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XV CONGRESS

Scandinavian eskers, global climatic relationships, and solar forcing

Jan LUNDQVIST

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The morphology of a number of eskers in Sweden formed during the down-wasting of the last Scandinavian ice sheet about 11,000 to 10,000 calendar years ago shows a subdivision into centres representing periods of 1, 3–6 and 10–11 years. It is proposed that these periods correspond to the summer/winter seasons, the El Niño — Southern Ocean (ENSO) cycle, and the sunspot cycle, respectively. If this is correct, the implication is a more global climatic relationship than earlier realised.

Jan Lundqvist, Department of Quaternary Research, Stockholm University, S-106 91 Stockholm, Sweden; e-mail: jan.lundqvist@geo.su.se

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INTRODUCTION

During the last few years a number of papers discussing the global climatic relationships have appeared. The effect of insolation upon the great climatic fluctuations has been more or less denied earlier but, recently, a paper by R. A. Kerr (1996) was titled "New Dawn for Sun-Climate Links". In such discussions recent observations from glaciofluvial deposits in Scandinavia may be relevant. A striking feature seen on many geological maps is a subdivision of eskers into shorter segments (e.g. G. De Geer, 1940; J. Lundqvist, 1958, 1987). Together, such segments form trains representing continuous meltwater tunnels in the inland ice. These features are here called esker trains, according to the terminology used by J. Lundqvist (1997) and thus slightly different from the use of this term of R. P. Goldthwait (1989). The segmentation must represent a periodicity in the meltwater discharge from the waning ice sheet, probably with a climatic background.

It has been inferred that there is a link between the esker deposits and the global climate. Gerard De Geer (e.g. 1926, 1927) had a general idea that the melting of glaciers should follow the same pattern globally and seemed scarcely explicable by any other common cause than variations in the amount of heat every year received from the sun. Due to overstatement of this idea, it became seriously disreputed. However, occasionally indications of solar forcing of the meltwater activity have appeared. For instance, in the same area where G. De Geer made his basic studies, H. Möller (1962) found evidence for an imprint of the sunspot cycle in some big Swedish eskers.

SEGMENTATION OF ESKERS

Eskers in the Swedish part of Scandinavia are often high ridges of gravel and sand. The ridges are mostly subdivided into shorter segments, implying an undulating crest with hills separated by lower parts. This segmentation is a result of variations in the sediment supply by the meltwater from the inland ice. A simple correlation between esker morphology and other factors can never be expected. There will always be a lot of noise depending on local topographic conditions in terms of sediment supply and meltwater inflow from different sources, but the striking segmentation of eskers in some areas has implied a challenge to analyse the cyclicity and its possible connection with climate. With this background four areas in southern to central Sweden have been selected for a closer study.

All the studied eskers were formed at tunnel mouths in an ice margin below the coastline of that time, that is, in subaquatic environment in accordance with G. De Geer's (1897) model. They are surrounded and partly covered by varved

