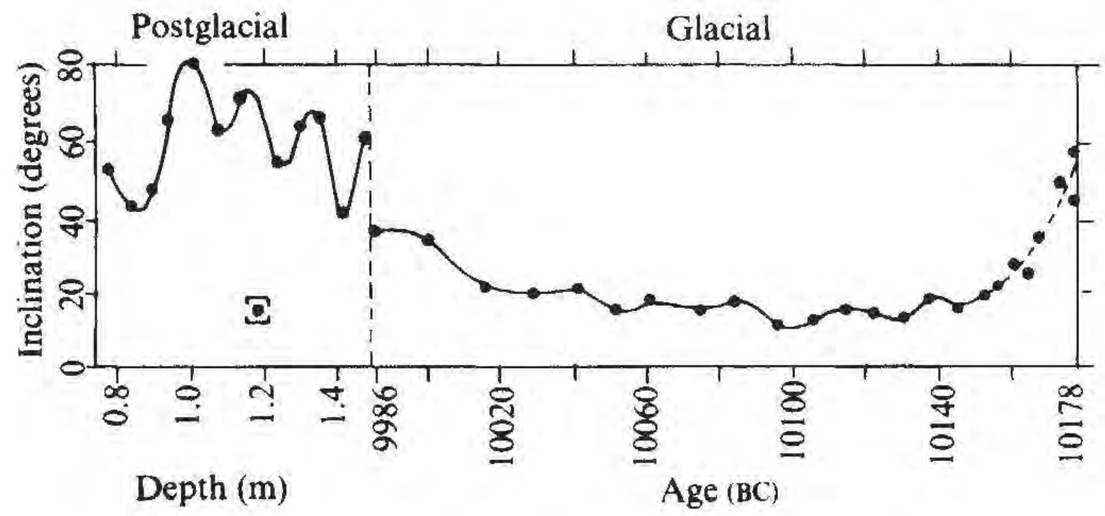
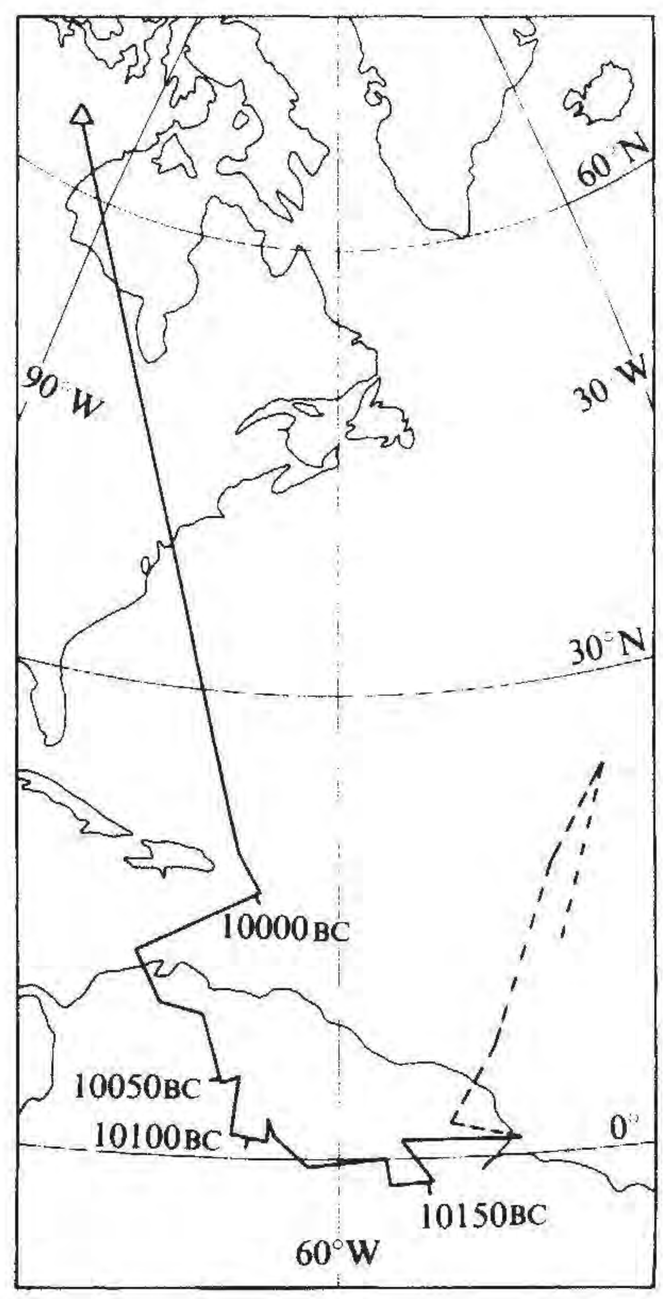


Fig. 1 Inclination of remanence after demagnetisation in an alternating field for samples from the Stärnö core. The rapid change in inclination before 10160 BC reflects the influence of water currents on the depositional remanence; the currents diminish rapidly as a consequence of glacial recession.

magnetic record in deep sea sediments is often lost because of post-depositional remagnetisation[3] and because of biological activity in the upper few decimetres of the sediments[4]. In lake sediments, where sedimentation is more rapid, the magnetic record is better preserved. Dating is, however, difficult because secular variations in atmospheric carbon isotopes and irregular distributions in the environment are known to produce errors. Furthermore, geomagnetic events, the levels of which may have been displaced by bioturbation[4], are usually dated by assuming uniform sedimentation between ^{14}C dated horizons. The Laschamp event, in particular, seems to have been detected at 12 locations although the reported age (Table 1) varies between 7,000 and 17,000 yr BP, a range outside the quoted error for individual determinations, but within the realistic error in dating.

