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ICE

INTERNATIONAL GLACIOLOGICAL SOCIETY

S Y M P O S I A

1982 August 23-27, New Hampshire, U.S.A.

SECOND SYMPOSIUM ON APPLIED GLACIOLOGY

(see pages 20-22 of this issue of ICE)

1984 September 2-7, Sapporo, Japan

SYMPOSIUM ON SNOW AND ICE PROCESSES AT THE EARTH'S SURFACE

Co-sponsored by the Japanese Society of Snow and Ice
(First announcement)

....

We also hope to hold a symposium in **1983**—a First Circular will be published soon, when the venue has been decided.

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ICE
NEWS BULLETIN OF THE INTERNATIONAL GLACIOLOGICAL SOCIETY

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CONTENTS

Members who joined the field trip following last year's Geilo meeting may be interested in the account of the flash flood in Jostedalen (page 5) contained in the Norwegian report submitted by Dr Gunnar Østrem.

This issue of ICE profiles the Division of Building Research with which our immediate past President Dr Lorne Gold is associated. In a future issue we hope to be able to present a profile on the British Antarctic Survey with which our new President Dr Charles Swithinbank is affiliated.

The Society's 1982 Symposium on Applied Glaciology will be held in Hanover, New Hampshire. First indications are that the meeting will be well attended. The various deadlines are given in the 2nd Circular and are summarized at the bottom of page 21.

COVER PICTURE. Scanning electron micrograph of a replica of dislocation structures in ice deformed to fracture (obtained by N. Sinha, DBR, see Profile p.15). Magnification: 2500 x.

DENMARK (GREENLAND)

GLACIER INVENTORY OF WEST GREENLAND

(A. Weidick, Geological Survey of Greenland (GGU), Copenhagen; N.T. Knudsen, Geological Institute, Århus University (GI/ÅU), Århus)

A glacier inventory of West Greenland is being made by the Glaciology Section of the Geological Survey of Greenland. The TTS World Glacier Inventory specifications are being followed as closely as the special conditions of Greenland allow. The geographical area covered is 484,000 km² between the southern tip of Greenland and latitude 71°N and between the west coast and the summit of the Inland Ice. According to the earlier inventory of hydrological basins about 85% of the area is covered by glacier ice. By May 1981 drafts of 76 of the 109 1:250,000 scale atlas sheets had been completed and over 3000 glaciers located and coded.

For areas of special interest (e.g. planning for hydropower development) a more detailed description of the glaciers is planned. The Geological Institute, Århus University, has completed a description of the glaciers between latitudes 63° and 64°N (N.T. Knudsen and A. Weidick: Glacier inventory, West Greenland, joint publication GI/ÅU and GGU).

QAMANÂRSSÛP SERMIA – FIELD WORK 1980

(O. Olesen, GGU, Copenhagen)

The station is located at approximately 64° 28'N, 49°30'W, at the head of Godthåbsfjord (Kangersuneq), and an elevation of 750 m. The work was started in 1979 and continues with measurement of the summer and winter mass balance on a lobe from the Inland Ice: Qamanârssûp sermia (1CH21002). A map (terrestrial photogrammetry) of this and the neighbouring unnamed lobe (1CH21001), at a scale of 1:10,000 with 10 m contour intervals, was made by the Geological Institute, Århus University (J.T. Møller, N.T. Knudsen).

JOHAN DAHL LAND – FIELD WORK 1980

(P. Clement, GGU, Copenhagen)

The station is located at 61°21'48"N, 45°21' 31"W in the Johan Dahl Land basin (1AG05), South Greenland, at an elevation of 850 m a.s.l. Glaciological investigations were started in 1977 and include mass balance measurements on the following glaciers: 1AG05001 – Nordbogletscher (Kukulup sermia), 1AG05008 and 1AG05009. Nordbogletscher is an outlet from the Inland Ice with an area of 208 km² while the other two are small local glaciers within the same hydrological basin. On all three glaciers complete mass balance was determined for the budget year 1979/80. Detailed ablation measurements were made on the tongue of Nordbogletscher and climatological elements were recorded at two weather stations. Observations were also made on a number of ice-dammed lakes and glacier fronts in the area.

Sedimentological investigations (air gun profile) on the amount of sedimentation and thickness of sediment in the proglacial lake of Nordbosø were carried out in collaboration with the Institute of Technical Geology, Technical University, Copenhagen.

MODELLING GLACIER RUNOFF IN WEST GREENLAND

(R.J. Braithwaite, GGU, Copenhagen)

A long-term project is underway at the Geological Survey of Greenland to develop runoff models which can be applied to the planning of hydropower projects in Greenland. A first regional runoff model for glaciers in equilibrium has been implemented. The model calculates mean annual runoff and its coefficient of variation and predicts that specific runoff from glacierized basins should be both higher and less variable than the runoff from unglacierized basins under the same conditions. A more advanced runoff model which includes explicit calculations of year-to-year variations in glacier mass balance is under development for Johan Dahl Land in South Greenland. The role of refreezing of meltwater requires further clarification but preliminary results from the model suggest that the observed runoff from Johan Dahl Land in 1976-79 is a little higher than the average for the last twenty years.

RUNOFF FROM GLACIERIZED BASINS IN GREENLAND AND CANADA

(L. Gottlieb, Institute of Hydrodynamics and Hydraulic Engineering, Danish Technical University, Lyngby)

Work has been continued on the development and application of a day-to-day runoff model for glacierized basins, using meteorological variables as input data. The model has been applied to two highly glacierized basins: the Peyto Glacier basin, western Canada, and Johan Dahl Land, South Greenland.

