Climatic and glacial changes during the last 150,000 years within the Arctic-European-Atlantic sector

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The climatic and glacial changes in the European and Arctic region are closely linked to the circulation changes in the North Atlantic. No area can be understood isolated and separated from the rest. We therefore need multi-parameter studies integrated over the entire Arctic-European-Atlantic sector of the globe. A few hints are here discussed.

The climatic-glacial records in Europe

The Grande Pile and Les Echets continual sequences (Mörner 1983) provide a very complete picture of the climatic changes in Europe (Woillard 1978; Mörner 1979a, 1981). The glacial records are much more incomplete and hard to put into a consistent picture; they only provide a mosaic of time-windows, where the time often is uncertain or unknown. Deep-sea cores provide additional data for the sea regions. Fig. 1 gives the paleoclimatic and paleomagnetic records of the Grande Pile.

It is clear that the glacial changes in the north and in the south differ considerably (Mörner 1974, 1977a). The maximum glaciations are not of the same age from north to south (Fig. 2).

Major problems concern the character of the first Post-Eemian cold phase in the Grande Pile and the character of the interstadial at around 40–50 KA. The chronology of the older parts remains a problem.

Several geomagnetic excursions (Fig. 1) have been established in the Grande Pile (Mörner 1979a, 1981) occurring with a cyclicity of about 11,000 years (Mörner 1986). Special attention is here called to (1) the three-parted D-excursion at about 33–38 ka which has VGP positions almost identical to those of the two-parted Lake Mungo excursion in Australia, (2) the F-excursion within the St. Germain II Interstadial which has a VGP-path almost identical to the one of an excursion found in varved clay in between two till beds in central Sweden, representing the Jämtland Interstadial and termed the Vålbacken Excursion (Mörner 1982) and (3) the H and I excursions within the classical Eemian pollen zone that seems to represent the double Blake Excursion. The paleomagnetic correlation between the St. Germain II Interstadial outside the ice caps and the Jämtland Interstadial inside the limits of the Fennoscandian ice cap is of great importance. In Lake Auersjøen on NW Svalbard (on Reinsdyrflya), which is located between the maxi-

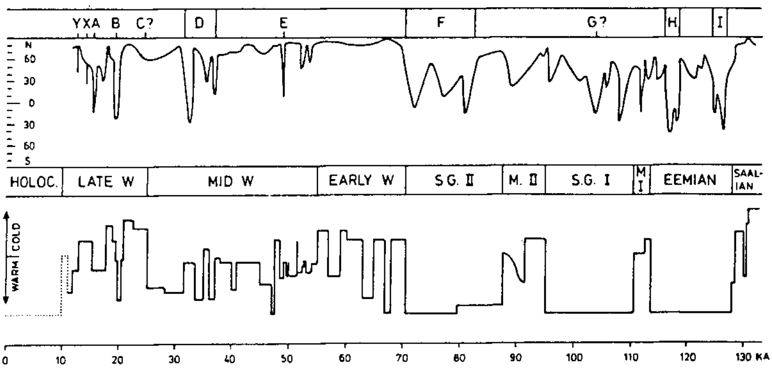

Fig. 1. Paleoclimatic and paleomagnetic record from the Grande Pile (Mörner 1979a). Base curve gives the cold/warm changes as registered by the sedimentological characteristics. Top curve gives the paleomagnetic VGP latitude changes. The letters refer to the geomagnetic excursions recorded. Time scale is partly tentative.

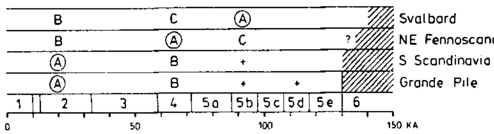

Fig. 2. Position and ranking (A = maximum, B = medium, C = minimum, + = trace of cooling) of the glacial maxima in four north-south located areas with respect to the oceanic isotope stages (hatched zones represent the Second Last Ice Age).

mum limits of the older large glacial episode with higher shorelines and the younger less extensive glacial episode with less high shorelines (Salvigsen & Österholm 1982), there is a geomagnetic excursion (Mörner unpublished) that is likely to be another correlative of the F-excursion. This would be in full agreement with Fig. 2 and the chrono-stratigraphic results of Miller (1987).

Atlantic circulation and continental climate

The interplay of cold Arctic water penetrating southwards and warm Atlantic water (the Gulf Stream) penetrating northwards has had a dominating controlling effect on the continental climatic-environmental changes within the European-Arctic sector. This interplay is primarily driven by the interchange of angular momentum between the 'solid' Earth and the hydrosphere (Mörner 1984a, 1987a, unpublished) as illustrated in Fig. 3.