Fig. 2 Motion of the Stärnö virtual geomagnetic pole. Pole positions are computed from the sample inclinations (Fig. 1) and the interpolated values of declination from the long core measurement, corresponding to the age of each sample. △, Postglacial mean direction (7800 ± 100 BC).



The Laschamp geomagnetic 'event'

SHORT lived geomagnetic 'events' provide useful stratigraphic markers; they may enhance climatic and evolutionary changes[1,2] and they provide stringent parameters for geomagnetic models. During such events the virtual geomagnetic pole undergoes excursions outside the usual range of secular variation but they are usually brief, generally lasting about 10^5 yr, so that their

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Table 1 Geomagnetic events probably corresponding to the Laschamp Event

Locality	Age (BC)	Dating method	Material	Reference
Puy de Laschamp, France	7000–9000	C^{14}	Volcanic scoria	15
Lake Tahoe, USA	≥1100		Lake muds	16
Gothenberg, Sweden	>12350	C^{14}	Varved clay/silt	17, 18
Viby, Sweden	12400	Varve chronology	Varved clay	6
Lake Erie, USA	≥12500		Lake muds	19
Mono Lake, USA	<13300	C^{14}	Lake muds	20
Lake Windermere, UK	13400 ± 400	C^{14}	Lake muds	21
Lake Chalco, Mexico	14450	C^{14}	Lake muds	22
Gulf of Mexico, USA	12500 – 17000	Fauna	Marine muds	23
Tlapacoya, Mexico	14770 ± 280	C^{14}	Lake muds	24
Gulf of Mexico, USA	17000 ± 1500	Fauna	Marine muds	25
Lake Biwa, Japan	17600 – 18700	C^{14}	Lake muds	26, 27
Laschamp + Olby, France	<20000	K/Ar	Lavas	28
Blekinge, Sweden	12077–12103 ± 150	Varve chronology	Varved clay	This work

At least four other established excursions have occurred during the last 0.69 Myr: the Biwa II and I events at 295,000 and 181,000 BP, respectively[26], the Blake Event at 111,000 BP[29], and the Mungo Event at 30,000 BP[30]. Others undoubtedly exist as such excursions are known throughout the geological record, for example during the Palaeo–Eocene[31]. Another event in silts of the Puget Lowland, USA was originally considered to be 20,000 yr old, but is now thought to be older than 45,000 BP. (K. L. Othberg, personal communication) and is, therefore, more likely to record the Mungo rather than the Laschamp Event.

In order to determine the age and duration of the Laschamp event we obtained samples of Swedish Quaternary laminated clays using the Swedish Geological Survey foil corer[5], whereby undisturbed, oriented cores 3.6 cm in diameter and up to 11 m in length can be obtained. Varved sediments, which have not undergone bioturbation, are particularly suitable for palaeomagnetic investigations, and have been studied in Sweden[6,7] and in North America[8]. Those studies involved measurements on individual samples, collected separately or extracted from cores.

After preliminary results had been obtained from a Swedish Geological Survey unoriented sediment core, new oriented cores were taken from two sites in southern Sweden (Blekinge), at Stilleryd (56.18° N, 14.83° E) and Stärnö (56.16° N, 14.85° E). Each core comprised a lower, varved, glacial sequence and an upper, postglacial, unvarved deposit. The susceptibility and natural remanence of each core were measured[9] at intervals of 1 or 2 cm and then samples of characteristic lithology were selected from both sites to test their stability in alternating magnetic fields. The results indicated that the samples were moderately stable up to at least 600 oersted. The cores were then demagnetised in fields of 100 or 150 oersted. The remanence of the cores was interpolated to the positions of the inter-varve boundaries using cubic spline functions in order to adjust the data for changes in the rate of sedimentation. Age bounds for the postglacial sequences were fixed by relating the altitude of each site and its environs to the shorelevel displacement curve for eastern Blekinge[10].

Each core was then cut into lengths of 5 or 6 cm and the samples were measured on a Digico magnetometer[11]. The inclinations of remanence in the Stilleryd core which showed post-depositional chemical alteration of the sediment were found to be scattered, with no obvious trends. At Stärnö, the record of inclination has been preserved (Fig. 1), with a marked magnetic unconformity at the base of the postglacial deposit. The varves of that sequence have been correlated with those at Stilleryd and an absolute date has been determined by connection with a series in the Swedish chronology. This is generally considered[12] to be more accurate than radiocarbon dating and is probably correct to ±150 yr (absolute) in the series considered here. The relative ages within each section are probably correct to within 5 yr. Measurements of the remanence immediately beneath two slumps in the Stilleryd core indicate that the magnetisation became blocked less than 9 yr after deposition and so the ages of sedimentation and magnetisation are virtually coincident in the undisturbed varve sequences.

We have computed the path of the virtual geomagnetic pole corresponding to the Stärnö palaeomagnetic record (Fig. 2). It indicates a geomagnetic quasi-reversal between 10153 BC and 10127 BC followed by a northward migration of the virtual pole at a rate of about 2.8° of latitude every 100 yr. The southernmost excursion of the pole lies close to the meridian 60° W, 120° E, found by Steinhauser and Vincenz[13] to be one of two preferred paths for palaeopoles during polarity transitions.

Studies of the unvarved sequences indicate anomalous changes in declination and low inclination values around 860 BC. This may well represent a more recent geomagnetic event, the Stärnö event, and may be the reversal reported by Ransom[14] on the basis of archaeomagnetic studies by Folgheraiter and Mercanton on contemporary fired clay and pottery, from Greece and Bavaria. At this stage, however, the event is defined in non-varved sediments and we intend to examine the corresponding horizon within a varved sequence to determine the age and nature of this more recent excursion.

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