedish west coast below this level). This layer serves as a regional marker bed in the marine deposits along the Swedish west coast (Fig. 4). It represents a regional environmental change in the Kattegatt (Mörner, 1969, pp. 169, 174). Extensive exposures in clay pits indicate that this layer was formed by heavy ice rafting (and not turbidity currents) in combination with normal setting of particles washed into the sea. The material is therefore suitable for paleomagnetic studies, which is indicated by the results that show consistent declination and inclination records in all cores (except for the declination record of cores B 873 and 901 which represent an ice marginal environment, where turbid-

FIG. 4. Zonation, magnetic inclination (upper diagram), stratigraphy (middle diagram) of five Swedish cores (location in Fig. 3), and corresponding chronology (lower diagram). The distances between the cores are given at the top. Four cores represent a marine environment and one a lacustrine environment. In all five cores, there are short, rapid, and fully reversed inclination records exactly in Fj zone (and only in this zone) corresponding to an equatorial mid-Pacific VGP (Fig. 9). This is known as the "Gothenburg Magnetic Flip" (Mörner and Lanser, 1974; Mörner, 1975d). The record of the "Flip" is reproduced, independently of lithology and environment, in exactly the same stratigraphic position in these five



cores. The middle diagram gives the zonation and stratigraphy. All four marine cores include a distinct marker bed (+): a thin, silty–sandy, interclay layer with abundant molluscs and ice rafted material (some pebbles with attached barnacles) that, for the first time in the Late Glacial sediments on the Swedish West Coast, include Cretaceous chert and chalk from Skåne–Denmark, and corresponds to the ice marginal position along the Fjärås line (Fig. 3). Besides this marker bed (+), cores B 873–901 possess characteristic glacial environmental changes (varved/ice marginal/unvarved/varved), and cores B 897 and B 896 possess characteristic malacological changes between arctic (A), boreo-arctic (Ab), and arctic–boreal (AB) faunas (Mörner, 1969, p. 167). A distinct climatic deterioration is recorded in the Fj zone of core B 896. Three samples of molluscs are radiocarbon dated (×) from the localities of cores B 897 and 896 (they are not corrected for ^{13}C deviation and the "sea effect," however). Core B 892 exhibits characteristic stratigraphic changes: 557 glacial varves of the LB and Vi-max zones, a sudden onset of the organic production at the LB/ÅG boundary, and three layers of increased washing in of alluvial Dryas Clay (Fj, OD, YD). The pollen diagram (Pinus, Betula, NAP) refers to Bergland's (1971) analysis from the core B 892 locality. The Fj zone (with increased clay content and reversed inclination) (represents the topmost part of the Oldest Dryas pollen zone with a corresponding cold peak registered in the Pinus peak and Betula low. The diagram at the base gives the zonation, the duration of the zones according to the radiocarbon and varve chronologies, respectively, and the age in years BP.