GISP DEEP DRILLING COMPLETED

(W. Dansgaard, N. Gundestrup and S.J. Johnsen, Geophysical Isotope Laboratory, University of Copenhagen, Copenhagen, Denmark)

Penetration to bedrock, the main goal of the joint American-Danish-Swiss Greenland Ice Sheet Program, was achieved at DYE 3. Drilling began in late May from the 901 m depth reached in 1980. The core diameter was 10 cm, recovery 100%, and the quality excellent. In the last six weeks of the season drilling speed averaged 115 m/week. From 700-1400 m the ice was brittle, from 2015 m onwards it was increasingly silty with pebbles of up to 1.5 cm diameter. The new electromechanical, battery-computer operated drill was not designed to work on silt yet it penetrated more than 20 m of silt before sticking at 2037 m depth on August 10.

DENMARK (NORWAY)

OKSTINDAN, NORWAY

(N.T. Knudsen and J.T. Møller, GI/ÅU; W.H. Theakstone, Manchester University, U.K.)

Measurements of meteorological variables including radiation, temperature, wind speed and humidity profiles and precipitation at and around Austre Okstindbre were continued. Meltwater flow and ablation was measured, together with variations in meltwater conductivity. Water samples were collected for determination of O^{18}/O^{16} o/oo and chemical constituents. Ice surface velocities were determined at 10 stakes placed in the ablation area the previous summer.

FINLAND

STRUCTURE AND MECHANICS OF PACK ICE, BOTHNIAN BAY

(M. Leppäranta, Institute of Marine Research, Helsinki)

The sea ice research program of the Institute aims at developing methods for sea ice forecasting in the Baltic Sea. In April 1979 the research vessel Aranda drifted with the ice in the Bothnian Bay for two weeks. A recently completed dissertation reports that the ice pack was found to be fractured into separate floes the diameters of which were fairly evenly distributed from tens of metres to 4-5 km. The thickness of level ice was about 0.5 m and the amount of deformed ice was comparable. Rates of pack ice deformation were about $10^{-6}s^{-1}$ over several hours. Ice drift followed the wind rather well with a response time shorter than one hour. Ice velocity spectra showed no clear peak at the Coriolis period. The governing forces in ice drift were the surface shear stresses of wind and water on ice and the internal friction within the ice. Estimates of the bulk and shear viscosities of pack ice varied in the range 10^7 to 10^{10} kg s^{-1}, while the compactness was 0.89-0.95. Largest viscosities resulted when the compactness was at its highest and at the same time deformation rates were small or the ice was ridging. Dissipation of kinetic energy in internal deformation processes was significant, and the main energy sinks were the friction in shearing between ice floes and the production of potential energy in ice ridges; the former was several times larger than the latter.

NORWAY

MASS BALANCE, METEOROLOGICAL AND HYDROLOGICAL INVESTIGATIONS AT SELECTED GLACIERS 1979

The Norwegian Water Resources and Electricity Board (NVE) conducted mass balance investigations at five glaciers in southern Norway, Ålfotbreen, near the western coast, Bondhusbreen, an outlet glacier from Folgefonni south of the Hardanger Fiord, Nigardsbreen, one of the largest outlet glaciers from Jostedalsbreen, the largest continuous ice mass in northern Europe, and two glaciers in Jotunheimen, Hellstugubreen and Gråsubreen, and one glacier in northern Norway, Engabreen. The Norwegian Polar Research Institute (Norsk Polarinstitutt) performed mass balance studies at two other glaciers in southern Norway.

ÅLFOTBREEN

When the winter balance was observed at the end of April only three stakes had survived the heavy winter accumulation. Snow depth soundings were made at 240 points relatively evenly distributed over the glacier surface, i.e. about 50 points per km^2. Snow depths varied from 4-8 m. The total winter balance was 15.8 x 10^6m^3 water or an average of 3.28 mH_2O. This is about 95% of the mean for the period 1963-79. Ablation varied from 4.5 m in the lower part to 2.5 m in the upper part of the glacier. In total 16.4 x 10^6m^3 water was removed from the glacier corresponding to 3.41 mH_2O, just above the mean for the period 1963-79. The net balance was thus a small deficit of -0.6 x 10^6m^3; the third consecutive negative balance on Ålfotbreen.

BONDHUSBREEN

Observations of the winter balance were made on 9 May. Only three stakes were visible between the highest point of the glacier (1635 m a.s.l.) down to about 1200 m a.s.l. As it is almost impossible to measure snow depths below that altitude due to crevassing the winter balance for the lower part of the glacier was estimated. Snow depths were measured at 110 points corresponding to 11 points per km^2. Depths varied from 3-8 m with a mean density of 0.46 Mg m^{-3}. The total winter balance amounted to 29.9 x $10^6 m^3$ water corresponding to 2.8 mH_2O or about 30% more than the mean for the two previous years. The summer balance was measured at 12 points and amounted to 26.4 x $10^6 m^3$ water, that is 2.5 mH_2O or some 15% less than the mean for the two previous years. Thus the glacier showed a positive net balance of 3.5 x $10^6 m^3$ water or +0.33 mH_2O. Meteorological observations were made at the outlet of Lake Holmavatn at 1130 m a.s.l. where a small automatic weather station had been installed. Good quality recordings were obtained throughout the summer. Water vapour observations showed that only 5 days during the entire period (104 days) had a water vapour pressure less than 6.1 mb. This indicates that evaporation from the glacier surface is neglectable.

