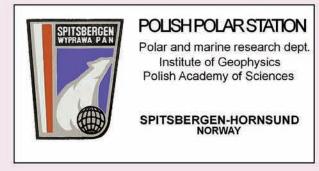


HOW ARE THE WATER SIGNALS ON A POLYTHERMAL GLACIER? MRS PILOT STUDY ON HANSBREEN GLACIER, HORNSUND, **SW SPITZBERG (NORWAY)**

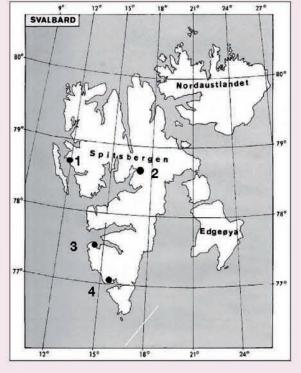


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NMR Survey on Svalbard

A first expedition was done in 2007 looking for candidate glaciers: 1-Elisebreen on Kaffioyra (Forlandsundet), 2-Ebbabreen on Petuniabukta (Billefjorden), 3-Scottbreen and Renarbreen o n Calypsobyen (Bellsund) and 4- Hansbreen (Hornsund, next figure). The last location was the best site to do a large surface NMR survey, done between half august and half september 2009 by a gant from the Polish Institute of Geophysics.



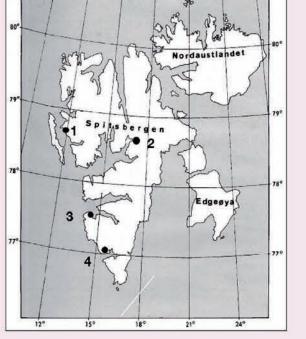
Polythermal glacier

Polythermal glaciers are widely sperad on polar regions and glaciated mountains. They have a layer of cold-ice (temperature below melting point) on acumulation zone and a temperate ice layer in their ablation zone. The subpolar Svalbard-type polythermal glaciers have the particularity that are predominantly cold-ice glaciers with a thin layer of warm basal ice beneth, on centre and ablation areas (next figure).

Enlarged area

Profile a

Profile b



Introduction and methods

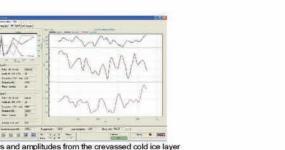
Using the properties of the Larmor frequency on a electromagnetic field hydrogen protons from water molecules can be excited if an electromagnetic pulse is sent to the underground by a transmitter from the surface. When the electromagnetic pulse is removed, the absorbed energy is released and can be detected by a receiver device (a new electromagnetic field is obtained at the Larmor frequency). That signal usually produce a voltage which amplitude decays exponentially with time until it vanishes, in witch the decay time depends on the permeability and the amplitude is directly related to the amount of water. NMR technique becomes a MRS method (magnetic resonance sounding, MRS) when the excitation field is increased at each step to obtain signals from deeper parts of the subsurface. However that techniques are limited by the electrical conductivity of the subsurface, the magnetic field (inclination and magnitude), the type of water containing rocks, the size of the antenna and the electromagnetic noise. The best conditions are met in resistive rocks (like the ice), no magnetic environments (volcanic rocks), high latitudes (like Svalbard), and coarse grained rocks or highly fractured rocks (fractured ice or crevasses), non salty water (low resistivity), low electronic noise (like in a polar environment) and large antennas. Extensive literature can be checked at : http://www.igeotest.ad/MRS/DocMRS.htm

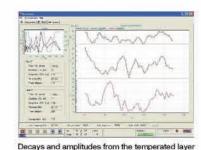
Field work

From the 21 August until the 10 September it has been done 19 NMR soundings (MRS) with the support of the Wroclawski University. For that a Numis LiteÆ device was used from Iris-Instruments and its available software as well (Prodiviner 3.04, Phar Lap's 386, Samovar). Those 19 MRS were placed on six stations and loops sizes range done were 30X30 m, 60X60, 90X90 and 120X120. Five electrical vertical soundings (VES) with an ABEM device (courtesy of the Faculty of Earth Sciences Silesia University) were done on the glacier margins, but als two resistivity measurements on the inner part of the Hansbreen glacier and the front of the glacier were done. Is important to note that a increasing loop size will integrate signals from different zones that have not been detected in the previous loop, so the average information is less particular and more general; also the accuracy in depth is lesser with large loops than with small ones and only common facies of the water signals can be correlated.

NMR signals

Looking at the signals of MRS 8 to MRS 11 on the middle of the glacier we obtain from the 30X30 loop the water content of the subsurface reaching values above 2% of water content (Eo= 24 nV). A general decreasing pattern in water content can be observed. Decays of the signals are above 200 ms. Enlarging the loop we obtain water signal in depth but also from other superficial runoff streams. In that sense at the firsts meters high water signals are detected (amplitudes of 60 nV and water content close to 8,5%), also high decays (more than 300 ms) are obtained. A general decreasing pattern in water content can be observed till 36 m depth. At deeper depths the water content increase but under a 2% (Eo<25 nV). Next loop (90 X 90 m) reach depths below 90 m but low water signals still appears (<2%, Eo<20 nV). Finally the dimension of the biggest loop (120x120 m) can be influenced by the anisotropy of the geological system and different signals can be detected, in consequence the data can have more than one solution and it means that in essence we are reaching a non layered boundary (substratum or sedimentary aquifer). Here high amplitude of water signals are obtained (Eo > 30 nV) and relative large decays are also observed (150 - 300 ms).

