Geophysical Research Abstracts, Vol. 7, 08082, 2005
SRef-ID: 1607-7962/gra/EGU05-A-08082

Mapping Layer Sequence and Folds of Pre-Holocene ice at the Greenland Ice-Sheet Margin to support Mining of Ice for Paleo-Environmental Studies

N. Reeh (1), J. Severinghaus (2), A. Ahlstrøm (1), E. Brook (3), V. Petrenko (2)

(1) Ørsted-DTU, Technical University of Denmark, Ørsteds Plads Building 348, DK-2800 Kgs. Lyngby, Denmark, (2) Scripps Institution of Oceanography, University of California, San Diego, La Jolla, CA 92093 USA, (3) Oregon State University, Department of Geosciences, 104 Wilkinson Hall, Cornvallis, OR 97330 USA (nr@oersted.dtu.dk / Phone: +45 45 25 38 38).

INTRODUCTION

Ice-core records from the large ice sheets of the Polar regions have provided rich information about climate and environmental changes during the past 400 000 years (400 ka) as demonstrated by the results of deep ice-core drilling programs in central Greenland (e.g. Dansgaard and others 1982; 1993) and Antarctica (Lorius and others 1985; Jouzel and others 1987). However, the old ice found at depth in the central regions of the ice sheets can also be retrieved from the ice sheet margin (Lorius and Merlivat 1977; Reeh and others 1987; 1991; 2002).

Since 1985, surface ice samples have been collected at 15 different ice-margin locations in Greenland (Reeh and others, 2002). A chronology for the ice margin records was established by correlating characteristic δ^{18}O-features (a proxy for the air temperature at the time when the ice was originally deposited on the ice sheet) in the ice margin records with similar features in dated Greenland deep ice core records. This showed that, at many ice-margin locations, a several hundred metre wide band of ice older than 11.5 ka, i.e. ice older than the present warm interglacial, exists adjacent to the ice edge.

In spite of the fact that, for a long time, it has thus been known that ancient ice occurs at the surface of the Greenland ice sheet margin, attempts at utilising this potential for retrieving large samples of ice for paleo-environmental studies were first initiated in 2001 (Petrenko and others, 2002). The main concerns have been (1) Likely disturbances of the layer sequence by folding and faults either at the ice margin proper or during the long travel of the ice from its deposition site far inland to its present site of occurrence at the ice margin, (2) Possible changes of trace constituents particularly the gas composition in the air inclusions in the ice, and (3) Lack of reliable dating methods for the ice at the margin.

However, recent studies on the ice-sheet margin at Pakitsoq, 50 km northeast of Ilulissat/Jakobshavn, West Greenland have demonstrated that these shortcomings can, to a large extent, be overcome. Concentration of gases retrieved from air-inclusions in the ice samples (e.g. Methane, δ^{18}O, and δ^{15}N), expected to be from the termination of the Younger Dryas cold interval 11,600 years ago, showed the same characteristic changes as found in Younger Dryas ice from Greenland deep ice cores (Petrenko and others, 2002). This shows that important trace constituents are still intact in the margin ice, and that it is possible to "date" the marginal ice with sufficient precision to make it useful for paleo-environmental studies. Thus big samples of well-dated old ice with intact content of trace constituents are potentially available at Greenland ice-sheet margins. The perspective is that trace constituents with concentrations so small that analysis has hitherto been hindered because of the limited amount of ice-core ice can now be investigated.

MAPPING FOLD GEOMETRY

Analysis of trace constituents such as methane, δ^{18}O of ice and air, and δ^{15}N as well as visual inspection also demonstrated the occurrence of a large-scale fold in Pakitsoq ice representing the Allerød/Younger Dryas/Pre-Boreal climate oscillation.

The ice margin at Pakitsoq has been studied since 1985 (Reeh and others 1987; 1991; 2002; Thomsen and Reeh 1994), providing information on ice ablation, surface and bottom topography, and ice-dynamics (Thomsen and others 1988; Reeh and others 1994). Ice older than 11.5 ka (Pre-Holocene ice) forms a c 500 m wide band adjacent to the ice edge. Visual inspection and shallow core drilling indicate a dip of the stratigraphy of c. 70°. Since 1992, the width of the Pre-Holocene ice band has diminished by 7 – 8 m/a. In the same period, the ice thickness has decreased by almost 1 m/a, because ice ablation (3 m/a) presently exceeds the vertical ice velocity supplying new ice to the surface (2 m/a). These observations clearly show that the Pakitsoq ice-margin sector is presently far from a balanced state, stressing the need for developing a model for the evolution of the ice margin in order to support the ice-mining activities.