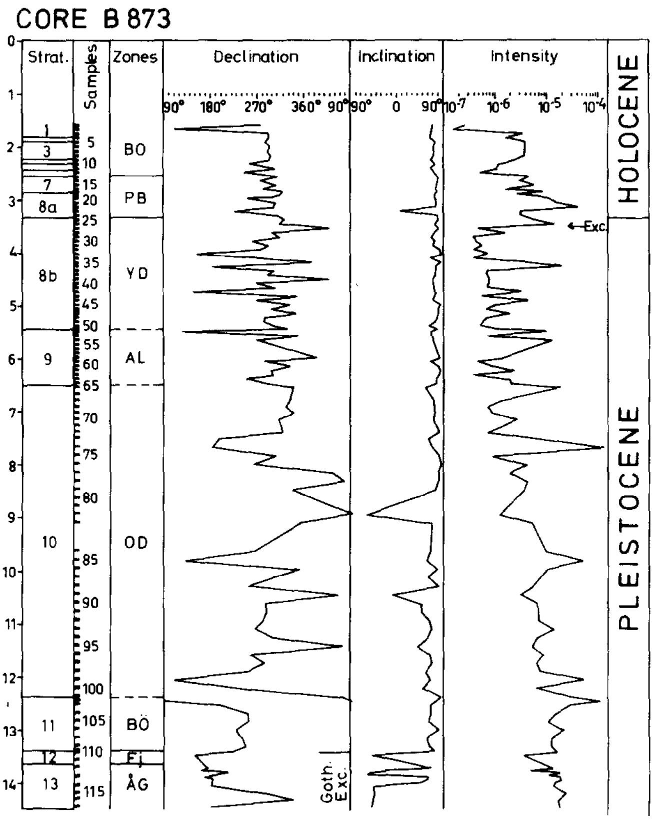


FIG. 5. Paleomagnetism of core B 873 (taken in the Botanical Garden of Gothenburg), a 14.5 m stratal sequence ranging from about 12,500 to 8500 years BP (redrawn from Mörner, 1973a, Pl. 1). AC cleaning (200 Oe) does not change the NRM values to any significant degree (Hospers *et al.*, 1973). The investigation of this core is fully described by Mörner *et al.* (Mörner, Ed., 1973 and 1976). The paleomagnetic data record a period of reversed polarity in layers 12–13 (=zones Fj–ÅG) known as the Gothenburg Event or Excursion. The bedding planes dip southwest. Declination swings around 270° (instead of 360° as is the case in Figs. 6–8). Turbidity currents must at least have affected the deposition of layers 12 and 13.

ity currents are to be expected, and are also indicated by the fossils).[1]

Core B 873 is the original core taken in marine deposits in the Botanical Garden of Gothenburg in 1970 (Mörner *et al.*, 1971; Hospers *et al.*, 1973; Mörner, 1973). A total of 123 samples were analyzed with 1 sample in the Fj zone and 11 in the ÅG zone (Fig. 5). The bedding planes show a clear dip to the southeast. The declination swings around 270°, instead of 360° as is the case in cores B 890, 892, 896, and 897, which seems to be the effect of some orientation error, the sediment dip, or turbidity currents. Turbidity cur-

[1] It should be noted that the danger of possible mechanical disturbance of the magnetic record in the varves is higher than commonly assumed. Recent repetitive sampling of thick varves in the Stockholm area (Mörner and Kukla, in preparation; Mörner, 1976e) has demonstrated large inconsistencies in the orientation of the magnetic vector in a single year layer. Declination values, in particular, are strongly affected. The disturbance is due to a mechanical contortion of the thick and sandy basal parts of the varves. To produce an apparent record of Gothenburg Magnetic Flip, however, any mechanical disturbence would have to change the original dip of strata by at least 90°. The bedding planes in Cores B 873 and 901 and the extension and appearance of the marker bed exposed in clay pits close to Cores B 896 and 897, do not show any such deformation. The reversed inclination record of the Gothenburg Magnetic Flip is, therefore, considered to record true geomagnetic field behavior.

rents must at least have affected the deposition of layers 12 and 13 (and may explain the declination values in B 873 and 901 that do not agree with those found in the other cores; the inclination values are consistent in all cores). In order to duplicate the original record and prove the validity of the "Gothenburg Reversal" of Mörner *et al.* (1971), a new core, B 901, was taken 60 cm from the old bore hole of B 873. The stratigraphic units were easily identified. A total of 78 samples were analyzed (ranging from the ÅG zone to the base of the OD zone) with 6 samples in the Fj zone and 25 samples in the ÅG zone (Lanser, in preparation).

Core B 897 corresponds to the Torsgården clay pit described by Mörner (1969, p. 167) which includes a radiocarbon date from the top of the LB zone. A total of 49 samples were analyzed, with 4 samples in the Fj zone and 7 samples in the ÅG zone (Fig. 6).

Core B 896 corresponds to the Ågård clay pit—the type locality of the Ågård Interstadial—described by Mörner (1969, p. 168); it includes two radiocarbon dates from the ÅG zone and clear malacological indications of a subsequent climatic deterioration representing the Fjärås Stadial (Mörner, 1969, 1971b). Two additional dates were recently made of shells from the ÅG zone: 12,700 ± 150 years BP (outer fraction of sample 1), 13,040 ± 155 years BP (inner fraction of sample 1) and 12,770 ± 190 years BP (sample 2), with ^{13}C correction corresponding to 12,340, 12,745, and 12,505 years BP, respectively. A total of 54 samples were analyzed, with 1 sample (No. 52) in the Fj zone and 51 in the ÅG zone (Fig. 7).

Core B 982 corresponds to the lacustrine sequence from Björkeröds Mosse, closely analyzed for pollen by Berglund (1971), which exhibits the Oldest Dryas/Bölling pollen zone boundary, i.e., the Fjärås/Bölling (Fj/BÖ) boundary in Mörner's system (1971a). A total of 181 samples were analyzed (Fig. 8), with 3 samples (57–59) in the Fj zone and 20 samples in the ÅG zone (60–79). Below the ÅG zone, there are 557 varves representing the LB zone (varves 210–557 and the Vi zone (varves 1–210).