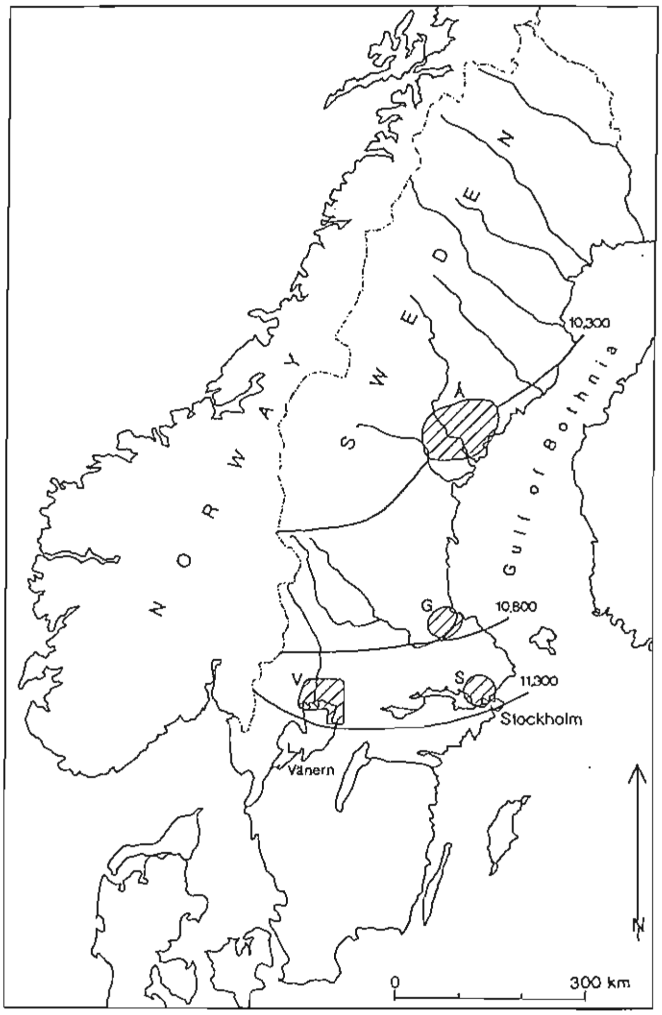

Fig. 1. Studied areas

Å — Ångermanland, G — Gävle, S — Stockholm; V — Värmland; lines with numbers show the ice margin with age in calibrated (calendar) years

glacial clay, making it possible to use the clay-varve dating method (G. De Geer, 1940) for dating at least in a local time scale. The regions included in this study are the Stockholm area (S in Fig. 1), southern Värmland 300 km to the west (V), the Gävle area 200 km to the north (G), and the province of Ångermanland another 300 km northwards (Å).

These regions were deglaciated in the Preboreal time and just at the beginning of the Boreal. The deglaciation there has been dated mainly with the clay-varve method (B. Strömberg, 1989) and ^{14}C. These methods do not give dates in agreement with each other (B. Wohlfarth *et al.*, 1997). Therefore all dates in the following are given in years calibrated according to H. Kitagawa and J. van der Plicht (1998). This implies dates from 11,300 to 10,000 calibrated yr BP for the deglaciation of the area under consideration.

A study of esker trains in the four areas together with some additional information from other places has given the following result. Over the Värmland–Stockholm region the retreating ice margin passed 11,200 to 10,900 BP (B. Strömberg, 1989; J. Lundqvist, 1997). The **Stockholm area** is the one studied by G. De Geer (see 1940) and H. Möller (1962). Here G. De Geer (1940) especially emphasized the occurrence of annual hills in the big eskers. This periodicity was even noticed as early as around 1880 in the Uppsala esker 70 km to the north (published by G. De Geer, 1937). However, on his 1940 maps a grouping of annual centres to units representing about 3–4 years can also be noticed. By means of detailed clay-varve chronology, H. Möller (1962) traced the 11-yr cycle in the same eskers.

The results from **Värmland** have been published in detail in a sedimentological paper on eskers (J. Lundqvist, 1997). In this region, corresponding to the early Preboreal, a 10–11-yr cycle is very clear. This value is the average from seven eskers with subunits corresponding to a cycle of 9 to 12 years and only one extreme value of 7.5. If we exclude this value the mean will be 10.7. Immediately to the south there is the basin of the big Lake Vänern and east of it the Närke plain, over which the retreat proceeded considerably faster. Here the 11-yr cycle is not obvious, but instead there is a distinct subdivision of eskers (Fig. 2) corresponding to the annual retreat of the margin around 11,300 to 11,200 BP. The occurrence of annual esker hills is also superimposed on the 11-yr cycle, although obscured in some eskers.