MODEL FOR THE TIME EVOLUTION OF THE STRATIGRAPHY

Here, we report on the development of such a model based on mapping the large-scale structures on the Pakitsoq ice margin by using GPS, ground penetrating radar (GPR), and trace element geo-chemical analysis (mainly δ^{18}O-analysis of ice samples). The samples for δ^{18}O-analysis were collected in several profiles across the large scale fold in the ice from the termination of the Younger Dryas period. The sampling was repeated in subsequent field seasons (2002, 2003 and 2004) in order to document the time evolution of the large-scale structures. Altogether more than 2000 samples were collected. Photographs taken from helicopter provided an overview of the fold. Poles were drilled into the ice in a network for measuring ablation rate (ice melt) and ice velocity and deformation.

The results of the different mapping methods were combined with observations of ice flow and deformation to set up a model for the three-dimensional structural evolution of the ice margin.

REFERENCES

Dansgaard, W., Clausen, H.B., Gundestrup, H., Hammer, C.U., Johnsen, S.J., Kristinsdottir, P.M. & Reeh, N. 1982: A new Greenland deep ice core. *Science* **218**, 1273-1277.

Dansgaard, W., Johnsen, S.J., Clausen, H.B., Dahl-Jensen, D., Gundestrup, N.S., Hammer, C.U., Hvidberg, C.S., Steffensen, J.P., Sveinbjörnsdottir, A.E., Jouzel, J. & Bond, G. 1993: Evidence for general instability of past climate from a 250-kyr ice-core record. *Nature* **364**, 218-220.

Jouzel, J., Lorius, C., Petit, J.R., Barkov, N.I., Kotlyakov, V.M. & Petrov, V.M. 1987: Vostok ice core. A continuous isotopic temperature record over the last climatic cycle (160,000 years). *Nature Lond.* **329**, 403-408.

Lorius, C. & Melivat, L. 1977: Distribution of mean surface stable isotope values in East Antarctica. Observed changes with depth in the coastal area. *Publ. Assoc. int. hydrol. Scient*. **118**, 127-137.

Lorius, C., Jouzel, J., Ritz, C., Merlivat, L., Barkov, N.I., Korotkevich, Y.S. & Kotlyakov, V.M. 1985: A 150,000-year climatic record from Antarctica ice. *Nature* Lond. **316**, 591-596.

Petrenko, V.V., Severinghaus, J., Brook, E., & Reeh,N. 2002: Using Methane ^{14}C to Determine the Origin of the Rapid Methane Rise at the End of the Younger Dryas 11,600 Years Ago: Increased Wetland Production or Methane Hydrates? A Progress Report**.** Poster presented at the American Geophysical Union 2002 Fall Meeting, San Francisco. *Eos Trans. AGU*, **83(47)**, Fall Meet. Suppl., Abstract pp61a-0307.

Reeh, N., Thomsen, H.H. & Clausen, H.B. 1987: The Greenland ice-sheet margin - a mine of ice for paleo-environmental studies. *Palaeogeogr. Palaeoclimatol. Palaeoecol.*

(Global planet. Change Sect.) **58**, 229-234.

Reeh, N., Oerter, H., Letréguilly, A., Miller, H. & Hubberten, H.W. 1991: A new, detailed ice-age oxygen-18 record from the ice-sheet margin in central West Greenland. *Palaeogeogr. Palaeoclimatol. Palaeoecol. (Global planet. Change Sect.)* **90**, 373-383.

Reeh, N., Thomsen, H.H., Oerter, H. & Bøggild, C.E. 1994: Surface topography, ice ablation, ice deformation and velocities along the Paakitsoq profile sampling line. *In* Thomsen, H.H. & Reeh, N. (ed.) Field report on palaeo-environmental studies at the Greenland ice sheet margin, Paakitsoq, West Greenland, 1994. *Open File Ser. Grønlands geol. Unders.* **94/15**, 20-29.

Reeh, N., Oerter, H., and Thomsen, H.H, 2002: Comparison between Greenland ice-margin and Ice-core Oxygen-18 records. *Annals of Glaciology*. **35**, 136-144.

Thomsen, H.H., Thorning, L. & Braithwaite, R.J., 1988: Glacier-hydrological conditions on the Inland Ice north-east of Jakobshavn/Ilulissat, West Greenlanf. *Rapp. Grønlands geol. Unders.* **138**.

Thomsen, H.H. & Reeh, N. (ed.) 1994: Field report on palaeo-environmental studies at the Greenland ice sheet margin, Paakitsoq, West Greenland, 1994. *Open File Ser. Grønlands geol. Unders.* **94/15**, 44 p