Figure 4 gives the inclination records, the zonation, the lithology, and the chronostratigraphic characteristics of the five cores. It should be noted that the zonation and correlations were established before the magnetic results were known, in accordance with the information referred to in the previous paragraphs. Short and rapid reversed inclination is recorded in all five cores exactly in the Fj zone (and only in this zone). The inclination is completely reversed. This, indeed, is good evidence of the Gothenburg Magnetic Flip for it is recorded in five cores with a spacing of 160 km, includes both marine and lacustrine environments, and was correlated prior to and on other grounds than the magnetic results.

This is the fundamental basis for the establishment of the Gothenburg Magnetic Flip and for its global correlations (Mörner and Lanser, 1974). The mutual correlations between the five cores, the close dating control, and the individual magnetic records are superior to all other records supposed to represent a magnetic excursion at about 13,000 years BP. The Gothenburg Magnetic Excursion and Flip are therefore proposed as a standard magnetostratigraphic unit in global correlations.

Recently, an even more remarkable confirmation of the magnetic results in figure 4 was established when the polar position (VGP) was calculated: all the data from the Fj zone give an equatorial VGP position in the central Pacific (Fig. 9). Canadian glacial clays postdating the Paris/Galt Moraines and predating the Niagara Moraines give a similar VGP (Mörner, 1976d). The same applies for some of the data of Easterbrook (1975) when calculated to VGP (Fig. 9). The excursion at 13 m depth in Lake Biwa (Nakajima *et al.*, 1973) gives a similar VGP. Recently, samples predating the Gschnitz Moraine in Austria have yielded a similar central equatorial Pacific VGP center (Mörner, in preparation). Canadian clays predating the Paris/Galt