NIGARDSBREEN

Winter balance measurements on this large glacier are always difficult and take a long time. In 1979 field work lasted from 8 to 21 May under bad weather conditions. Snow soundings were made at 338 points, most of them above 1500 m, giving a point density of 10 per km^2. The areas below 1500 m proved to be very difficult to observe partly due to weather conditions and partly due to many large crevasses. Because the winter balance had been measured on the lowest part of the tongue an interpolation could be made for the crevassed areas. Snow depths showed variations from 3.5 to 9 m. A further accumulation of 10-20 cm H_2O fell after the snow survey. Total winter accumulation amounted to 132.8 x $10^6 m^3$ water which corresponds to 2.8 mH_2O or over 20% more than the average for the period 1962-79. The summer balance, measured at 29 points, was 98.5 x $10^6 m^3$ water, corresponding to just over 2 mH_2O which is slightly above the average for the period 1962-79. The net balance was thus positive, the glacier increasing by 71 cm H_2O during 1979. Meteorological observations were made as in previous years with thermograph, hygrograph and pluviograph recordings on one-monthly charts.

STORBREEN

Mass balance measurements have been made on this east-facing valley glacier in the Jotunheimen area since 1949 by Dr Olav Liestøl of the Norwegian Polar Research Institute, probably the second longest of such detailed investigations in the world after Storglaciären in Swedish Lappland. The winter balance was 1.55 mH_2O, 12% higher than for the period 1949-79, the summer balance 1.45 mH_2O or 88% of the average for the same period and the net balance consequently +0.10 mH_2O compared to the long-term average of -0.27 mH_2O. This year was the first since 1974 with a positive balance.

HELLSTUGUBREEN

Observations of the winter balance were made on 10 May under good conditions. Snow depths were measured at 125 points, a density of 25 points per km^2. The thickness varied from 1 to 7.5 m. The total winter balance amounted to 4.75 x $10^6 m^3$ corresponding to 1.43 mH_2O or 32% higher than the average for the period 1962-79. The summer balance, measured at 17 points, was 4.8 x $10^6 m^3$ or 1.45 mH_2O, slightly higher than the average for 1962-79.

GRÅSUBREEN

The snow survey to determine the winter balance was made on 11 May under good conditions and the snowpack was measured at 110 points, more than 40 points per km^2. The greatest depth was 3.4 m but some areas had less than 1 m snow. The total winter balance was 2.3 x $10^6 m^3$ water corresponding to 0.9 mH_2O or 28% more than the average for 1962-79. The summer balance was measured at 15 points and was 2.2 x $10^6 m^3$ water which is almost the same as for the two previous years but only 80% of the average for the period 1962-79. The net balance at +0.11 mH_2O was thus slightly positive for the first time since 1974.

ENGABREEN

The winter balance was measured from 21-25 May under good conditions. Snow depths were checked at 15 stakes and the snowpack measured at 183 points, almost 6 points per km^2 above 1000 m a.s.l. The winter balance was 138.4 x $10^6 m^3$ water corresponding to 3.6 mH_2O or 16% more than the average for the period 1970-79. The summer balance, measured at 183 points, was 122.5 x $10^6 m^3$ corresponding to 3.2 mH_2O or 40% more than the average for 1970-79 and the highest observed since 1972. In spite of this unusually large melt during the summer the net balance was positive at 16 x $10^6 m^3$ or 42 cm H_2O. Engabreen has shown a positive mass balance every year since 1970. The meteorological program was the same as in previous years with stations at 880, 1100 and 1360 m a.s.l. The water vapour pressure was about 8 mb during the entire summer, only one day having a vapour pressure less than 6.1 mb. Thus conditions for evaporation from the glacier surface were very poor – in fact condensation was probably taking place. The total water discharge was calculated from automatic water gauge recorders and an established rating curve.

COMPARISONS BETWEEN MASS BALANCE AT THE GLACIERS UNDER STUDY

All the glaciers in southern Norway except Ålfotbreen experienced a higher winter accumulation than normal – the highest relative figures were found on Gråsubreen and Hellstugubreen. The summer balance was close to the normal ("normal" being the average of the previous years for which mass balance investigations have been made). Most of the glaciers under study showed, therefore, a slightly positive balance – the glaciers in the Jotunheimen were very close to steady-state.

REVIEW OF MASS BALANCE INVESTIGATIONS MADE AT SELECTED GLACIERS IN NORWAY 1962–79

The greatest glacier loss occurred in 1969 when Ålfotbreen lost 2.17 mH_2O and most of the other glaciers also had their greatest negative balance since the observation series started. The balance year 1962 showed in general a very high positive mass balance, Nigardsbreen added 2.24 mH_2O to its mass that year. In general, the glaciers in the western part of Norway have experienced, during the last decades, an increase in mass whereas the glaciers in the continental, eastern, part of southern Norway (mainly the Jotunheimen glaciers) have still been retreating. Glaciers in northern Norway, represented by Engabreen, seem to have increased in volume like the glaciers in the southwestern part of the country. Observations of the ice front indicate that certain parts of the Jostedalsbreen ice cap seem to push forward whereas the studied outlet glacier, Nigardsbreen, has still been retreating in spite of its mass growth. Engabreen, on the contrary, has shown a substantial change in its front position – measurements performed since 1966 document a net advance of 143 m and this advance seems to continue. Certain years seem to show general trends in the mass balance for all the investigated glaciers. The years 1963, 1965, 1969, 1977 and 1978 gave negative mass balances and in 1969 a large negative balance was observed, certainly due to the unusually warm summer. The years 1964, 1965, 1967 and 1974 showed a positive mass balance for all the glaciers.