In the **Gävle region**, deglaciated around 10,800 (10,900 – 10,750) BP (B. Strömberg, 1989), the sediment supply seems to have been more even, and most pronouncedly after 10,750 BP. Eskers are more coherent and only their crests show undulations corresponding to the breaks in the above-mentioned esker trains. Two large esker trains were considered here. Their subdivision corresponds to 7.5 and 14 years, respectively. Within each train subsequent segments give a mean value of 10.5. Although much less convincing, this is in agreement with the values from the southern region. However, within the different segments a subdivision of lower order is seen, corresponding to a cycle of 2.5 to 3.5 yr, with a mean value from several units around 3. Towards the north this cycle seems to become somewhat longer, 5–6 yr, thus approaching the 7.5 yr subdivision.

Twelve esker trains were studied in the province of **Ångermanland** (*cf.* J. Lundqvist, 1987). In the coastal area, deglaciated about 10,400 BP (I. Fözö, 1980), we find a tendency to a 3-yr cycle. If we omit two eskers where observations are poor due to clay cover and excavations, the uniformity is very good. Towards the inland, in an area deglaciated 10,300–10,200 BP, the individual units seem to correspond to a slightly shorter time, 2.5–3 years. This is based on observations from all 12 eskers, the uncertain cases included. Since there are parts of the eskers where the values may refer to a cycle of lower order this figure is probably too low. Several other parts show cycles of 4.5 to 5.3 years. Values ranging from 0.5 to 1.5 yr are obtained from small esker segments. Most probably they represent annual variations. These are best developed on the highest levels approaching the coastline of that time and in the near-coastal area.

Finally, it may be relevant that H. Möller (1962) by map studies found traces of the 11-yr cycle also at the northernmost part of the Gulf of Bothnia, another 300 km to the north. However, since no field studies were made this observation must be considered uncertain. The area was deglaciated around 10,000 BP.

In summary, in early Preboreal (11.2–10.9 ka BP) a 10–11-yr cycle can be traced. A shorter cycle, 3–6 yr, is first noticed around 10.8 ka BP, and becomes more distinct from about 10.4 to 10.2 ka BP. There is a tendency to shortening with time, but this could be an effect of increased influence of seasonal variations. Possibly there is an increased influence of the 11-yr cycle around 10 ka BP but this is highly uncertain due to limited information. In spite of some amount of noise the tendencies are clear.

CONCLUSIONS

Although there is a lot of noise in the observations described above, they seem to indicate a periodicity in the morphology (sediment amount) of the eskers within the area under consideration. Except the lowlands mentioned above, the landscape is undulating with a bedrock relief of 50–400 m, often with steep bedrock hills and sharply incised valleys. We would expect that local topographic irregularities should complicate the pattern. Since this is the case only to a surprisingly small extent it is reasonable to assume some regional forcing factor, possibly the climate-related glacier melting.

The 1-yr periodicity corresponding to the summer/winter cycle is most obvious in areas where the ice margin was standing in deep water. In such areas there was minor topographic influence and fast retreat. However, a similar periodicity is also noticed towards the supra-aquatic area where the water depth was smaller and calving less important. The relation between the annual cycle and the melting/freezing is easy to understand. Even in a big ice sheet there is more melting during the summer and refreezing during the winter.

The cycles of 3–6 years and about 11 years are more enigmatic. The 11-yr cycle supports the effect of the sunspot cycle in spite of its weakness. The general influence of solar forcing has been observed recently in several studies (M. Stuiver *et al.*, 1995; T. J. Crowley, K.-Y. Kim, 1996). As pointed out by R. A. Kerr (1996) with quotations from other researchers that influence is of the order of tenths or even hundredths of a degree. Obviously we need an amplifying factor. The sunspot signal can only have a triggering effect. Our eskers do not give an answer to this question but the very fact should stimulate the quest for an amplifier.