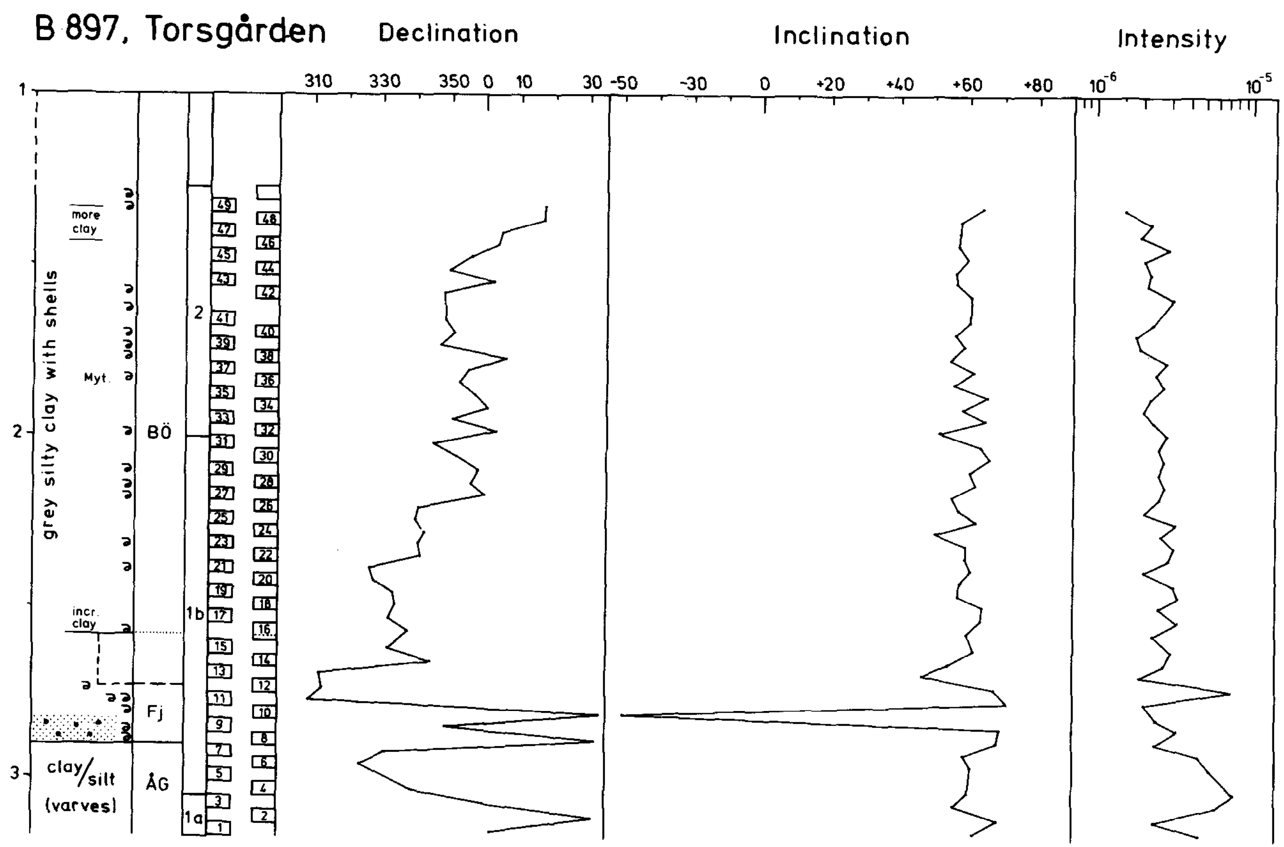


FIG. 6. Paleomagnetism of core B 897. The stratigraphy and dating is discussed by Mörner (1969, p. 167). Sample 10 in the Fj zone exhibits a fully reversed inclination corresponding to an equatorial mid-Pacific VGP position (2° S Lat., 164° E Long.).