THE ENERGY BALANCE AT ENGABREEN

Similar attempts to those of 1978 were made to measure the energy balance at Engabreen both in the snow covered areas (1100 m a.s.l.), from June 15 to August 30, and on the tongue (50 m a.s.l.), from June 1 to September 13. The methods and instruments used have been described previously.

Global radiation was recorded by two Robitzch actinographs, one near the observations hut and the other near the terminus. Daily measurements of ablation were made in the snow covered area and weekly observations of ice melt on the tongue. Radiation accounted for almost 40% of the ablation in the upper part but a slightly smaller percentage on the tongue. However, there are fairly large variations throughout the summer. It is assumed that the incoming radiation is, in fact, relatively constant so the great variations are thought to be caused by rapid changes in convection and condensation when wind, temperature, and moisture changes from day to day or even during single days.

CALCULATIONS OF THE "NORMAL" DISCHARGE IN THE SVARTISEN AREA.

The "normal" discharge is defined as the average annual discharge (hydrological not calendar or glaciological year) in the period 1931-1960. During this period most glaciers in the Svartisen area retreated quite significantly and all rivers draining glacierized areas received more water than they normally should have done if the glaciers had been in a steady-state condition. In the 1970's the climatological conditions have been favourable for glaciers and most have added some of the annual solid precipitation to their mass. This results in water discharges which are smaller than they should be. It is impossible to make a long-term forecast of glacier variations so, for hydrological purposes, it is most useful to consider that the "normal" discharge is that quantity of water which would run in the rivers under glaciological steady-state conditions. Therefore, glacier mass balance results must be used to correct the observed discharge figures and calculate a "normal" figure. This has been done for 11 discharge stations in the Svartisen area. As glacier measurements are only made on about 5% of the total glacier surface in the area the question of their representativeness may be raised. A comparison was made of winter and summer balances on Høgtuvbreen and Trollbergdalsbreen with those measured at Engabreen. The results indicate that there is a definite connection between summer balance and the glacier mean elevation whereas the precipitation is, in general, more related to distance from the sea – the western basins receive more snow during the accumulation period. Other factors which influence the winter balance include the length of the winter (indirectly a function of altitude), wind exposure resulting in redeposition of snow, and local topography.

FLASH FLOOD IN JOSTEDALEN 1979

On 14-15 August 1979 a catastrophic flash flood occurred in the Jostedalen valley. The water level in the river rose higher than in August 1898 when the last catastrophic flood took place. The cause of this flood has been investigated.

The daily glacier melt was in the order of 5 cm H_2O on the tongue of Nigardsbreen, quite normal for that time of the year. Most of the water must have come from a very concentrated rain storm which passed the area on August 14. At Fåberg almost 78 mm of rain was measured in the 24 hour period starting at 0700 hours on August 14. This is the highest recorded daily precipitation since the station was established in 1895 and is, in fact, 36 mm more than the previous record on 15 August 1898 that caused the earlier flash flood. At the front of Nigardsbreen 91 mm of precipitation was measured between 1300 and 1900 hours on August 14. There was apparently great local variation in the amount of rain that fell but it is quite clear that it was this precipitation which caused the flood as it fell during a period when glacier melt produced a "base flow" of water in the main river.

BRIMKJELEN

The ice-dammed Lake Brimkjelen has caused several flash floods in the lower part of Jostedalen when its water has suddenly released. However, the damming outlet glacier Tunsbergdalsbreen has been shrinking during the past decades and the amount of water necessary to cause a sudden outburst is getting smaller. Consequently, the quantity of water now released is so small as to be almost unnoticeable downstream in the valley. An estimate of the lake volume in 1978 indicated that between 1.0 and 1.5 x $10^6 m^3$ were released each time the lake emptied. The catastrophic flash flood in 1926 was caused by a release of some 25-30 x $10^6 m^3$ water. If Tunsbergdalsbreen should grow again it is assumed that the amount of water released from the lake on each occasion would be greater and this has been taken into consideration in the design of a new dam for the hydro-electric power station Leirdøla.

SUBGLACIAL HYDROLOGY AT BONDHUSBREEN

A subglacial water intake, constructed in bedrock under Bondhusbreen, an outlet of the Folgefonni ice cap, has collected water all year. However, in winter the discharge decreased gradually from 0.4 $m^3 s^{-1}$ in December to 0.1 $m^3 s^{-1}$, its level when the summer meltwater discharge started on May 15. By the end of the month it had increased to 2.7 $m^3 s^{-1}$. Maximum discharge was observed at the end of June at 11 $m^3 s^{-1}$. Total discharge in 1979 was about 60 x $10^6 m^3$. Mass balance measurements indicate that less than half of this, about 26 x $10^6 m^3$ originated as glacier melt, the rest must originate from liquid precipitation draining the 12.5 km^2 basin. The water gauge indicated three unexpected events in the summer when the discharge suddenly decreased and then increased again. These sudden changes may be explained by a blocking effect somewhere under the glacier but no direct observation has been possible. The theory of a subglacial ice dam may be supported by the fact that large ice blocks were carried by the water when the rapid increase occurred. Each event lasted only a few hours.

NEW GLACIER MAP OF BONDHUSBREEN

An earlier map, based on 1959 aerial photographs, had been made for the mass balance studies carried out from 1964-1968. In connection with the subglacial water intake it was necessary to carry out further mass balance studies for which a new map was required. Special photography was taken on 11 August 1979 from 6100 m a.s.l. giving an average picture scale of 1:30,000. The map is printed in 5 colours at a scale of 1:10,000 with 10 m contours on the glacier and 20 m elsewhere. Moraine ridges, large blocks and all triangulation points are plotted on the map as well as special glaciological features such as crevasses. To conform to the requirements established at the 1965 International Glacier Mapping Symposium both UTM and geographical coordinates are marked. The reverse side of the map has some detailed information on the glacier, such as front variations since 1875, some old photographs showing the snout taken from the same position in 1891, 1904 and 1971 and some information about the diversion scheme. This new map will now be used as the base for further glaciological studies.