The 3–6 yr period might be somewhat easier to visualise. The only known cycle of that magnitude is related to the El Niño — Southern Ocean (ENSO) phenomenon. El Niño is a process belonging to the southern Pacific but its effects upon the climate at least all over the southern hemisphere are but too well known. However, there seems also to be a global effect, either of El Niño itself or of an unknown factor with influence upon the global climate. A periodicity of the same order was noticed in tree rings and varved clay in Scandinavia already by G. Sirén and P. Hari (1971). Recent studies have given more evidence for the global effect of El Niño (E. M. Rasmusson, 1985; R. H. Grove, 1998). Most work on this topic has concerned the last few centuries but there are also indications that El Niño was active as early as 12,700 calendar years ago (G. Sirén, P. Hari, 1971; D. K. Keefer *et al.*, 1998). The time period identified covers the whole time span under consideration here. The implication, although speculative, would be that there is some other link than the North Atlantic circulation system between the northern hemisphere glaciated regions and the rest of the world, at least if W. S. Broecker and G. H. Denton (1989) are on the right track when they claim that the conveyor belt formed by the North Atlantic current system was shut off in glacial times.

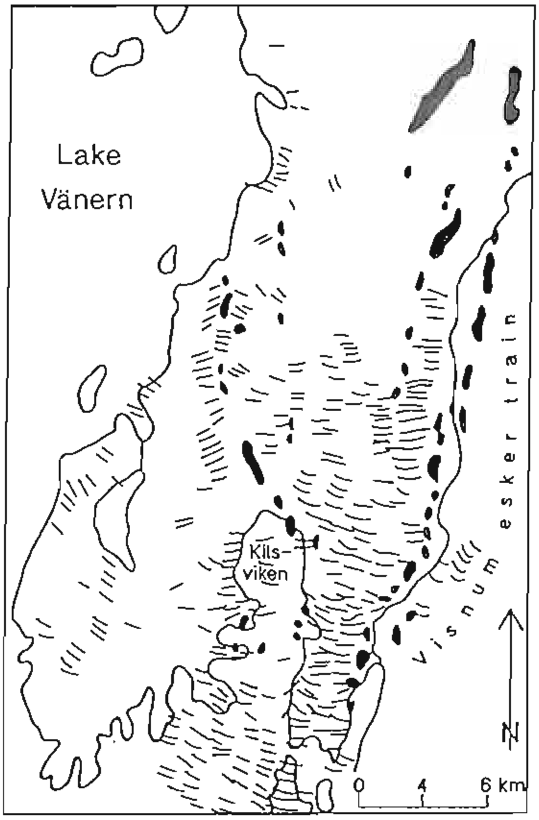

Fig. 2. Eskers in southeastern Värmland (the southeastern corner of the area V in Fig. 1)

Black is eskers, the eastern of which is discussed here. Small lines show minor moraines. Reprinted from "Structure and rhythmic pattern of glaciofluvial deposits north of Lake Vänern, south-central Sweden" by J. Lundqvist (1997, p. 135), by permission of Scandinavian University Press

In conclusion, it is inferred here that the signal of three cycles can be traced in the down-wasting of the last Pleistocene Scandinavian ice sheet. These cycles correspond to the year, El Niño, and the sunspots. The ideas are speculative but if correct, they may have a significance for the understanding of the global climate.

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OZY W SZWECJI A GLOBALNE ZWIĄZKI KLIMATYCZNE I ZMIENNOŚĆ PROMIENIOWANIA SŁONECZNEGO

Streszczenie

W morfologii wielu ozów szwedzkich, powstałych podczas zaniku ostatniego lądolodu skandynawskiego 11–10 tysięcy lat temu, zaznaczają się kulminacje reprezentujące okresy jednoroczne oraz 3–6- i 10–11-letnie (fig. 1, 2). Przypuszczalnie okresy te są spowodowane odpowiednio przez sezonowość letnio-zimową, cykliczność zjawiska El Niño oraz zmieniającą się intensywność plam słonecznych. Jeśli takie powiązania okazałyby się prawdziwe, to mielibyśmy znacznie więcej globalnych zależności klimatycznych niż przypuszczano dotychczas.