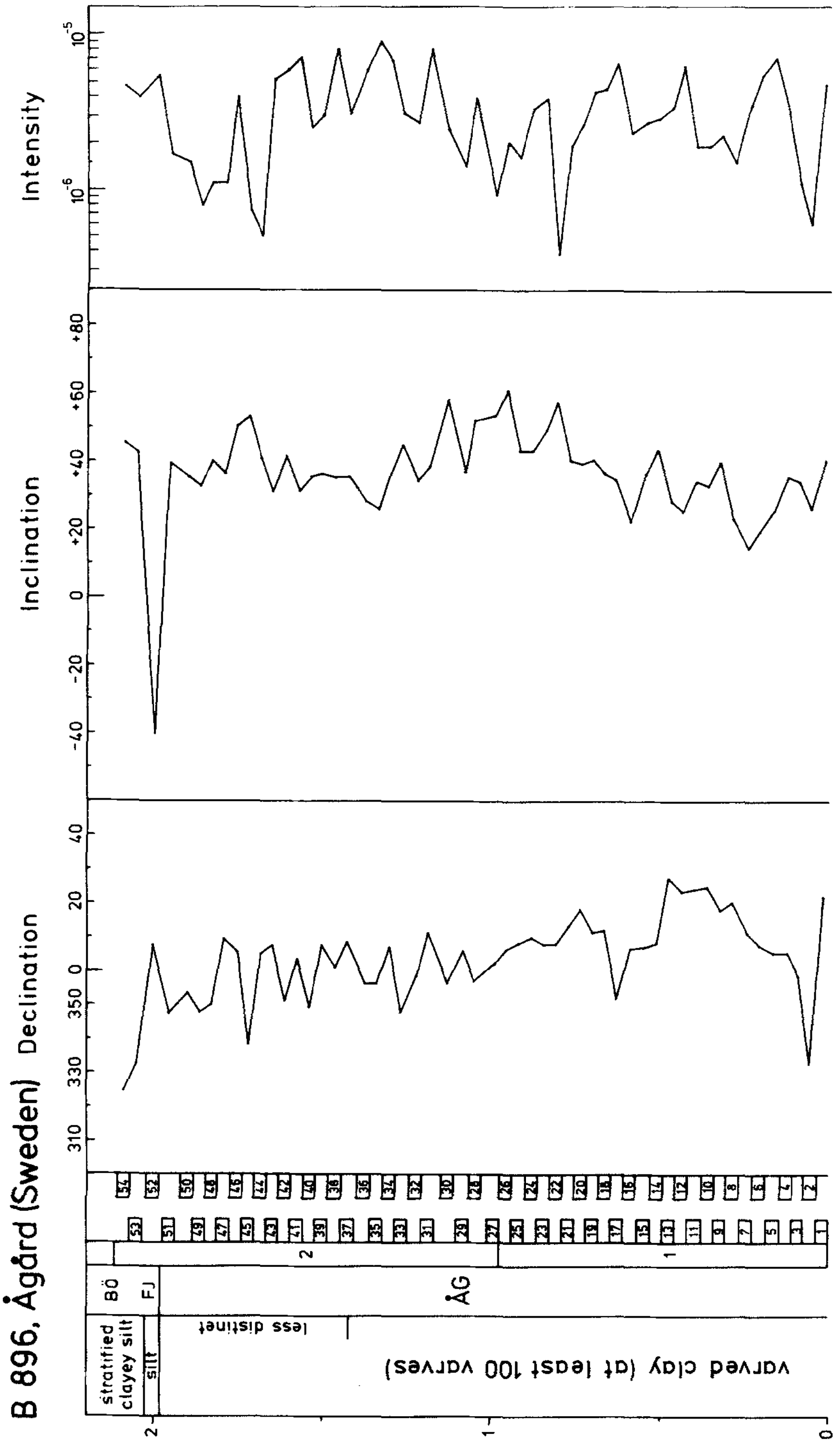


FIG. 7. Paleomagnetism of core B 896, taken at the type locality of the Ågård Interstadial (Mörner 1969, p. 168). Shells from the ÅG zone are radiocarbon dated at 12,575 ± 235 years BP and 12,930 ± 270 years BP. Sample 52, right in the Fj zone, exhibits a fully reversed inclination corresponding to an equatorial mid-Pacific VGP (9° N Lat., 186° E Long.). The mean values of the ÅG zone give VGP positions in the Pacific at about latitude 43–55° N.