SEDIMENT TRANSPORT STUDIES IN NORWEGIAN GLACIER STREAMS 1979

Sediment transport studies have been undertaken in selected glacier streams since 1967. Results are reported annually in the series "Materialtransportundersøkelser i norske breelver 19.." (Sediment transport investigations in Norwegian glacier streams 19..). Investigations started on three glaciers in 1967 and increased year-by-year until in 1972 eight glacier streams were being sampled on a daily basis in the melt season. Results are used by hydro-power engineers in planning future power stations. During the past three years studies have concentrated on Nigardsbreen and Engabreen. There are lakes near both glacier fronts so sediment sampling has been performed at the front, i.e. inlet of the lake, and at the outlet to determine the amount of sedimentation taking place in the lake. In addition, in 1978 and 1979 studies were performed in the sedimentation chamber at Bondhusbreen. A subglacial intake was made under the glacier and a large hall was constructed in bedrock to remove sand, gravel, pebbles and rocks which were moved into the tunnel system of the hydro-electric power plant using the meltwater from the ice cap. The sedimentation chamber is cleared every winter. Its contents have been measured and, at the same time, studies have been performed on the suspended sediment in the water passing the chamber to establish the relation between suspended sediment and bottom load. This relationship has been studied annually at Nigardsbreen, for 11 years, and Engabreen, for 10 years, by measuring the increment of the lake deltas. The volumetric increment is of the same order of magnitude as the amount of suspended sediment carried by the stream. The long-term studies are very valuable because it has been shown previously that one year with a large transport of solid matter in one particular stream indicates that similar conditions are also valid for other glacier streams in the area. The two series of observations can therefore be regarded as representative of variations in the transport of solid matter in the glacier streams of southwestern and northern Norway respectively. The results are used mainly for engineering purposes but can also be used in a discussion of the erosional effect of glaciers on the landscape.

Water samples were normally taken five times a day from the beginning of June to early or mid September. However, during periods of rapidly increasing discharge samples might be taken every hour. Several times a day duplicate samples would be taken to test the reproducibility of the results.

NIGARDSBREEN

This glacier covers 48 km^2 and discharges through a single stream into Lake Nigardsvatnet. The delta being formed at the lake inlet was completely uncovered in 1968. Delta surveys are made along fixed profiles and accurate measurements made every 5 m. There was no flash flood in the spring but a high discharge was measured on June 7 and another small rise at the end of June, to 31.5 m^3s^{-1} still a relatively low figure. Discharge remained fairly low until the middle of August when the sudden rainfall which caused the flash flood in Jostedalen took place (see above). Just after midnight discharge rose to 96 m^3s^{-1} compared to the previous record of 56 m^3s^{-1} in 1963. Almost 9,600 metric tons of suspended sediment were transported by the stream into the lake, more than the total transport for the rest of the summer. The highest concentration was observed at 2000 hours on August 14 at 3,234 mg l^{-1}. This maximum might have been exceeded later during the night. The previous maximum concentration was observed in July 1969 at 2,157 mg l^{-1}, and the highest daily transport was 1,279 metric tons at the end of August 1970. Total sediment transport from the glacier in 1979 has been calculated at 18,400 metric tons, the highest since the start of records. The delta increase was almost 25 cm in the entire area under study equivalent to about 14,000 metric tons. It can be concluded that about 32,400 tons of solid matter was removed from the glacier during the summer corresponding to an average erosion of 0.25 mm. Average annual transport of solid matter over the last 11 years is 22,810 metric tons. At this rate Lake Nigardsvatnet will be completely filled in about 500 years.

ENGABREEN

The delta survey was made through the lake ice in January 1980 along eight profiles at 5 m intervals. 11,100 metric tons of suspended material was transported into the lake and only 1,800 tons left it. The 84% left in the lake is close to the average for the last 11 years. After making allowances for redistribution of the sediment due to sliding it was calculated that the total accumulation of coarse material was 7,300 metric tons or 37% of the total solid matter carried by the glacier stream. This corresponds to an erosion of 0.19 mm in the glacier basin. The annual transport for the last 10 years has been 22,940 metric tons of solid matter most of which, 20,700 tons, has been left either in the delta or on the lake bottom. At this rate it would take almost 4500 years to fill Lake Engabrevatnet.

BONDHUSBREEN

Transport in 1979 was dominated by two periods of high discharge – during three days at the end of June and five days in the middle of August more than 50% of the total sediment transport was moved by water from the sedimentation chamber. The highest concentration was measured on June 26 at 748 mg l^{-1} compared to a normal range of 15-80 mg l^{-1}. From 8 June to 18 August 3,100 metric tons of suspended sediment were moved into the collecting tunnel system. When the sedimentation chamber was cleared the following winter 5,200 tons had settled out. Thus total transport was in the order of 9,300 metric tons of which bottom load accounted for 56%, more than the values obtained for Nigardsbreen and Engabreen during the last few years.