At around 13,000 B.P., there was a rapid immigration and spread of a new marine fauna and flora in northwestern Europe. It was linked to the initiation of a rapid deglaciation of the Fennoscandian ice cap and to a significant continental climatic amelioration. A similar event occurred at around 10,000 B.P. (and marks the onset of the Holocene). Both events must represent significant intensifications of the flow of warm surface water (heat) carried by the Gulf Stream to northwestern Europe and the Arctic. Reversed effects are noted at around 11,000 B.P., 2,500 B.P. and during the so-called Little Ice Ages when pulses of southward expansions of Arctic water are recorded.

This illustrates the very strong sensitivity of northwestern European continental climate to southward migrations of Arctic water (cooling), or northward migration of Atlantic water and intensifications of the Gulf Stream flow (warmings).

During the Holocene, we record 16 short-term oscillations in eustatic sea level in NW Europe, in absolute air temperature in southern Scandinavia, in percentage sub-polar forams in cores from the Denmark Strait and in paleo-magnetic records in sediment cores from southern Scandinavia (Mörner 1984a, 1986). All this is easily explained in terms of a 'rotational-gravitational-oceanographic' model (Mörner 1984a, 1984b) where there is a feed-back relation between the interchange of momentum and the redistribution of mass (and by that energy).

The model is tested against rotational records (LOD) of the last centuries and the corresponding changes in continental climate, sea level and ocean temperature (Mörner 1987a, unpublished). It is also applicable on the El Nino problem.

For the long-term changes in Atlantic circulation (e.g. Ruddiman & McIntyre 1981) the same model could be applied. It is proposed (Mörner 1984a) that the so-called Milankovitch variables have a much stronger and more important impact on climate via internal processes (including differential rotation) than via direct insolation changes.

It all leads back to the basic concepts of energy, mass and momentum.

Crustal uplift in Fennoscandia and Svalbard

The long-term crustal movements in northwestern Europe (Mörner 1980a) indicate that crustal movements and corresponding asthenospheric flow were causally connected over much larger distances than just the Fennoscandian Shield. The rapid uplift at around 22 Ma, for example, affected the whole of Fennoscandia together with the Barents Sea and the Svalbard region. Even the postglacial uplift must be analysed in a broader context than just one simple glacial isostatic process. It is clear that the uplift of the Fennoscandian Shield is composed of one exponential, typical glacial isostatic factor and one linear factor of uncertain origin (Mörner 1977b, 1979b, 1980b). The same obviously applies for the Svalbard region (Mörner 1978a) – a glacial isostatically collapsing dome over Svalbard and a linear uplift centered over the north-central Barents Sea.

It is a complete misunderstanding and misinterpretation to claim that the sea level data indicate a Late Weichselian center of glacial isostatic downwarping over the central Barents Sea.

The linear uplift factor in the Svalbard and Barents Sea area is connected with the linear uplift factor in Fennoscandia (Mörner 1978a, Fig. 1). It is caused by a phase boundary displacement or a relaxation of the low-velocity zones within the lower lithosphere (Mörner 1987b), i.e. something quite different to the horizontal astenospheric mass-flow of the glacial isostatic process.

The glacial isostatic uplift of Fennoscandia began 13,000 B.P., increased exponentially, peaked at 10,000 B.P., decreased exponentially and died out 4,500 B.P. (Mörner 1979b, 1980b). It is, therefore, of great interest that Forman & Lehman (1987) demonstrated that the uplift in NW Svalbard 'commenced slowly around 13 ka B.P.' and reached peak-rates at 10,000–9,000 B.P. This is so similar to the Fennoscandian records that there is probably a causal link between the two areas.

It is therefore interesting to note that there both at 13,000 B.P. and 10,000 B.P. were major intensifications of the Gulf Stream pulse. This should represent considerable speed-ups of the 'solid' Earth's rate of rotation. These rotational signals are likely to have affected the astenospheric mass flow in such a way as to have affected the total uplift as well. This may explain why there is no identifiable lead-lag relation between deglaciation and uplift; if anything, uplift seems to lead (instead of lagging).

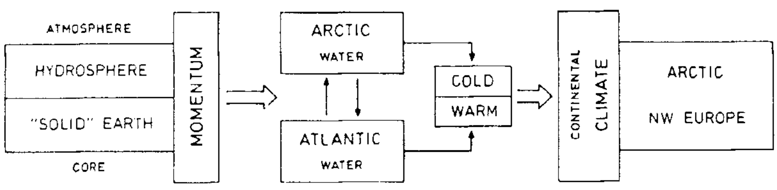

Fig. 3. The interchange of momentum between the 'solid' Earth and the hydrosphere drives the North Atlantic circulation controlling the interplay between cold Arctic water and warm Atlantic water, which has a dominant effect on the continental climatic changes within the European-Arctic sector.

Similarly, the onset of the linear uplift factor at about 8,000 B.P. is linked to the onset of a global geoid deformation cycle.

In conclusion, this indicates that all processes need to be analysed from a multiple point of view, and that the key words are interaction and complexity (Mörner 1978b).

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