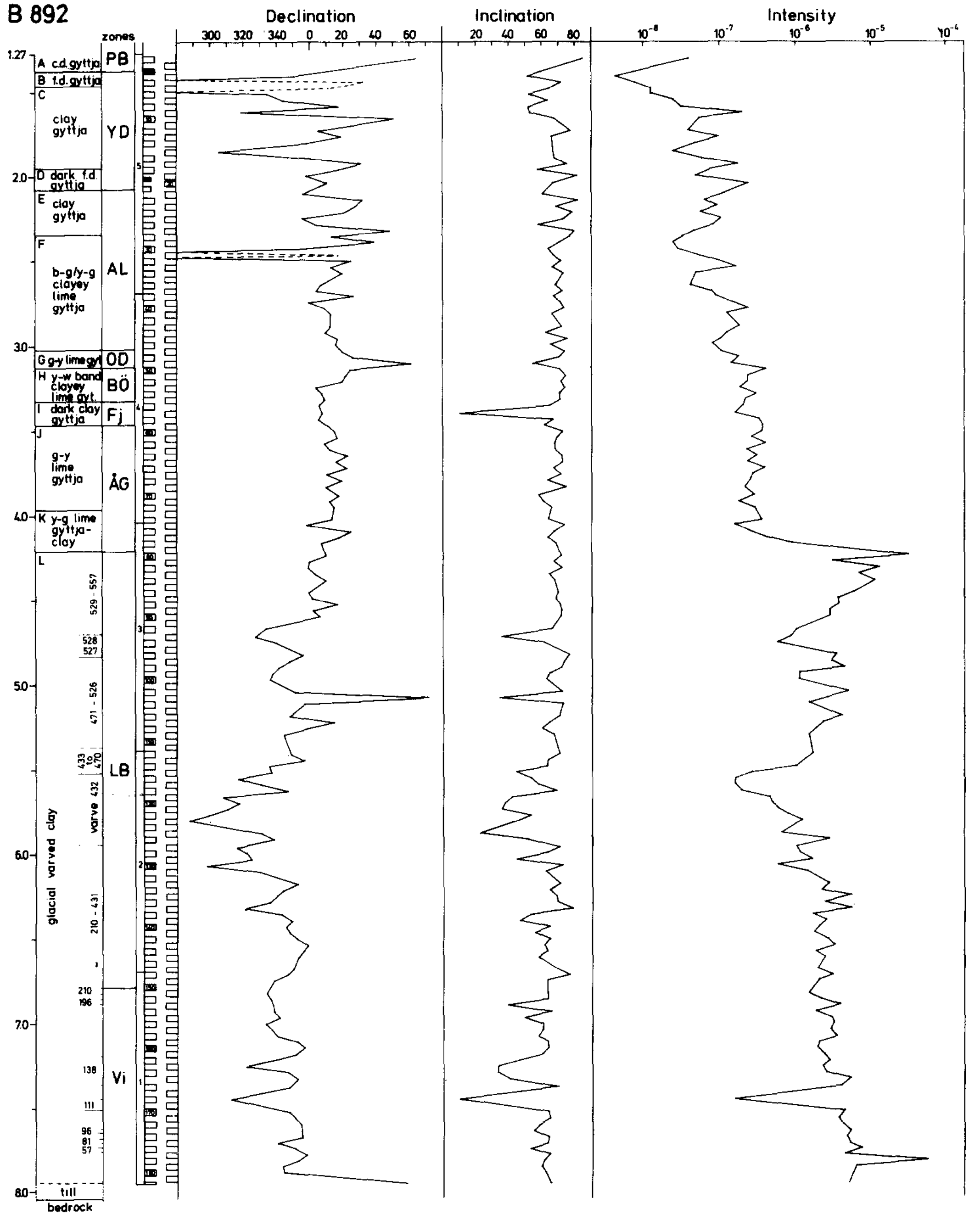


FIG. 8. Paleomagnetism (NRM) of core B 892 from Björkeröds Mosse (an overgrown lake). The same locality has been pollen analyzed by Berglund (1971) who established a detailed pollen zonation back to the layers H/I boundary corresponding to the Bölling/Oldest Dryas boundary. The layer L/K boundary represents a sudden organic increase and corresponds to the climatic amelioration at the LB/ÅG boundary. Layer L includes 557 varves representing the Vi zone (varves 1–210) and the LB zone (varves 210–557) and dating the free melting and onset of the sedimentation at about 13,460 years BP. Sample 57 from the middle of the Fj zone (layer I) exhibits very low intensity, which after AC cleaning changes over to fully reversed inclination (all other samples remain normal) corresponding to an equatorial mid-Pacific VGP position. Samples 4 and 5 (at the top of the YD zone) exhibit reversed declination corresponding to a low-latitude VGP in West Africa. This is known as the "Ornö Declination Departure," is recorded in eight other cores, and is dated by varves at 150 ± 10 varves prior to the Pleistocene/Holocene boundary (Mörner, Ed., 1976, Chap. XX; Mörner, 1976c).

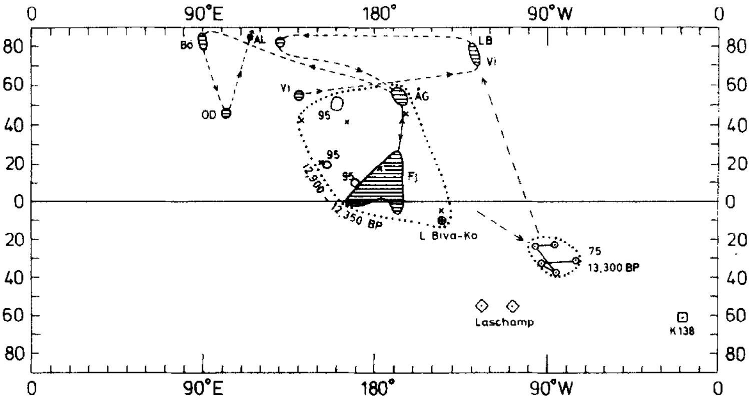


FIG. 9. Virtual geomagnetic pole (VGP) migration 13,700–11,500 years BP (zones Vi–AL) according to Swedish data: dashed lines and hatched areas with zone letters. All Swedish records of the Gothenburg Magnetic Flip fall within the hatched equatorial mid-Pacific area (i.e., the reversed inclination samples of cores B 897, 896, and 892, and B 873 and 901 after correction of the declination values). Open circles give VGP of localities 75, 90, 94; and 95 in Ontario (Canada). Additional data: X = VGP of some of Easterbrook's data from Washington (dated within 12,900–11,000 years BP), cube = VGP according to data at the Y½ boundary in core K138 of Clark and Kennett (1973), rombs = VGP according to Laschamp data of Bonhommet and Zähringer (1969), and encircled cross = VGP of the excursion at 13 m in Lake Biwa (Nakajima *et al.*, 1973). The data cluster around two low-latitude regions marked by dotted circles: (1) a Pacific center, the Gothenburg Excursion and Flip at 12,900–12,350 years BP ranging from the equator up to 55–60° N Lat. and including the Swedish ÅG and Fj data, the Canadian Loc. 95, 90, and 94:15 data, several of Easterbrook's data, and the Lake Biwa datum, and (2) a southeast Pacific center, the Port Dover Excursion at about 13,300 years BP including the Canadian Loc. 75 and 15:1 data (dashed lines from this center indicate its chronological position within the Vi zone).

Moraines, hence dating about 13,300 years BP, give a VGP in the southeast Pacific Ocean (Fig. 9) for which the term "Port Dover Excursion" has preliminarily been used (Mörner, 1976d).

The magnetic records from the ÅG zone give a midlatitude VGP position in the north Pacific (Fig. 9). This position is also valid for the Swedish east coast cores (Mörner, 1975b, e) and a varved clay sequence taken in Leningrad (Mörner and Krasnov, in preparation).