CONCLUSION

Experience has shown that 20-50% of the annual sediment transport occurs during the first flash flood of the summer. Thus it is extremely important to cover that flood with frequent water sampling. If no pronounced flood occurs one must believe that a certain quantity of sediment remains under the glacier to be flushed out during a subsequent year. It is therefore important to maintain a sediment sampling program through a number of years. If another flash flood occurs during the fall, often due to heavy rain, it has been found that smaller quantities of sediment are carried than in the first part of the melt season. In addition to these variations it has been observed that short-term fluctuations may occur, e.g. sudden clouds of sediment. The duration of these clouds is so short that they may pass without being sampled. An instrument was therefore developed to monitor the turbidity of the stream by passing it in front of a light source and photo cell so a continuous record could be kept throughout the season. Unfortunately this instrument was damaged and partly removed by the flash flood at the inlet of Nigardsvatn in August 1979.

The average sediment concentration for all samples taken from June to August 1979 at the Nigardsvatn inlet was 119 mg l^{-1}. This was a record, almost 80% more than the average for the last 11 years. However, if the figures for the two day flood are removed, the 1979 average drops to 57 mg l^{-1} which is under the average for the same 11 years. This indicates the great influence of a single flood and emphasizes the importance of frequent sampling during periods of high discharge.

Gunnar Østrem

BRITISH ANTARCTIC SURVEY, CAMBRIDGE
(J.G. Paren)

RADIO ECHO SOUNDING
C.S.M. Doake and R.D. Crabtree used an airborne radio echo sounder in one of the Survey's Twin Otter aircraft for the first time since 1975. Sixty one hours were flown with the benefit of an American fuel depot in the Ellsworth Mountains under a collaborative programme with Lamont-Doherty Geological Observatory. Seven profiles directed northwards from the mountains yielded the first ice depth data within this least known corner of the West Antarctic ice sheet. A doppler radar system was used to ensure precise positioning of the profiles even in featureless terrain. Several distinct morphological provinces were delineated on the basis of bedrock topography and surface elevation data. There is evidence of a sub-glacial trough with depths of 1000 m below sea level which could link the Amundsen and Weddell seas through Pine Island Glacier. The glacier itself was found to be 500 m thick at the ice front, confirming earlier speculation that it must be an exceptionally fast-moving and unrestrained outlet for the Bentley Subglacial Trench. Additional flight tracks across Ronne Ice Shelf were able to resolve some ambiguities remaining from earlier American soundings.

RUTFORD ICE STREAM, GROUNDING LINE STUDIES
Analysis has continued of experiments made by S.N. Stephenson on Rutford Ice Stream where it joins the Ronne Ice Shelf and starts floating on the sea. The exact position of the grounding line was located by tiltmeters which detect tidal flexure of the ice shelf. The observations will serve as a reference against which any future advance or retreat can be measured, since trends in this region could pressage large scale changes further inland. Records from three tiltmeters deployed for a six week period across the grounding line are being used to generate profiles of the amplitude and bending axis of ice shelf flexure and its tidal dependence.

CORING AND CLIMATE STUDIES
The international Glaciology of the Antarctic Peninsula (GAP) project aims to derive a climatic record for the Antarctic Peninsula over the last 1000 years from the evidence of impurities in ice cores. An extensive network of shallow hand drilled cores has shown close relationship between stable isotope ratio and air temperature. Additional methods are being developed to characterise other climatic parameters. Detailed shallow core sampling was undertaken this season by J. Mumford across a major climatic divide in Palmer Land. Evidence to date suggests that the best isotope records are preserved on the plateau region at the southern end of the Antarctic Peninsula. An 83 m core was recovered from this area by a party led by J.G. Paren using an electromechanical drill on loan from the U.S. National Science Foundation. It is planned to use the core to extend the calibrations of impurities against instrumental climatic records available for the region from the last 50 years. The core is the deepest yet drilled in the peninsula and will provide the first profiles extending to the period before instrumental observations were made.

TRANSPORT OF ATMOSPHERIC POLLUTANTS
The distribution of heavy metals in polar ice cores could provide one of the first realistic tests of models describing the global dispersion of industrial pollutants. High resolution analysis of a short core from the Antarctic Peninsula plateau region has now been undertaken by M.P. Landry and E.W. Wolff using methods based on anodic stripping voltammetry and flameless atomic absorption spectroscopy. The data show that marked fluctuations in concentration occur both on the time scale of individual snowfalls and also from year to year. Such variations are evidently linked to meteorological processes rather than to changes in emission rates. It seems likely that related factors could play a major part in shaping the longer term profiles in ice cores. A direct link between concentrations in air and snow is usually assumed. In an attempt to secure supporting evidence, a series of field trials was made by D.A. Peel in which airborne microparticles and falling snow were collected simultaneously.

ICE SHELF INVESTIGATIONS
Whilst chemical and physical analysis of the body of the ice sheet can reveal much about the changes that have occurred at the upper surface which may favour growth or decay, conditions at the base of the ice sheet play a major part in controlling stability, most particularly in marginal areas. An oceanographic programme on George VI Ice Shelf has been investigating the extent to which the ice shelf modifies the underlying ocean water and how this in turn regulates the thermodynamic stability of the ice shelf. A hot-water drill designed and operated by J. Loynes has been used to penetrate 130 m of ice to allow oceanographic sensors to be lowered into the ocean water. This has made it possible to select the most suitable sites for oceanographic profiling, which up to now were restricted to natural access points close to the northern ice front. A 15-30 cm s^{-1} northerly current found at the western end of the ice front at a depth of 100-150 m has

been interpreted as an outflow of cool and less saline water derived from the ice shelf.