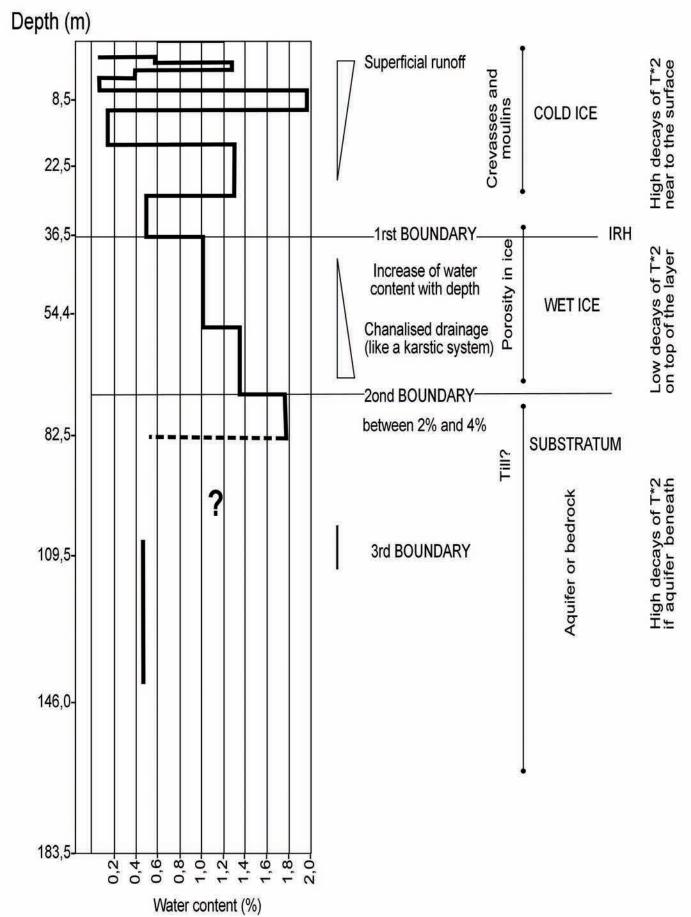




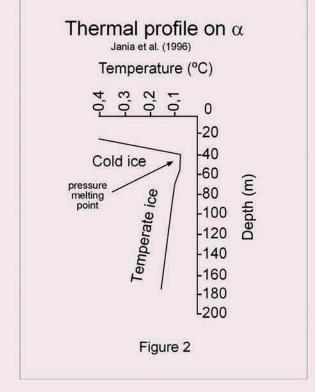
NMR survey on Hansbreen: Glaciological results



1D SYNTHETIC MODEL



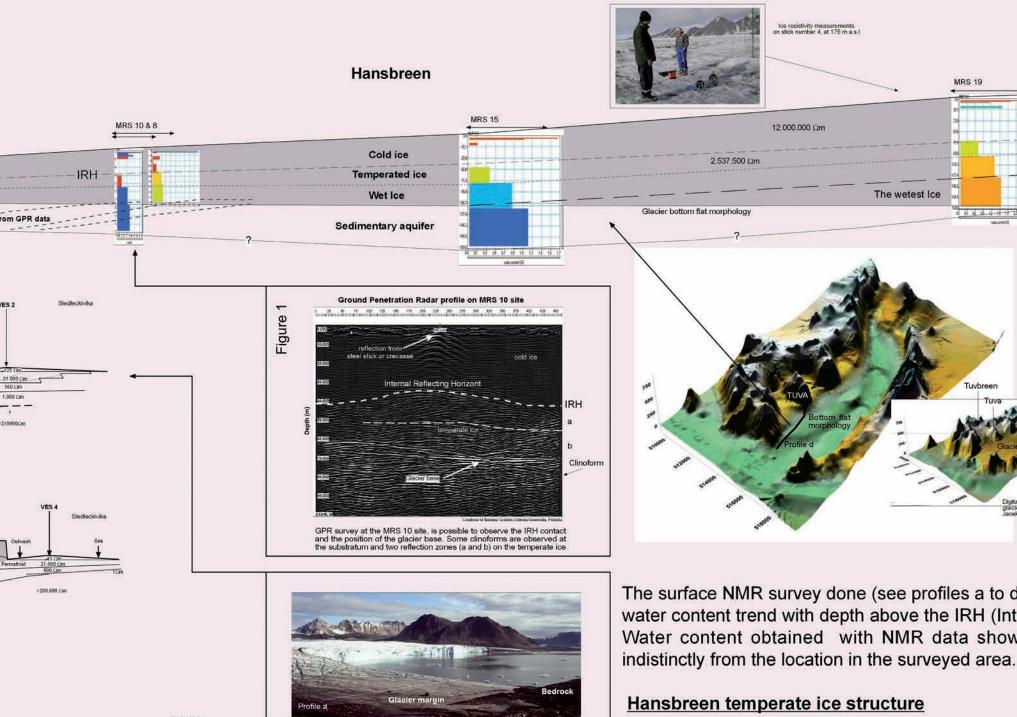
temperate ice below Thermal profile on α