The Swedish cores discussed above all have a very well established chronology. However, layers of the Fjärås Stadial are so thin that the Gothenburg Magnetic Flip is only established in one or a few samples per core. Core B 938, a piston core recently taken off southeast Sweden, is interesting in this respect (Fig. 10) because it exhibits constantly reversed inclination in seven samples (the upper five being constantly normal). The switch from reversed to normal takes place within 7 cm in a reddish-brown clay that shows not the slightest trace of any lithological changes and shows, from X-ray analyses, unchanged minerological composition. The corresponding VGP position is in the Pacific (at low and midlatitudes, respectively) agreeing well with the VGP curve in figure 9. From the stratigraphy, the varves, and the position in the deglaciation history, core B 938 cannot yet be more precisely dated than about 12,800–12,000 years BP (12,400±400 years BP) which, however, is enough to assure that the reversed inclination in core B 938 is a new record of the Gothenburg Magnetic Excursion (Flip).

The Fjärås Stadial lasted for about 50 years (Mörner, 1969; 1971a, b), possibly 85 years (Mörner, 1975c), which means that the magnetic "flip" only covers some tens of years and that the inclination switches only took some years (cf. Mörner, 1977).

During the Vi and LB zones, cores B 664, 892, and 893 (like the Canadian samples of the same age; Mörner, 1976d)

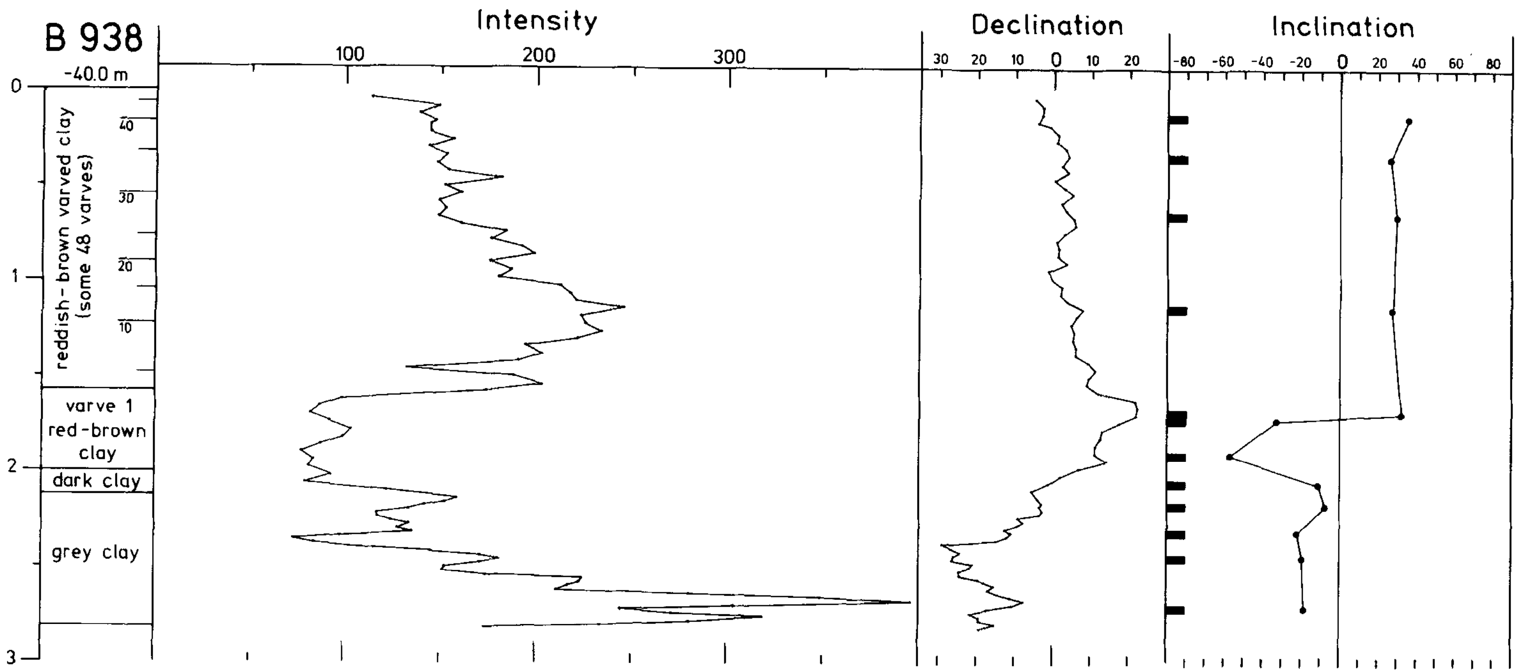


FIG. 10. Core B 938 is an unoriented piston core (hence the declination is relative) taken in the Bay of Hanöbukten. Intensity and declination are measured on the Digico long core system. Inclination is measured of 12 separate samples (black rectangles). The stratigraphy is typical for this area of the Baltic. The change from unvarved (grey) to varved (reddish-brown) clay represents a regional climatic–environmental change. Chronologically, the core represents a short period sometime between 12,800 and 12,000 years BP. Future varve chronological studies will sharpen the dating control. The inclination record shows a rapid switch (within 7 cm) in the upper part of the thick and uniform reddish-brown clay. X-ray analyses indicate that the minerology remains unchanged across the switch. The reversed *inclination* represents the Gothenburg Magnetic Flip.