Recent studies by J.R. Potter have used an instrument which generates a continuous profile of temperature and salinity as it is lowered through the water column. Despite slight smoothing of the fine structure during initial lowering of the probe, unexpected and abrupt changes of salinity in layers less than 20 cm thick were reproduced on both lowering and raising the probe. A current meter was moored beneath the ice shelf at the end of the 1979-80 season to record changes in salinity and temperature at hourly intervals. Four months of good data were recorded during a previously unmonitored winter period. Two current meters have now been moored at a central site for year-round observation.

Indirect evidence for the existence of a substantial body of fresh water underlying the ice shelf was earlier deduced by J.M. Reynolds from resistivity profiles measured at three sites along a flowline. Direct evidence for the depth of water has now been obtained by C.S.M. Doake from the first series of seismic soundings ever carried out in the Antarctic Peninsula. Water depths ranged from 60 m on the western side (where they agreed closely with values calculated from the resistivity survey) to 450 m on the eastern side. A ridge was found near the middle of the sound between two deep troughs extending to 1000 m below sea level. A similar feature has been noted from depth soundings near the northern ice front and it can now be surmised that the ridge may extend along a 400 km length of the sound.

U.S.A.

POLAR OCEANOGRAPHY BRANCH, NAVAL OCEAN RESEARCH AND DEVELOPMENT ACTIVITY (NORDA), U.S. NAVY
(J.P. Welsh)

ARCTIC LASER TERRAIN PROFILES INVENTORY
(C.J. Radl and J.P. Welsh)

Laser profilometer data have been collected over Arctic sea ice since 1968 by the Polar Oceanography Branch. The laser terrain profiling system functions as a very accurate altimeter. The final product is a continuous two-dimensional profile of the ice surface. The continuous record of instrument height above the surface yields a vast quantity of data characterizing the surface of the Arctic environment which can be directly applied to many historic, present, and future Arctic investigations. Statistical analysis can yield information regarding the overall and regional distribution of various sea ice features and conditions such as roughness, ridge height distribution and frequency, power spectral density, as well as support and refinement of various ice prediction models. The laser profiling system is not restricted by Arctic darkness and it eliminates inherent human limitations for objectively and quantitatively estimating magnitudes of ice canopy features. Historical trends and alterations along with future predictive changes will become more apparent and precise as the data collection process is continued and repeated for various times and locations. The data is stored on FM analog tapes which are in the process of reduction and analysis. Sea ice laser data covering approximately 50,000 miles of long track lines (>20 miles) and numerous shorter track lines have been catalogued since 1970. NORDA Tech Note 77 gives a description of the data reduction process. In addition, a report providing the chronological and geographical location of laser data available from NORDA (1968 to present) is in final draft form.

POPULATION DENSITY FUNCTION OF ARCTIC SEA ICE TERRAIN PROFILES
(J.P. Welsh and C.J. Radl)

Laser data reduction and analysis requires a significant amount of operator/computer time and interface. Only a small portion of the total laser data available at NORDA has been completely reduced (approximately 5000 track miles consisting of 8×10^6 data points). A publication is in preparation which will produce the population density function for sea ice roughness in the Arctic environment. These 8 million data points will serve as the data base to which future reduced laser profiles will be added leading to an updating process to attain the greatest precision possible.

ANALYSIS OF LANDSAT AND SEASAT DIGITAL IMAGERY
(D.T. Eppler)

Digital LANDSAT/MSS and SEASAT/MSS imagery is being analyzed using NORDA's image processing facility. Optimum enhancement of sea ice features in LANDSAT frames is achieved by subtracting band 4 (0.5-0.6 mu) from band 7 (0.8-1.1 mu). The resulting image is displayed at near maximum contrast. Q-mode factor analysis of pixel values in all four MSS bands is being used to define type responses of different ice and water surfaces imaged by LANDSAT.

MICROWAVE STUDIES OF SEA ICE
(A.W. Lohanick, J.P. Welsh and R.D. Ketchum)

Portable microwave (33.6 GHz) radiometer and source are being used in the field to measure transmission, scattering, attenuation and radiation from sea ice and snow. These in situ measurements are being used to gain an understanding of the microwave properties of sea ice and snow. The objective is to determine the relationship of microwave measurements in and from sea ice and snow between the in situ, airborne and satellite scales.

Experiments have been conducted on sea ice off Point Barrow, Alaska, in March and October 1978, from Tuktoyaktuk, NWT, in March 1979, on the Juneau Icefield, Alaska, in July 1980 and 1981 and 32 nm offshore from Tuktoyaktuk in March 1981.

AIRBORNE MICROWAVE STUDIES OF SEA ICE

(J.P. Welsh, R.D. Ketchum and A.W. Lohanick)

An airborne passive microwave (33.6 GHz) mapping system (MICRAD) was flown over pack ice in the Chukchi and Beaufort seas in April 1976. The prototype system has been improved and now exists as the K Band Radiometric Mapping System (KRMS). The KRMS is presently being modified as well as two U.S. Navy P-3 aircraft to fly two 15-day missions each year during 1982, 1983 and 1984. Each mission will include experiments directed towards understanding seasonal and regional variations of microwave properties of sea ice and snow in Polar areas, especially the Arctic. This effort is related as the intermediate scale (airborne) portion of a three part program to determine the relationship of microwave measurements of sea ice and snow properties between the in situ, airborne and satellite scales.

AIRBORNE SAR IMAGERY OF ICEBERGS AND GLACIERS

(R.D. Ketchum)

Analysis of coincident steep angle X/L band airborne SAR sea ice imagery has shown that icebergs provide a good X-band (3 cm) radar return, but that L-band (25 cm) radar returns from icebergs are unpredictable. The occasional presence of false images (time delayed signals) observed on the far range side of some icebergs strongly suggests that L-band radar signals are penetrating and experiencing multiple internal iceberg reflections, probably from the iceberg/water interface. Frequently, data voids appear in the iceberg area indicating signal loss. Similar phenomena have been observed in coincident X/L band imagery of glaciers and glaciated land masses. That is, good radar returns are received by the X-band radar, whereas subdued radar returns are received by the L-band radar due to signal loss. Background terrain generally provides adequate returns to both radars. Based on these observations, it is suggested that an X/L band SAR system has strong potential for mapping glaciated areas.