Profile d

Crystal Cave galleries (>300 m)

S-N



Hansbreen front and Siedleckivika bay on september 2009, location of the profile "a

The surface NMR survey done (see profiles a to d) usualy had a decreasing water content trend with depth above the IRH (Internal Reflecting Horizont). Water content obtained with NMR data show values higher than 3%

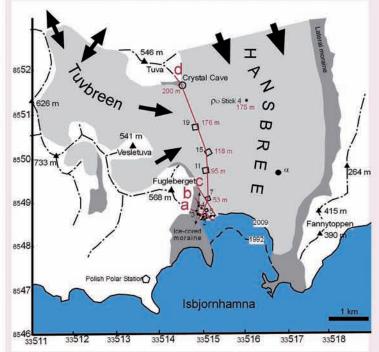
Hansbreen temperate ice structure

Hansbreen ablation zone has a complex temperate ice structure, uplighted by the surface NMR survey done on september 2009 (see profiles a to d). Below the IRH (Internal Reflecting Horizont) a general increasing water content trend with depth can be observed, but also from top (Tuva and Cristal Cave zone) to front (Siedleckivika bay). Such thermal structure has been also recognised on Crystal Cave (Tuva) by Benn et al. (2009), where at 60 m depth those authors locate the boundary between cold and tempered ice. Also from GRP data is possible to distinguish, regarding the reflection densities, two levels on the temperated ice layer (see figure 1), related both with the water content quantity on ice. Water content obtained with NMR data, using specific software (Samovar 6.2 from Anatoly Legchenko), show values lesser than 3%. Such results are consistenst with GPR data (Moore et al. 1999) in Hansbreen. Similar values are obtained on the Rhone glacier in th Alps (Walbrecker et al., 2008), a temperaded glacier recently surveyed with surface NMR techniques.

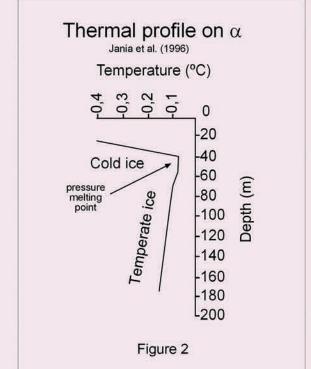
Hansbreen glacier



Hansbreen glacier is a medium size (56 sq. Km) Svalbard tidewater glacier located close to the Polish Polar Station Fjord Hornsund (1). A surface NMR has been done on the ablation zone, between the front (2) on Siedleckivika bay and the Tuva mountain (3). In Hansbreen it has been observed that the ablation depends on daily mean and maximum air temperatures, but also in wind speed conditions. So the water flow through crevasses and moulines can change quickly from one day to other on the first 20 m depth.



Two main layers forms the thermal structure at the ablation zone, cold ice for the uppermost layer and



Acknowledgements

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Profile c

Hansbreen cold ice structure

Hansbreen ablation zone has a cold ice layer above temperate ice. Such boundary is reached below 20 m depth, reaching the pressure melting point in wich an inversion of the thermal structure is observed (figure 2). High values of water content are observed from GPR (Ground Penetration Radar), typically 4 % (Moore et al., 1999) associated with surface crevassing and moulins. Those authors also observe that saturated crevasses overlays dryer ice.

Literature

Benn, D.; Gulley, J.; Luckman, A.; Adamek, A.; Glowacki, P.S. (2009) Englacial drainage systems formed by hydrologically driven crevasse propagation; Journal o Glaciology, 55, 191, 513-523

Vertical shafts were folloed through more than 70 m to subglacial conduit. Deep hydrofracturing occurred at this site due to a combination of extensional ice flow and abundant surface metwater at a glacier confluence. The surface-to-bed drainage can occur wherever high meltwater supply coincides with ice large tensile stresses (Benn et al., 2009)

Jania, J.; Mochnacki, D. and Gadek, B. (1996) The thermal structure of Hansbreen, a tidewater glacier in southern Spitsbergen, Svalbard; Polar Research, 15 (1), 53-66

Walbrecker, J., Hertrich, M. and van der Kruk, J. (2008), Water content determination on the Rhone glacier (Valais, Switzerland) using sample-scale-NMR, surface-NMR and GPR methods. Abstract from poster sesion at the 68. Jahrestagung der Deutschen Geophysikalischen Gesellschaft 3.-6. Mars 2008 in Freiberg, Germany, pag. 108

Moore, J.C.; Pälli, A.; Ludwig, F.; Blatter, H.; Jania, J.; Gadek, B.; Glowacki, P.; Mochnacki, D. and Isaksson, E. (1999) Highresolution hydrothermal structure of Hansbreen, Spitsbergen, mapped by ground-penetrating radar; Journal of Glaciology, 45, 151, 524-532