Late Wisconsin-Weichselian				
	10,000	IV	normal	shift to the Canadian Arctic
				Siberia & Siberian Arctic Ocean
	12,350	III	Gothenburg Excursion: the "Flip"	equatorial Central Pacific
	12,400	II	Gothenburg Excursion: irregular magnetism	the Pacific region (13,250 BP Canadian clay gives the VGP in the SE Pacific)
	13,750	I	normal	Siberia & Siberian Arctic Ocean
	15,500		— — —	(no data)
	23,000			

FIG. 11. Summary of the main paleomagnetic stages and the polar migration during the late Wisconsin–Weichsel according to our Swedish and Canadian data. Columns: (2) radiocarbon dates in years BP; (3) subdivision into four main paleomagnetic stages; (4) paleomagnetic characteristics; and (5) mean VGP positions. The Gothenburg Excursion, in a broad sense (II–III), covers a period of 1400 years ranging from 13,750 to 12,350 years BP, during which the VGP was in the Pacific region (in opposition to stages I and IV).

display irregular magnetic records (Figs. 8 and 9) including some "flips" to equatorial and low latitude VGP positions (e.g., the Port Dover Excursion at about 13,300 years BP). The entire Gothenburg Magnetic Excursion is therefore considered to cover a period of 1400 years from 13,750 to 12,350 years BP (zones Vi, LB, ÅG, and Fj in Scandinavia) with the VGP migrating in the Pacific region (in opposition to the periods before and after) and being characterized by (1) a period of irregular magnetism from 13,750–12,400 years BP, including at least one rapid "flip" (the Port Dover Excursion), and (2) the rapid Gothenburg Flip at 12,400–12,350 years BP, recorded as fully reversed inclination in the Fj zone in northern Europe and corresponding to an equatorial VGP position in the central pacific. This is illustrated in Fig. 11, which is based on our Swedish (this paper) and Canadian (Mörner, 1976d) data.

The Gothenburg Magnetic Flip represents the shortest interval of reversed polarity and the most rapid polarity switches known at present. Unlike most paleomagnetic records, it is very closely fixed in age. This makes it a useful marker level for global correlations (cf. Mörner, 1974, Fig. 1; Mörner and Lanser, 1975, Fig. 3). It also makes it important for the understanding of the nature and causation of magnetic changes and geomagnetic dynamo theories (Mörner, 1977).

CONCLUSIONS

1. Chronostratigraphy and zonation offer unique dating control for the Late Quaternary sediments in southern Scandinavia.

2. The Fj zone (Fjärås Stadial) in southern Scandinavia, closely dated at 12,400–12,350 years BP, is characterized by fully reversed inclination corresponding to a central equatorial Pacific VGP position. This period is known as the Gothenburg Magnetic Flip.

3. The record of the Gothenburg Magnetic Flip is reproduced (quite independently of lithology) in exactly the same stratigraphic position in five different cores (within 160 km; two cores were taken 0.6 m apart) that represent both marine and lacustrine environments. Consequently, the investigation meets the requirement

of the 1974 Tokyo conference that the only valid proof is to reproduce the results in the same stratigraphic position, independently of lithology.

4. The zones ÅG, LB, and Vi (12,400–13,750 years BP) are characterized by irregular, but generally normal, magnetism with the corresponding VGP migrating in the Pacific region. This is defined as part one of the Gothenburg Magnetic Excursion, in a broad sense. Canadian clays dating to about 13,300 BP give a southeast Pacific VGP, preliminarily labeled the Port Dover Excursion.

5. The zones BÖ, OD, AL, and YD (12,350–10,000 years BP) are characterized by generally normal magnetism. Canadian clays covering the period of about 16,000–13,750 years BP indicate normal magnetism. The corresponding VGP positions were in Siberia and the Siberian Arctic Ocean with a shift to the Canadian Arctic region during the YD zone.

6. Low latitude and equatorial VGP positions are well documented. This is important for understanding the nature and causation of magnetic changes, including geodynamo theories.

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