SIZE-FREQUENCY DISTRIBUTION OF ICEBERGS: BAFFIN BAY/DAVIS STRAIT

(J.P. Welsh, B Winn and L.D. Farmer)

Measurements of two dimensional size from aerial photography have been made on 634 icebergs in Baffin Bay and Davis Strait. Size has been defined as the area of the iceberg shown on the aerial photography. Icebergs partially obscured on the photography and growlers (area $<300\ m^2$) have been excluded from this study. The objective is to describe the distribution of iceberg size and to test the hypothesis that the size distributions from different years and different geographic regions are not significantly different. Non-parametric goodness-of-fit tests are being used.

DETERMINATION OF ICEBERG PROVENANCE BY ANALYSIS OF SEDIMENT GRAIN SHAPE

(D.T. Eppler, L.D. Farmer and J.P. Welsh)

A preliminary study is underway to assess the utility of using quartz sand grain shape to indicate iceberg provenance. Past studies show that the shape of detrital quartz sand reflects the provenance of sediment in fluvial and marine systems. The present study will extend this work to glacial systems. Samples of ice-entrained sediment were taken from the Gilkey Glacier and its tributaries (Juneau Icefield, Alaska) during July 1981. The extent to which quartz sand varies in shape within and between glaciers in the Gilkey system will be defined on the basis of these samples. If differences between glaciers are sufficient to permit sediment source (provenance) to be determined by shape, the study will be extended to include Greenland glaciers that calve bergs into Baffin Bay. An attempt will then be made to determine the source of grounded bergs by comparing the shape of sand entrained therein with shape distributions that characterize West Greenland glaciers.

DYNAMICS OF LARGE-PARTICLE SYSTEMS

(D.T. Eppler and L.D. Farmer)

Flume experiments are being conducted to aid in developing models that describe the movement of floes in an ice pack. The objective is to develop an understanding of the dynamics of systems of large particles in general, not to model the movement of ice floes per se. The experiments are being run in a 250' tilting flume operated by the United States Geological Survey Gulf Coast Hydroscience Center adjacent to NORDA. Assemblages of plywood blocks are placed in a current and their velocity and patterns of movement are recorded. Parameters such as current velocity, block size, block shape, number of blocks used, and initial block orientation are varied between runs according to a Plackett-Burman screening design. The present series of runs will identify the variables that exercise dominant control over the dynamics of the system. Subsequent experiments will define in greater detail the response of the system to the identified dominant variables.

UNIVERSITY OF COLORADO

(J.T. Andrews, E. Lind and P. Clark, Department of Geology)

Field work was limited in 1980 to two field parties working in southern Baffin Island. Lind mapped glacial erosional and depositional landforms along the south side of Frobisher Bay between Cape Rammelsberg and the Bay of Two Rivers. Marine beaches were surveyed and shells collected for ^{14}C dating. Clark worked in the area of Lake Harbour and southward towards the coast of Hudson Strait on a long term project funded by the National Science Foundation to study the glacial geology and Quaternary history of Hudson Strait. Shells were collected for ^{14}C dating. During the 1980 calendar year three Ph.D. theses on the glacial history of Baffin Island were accepted (P.T. Davis, W.W. Locke, III and W.N. Mode) and three M.Sc. theses (Brigham, Hawkins and Muller).

UNIVERSITY OF MAINE AT ORONO

(T. Hughes, Dept. of Geological Sciences)

A report on the CLIMAP work, edited by G.H. Denton and T. Hughes, has been published as "The Last Great Ice Sheets" by Wiley-Interscience. It includes a thorough description of deglaciation in the Northern Hemisphere and Antarctica since the Late Wisconsin/Weichselian glacial maximum, reconstruction of the ice sheets and of selected valley glaciers and ice caps during that maximum, a description of worldwide mountain glaciation at the maximum, an analysis of the dynamics of deglaciation in West Antarctica since the maximum, and an hypothesis for the formation and collapse of ice sheets based on marine mechanisms.

Current numerical modelling work includes a study of atmosphere-ice-ocean interactions in relation to disintegration of the late Wisconsin/Weichselian ice sheets (J. Fastook and T. Hughes). The ice sheet disintegration model uses atmosphere-ice Milankovitch interactions to compute melting rates along the low-latitude terrestrial ice front, calculates the rise in sea level for each retreat step of these margins, calculates the retreat rate of high-latitude marine fronts caused by the rise in sea level, adjusts the ice divide separating ice flowing toward the terrestrial and marine fronts, and then repeats the whole series of calculations until the ice sheets are removed.

An iceberg calving model,based on Schmidt's finite-element computer program of ice dynamics, is being used to examine calving along both tidewater margins and floating margins of glaciers and ice sheets (J. Fastook and W. Schmidt). It predicts the stress, strain rate, and velocity fields in the ice and rates of iceberg calving in relation to these fields and water in crevasses.

A finite-element model of ice stream dynamics is being developed that will be applied to Byrd Glacier using University of Maine 1968-69 field data and aerial photogrammetric data provided by H. Brecher (Ohio State University) and to Thwaites and Pine Island glaciers using photogrammetric data from 1972 and 1980 LANDSAT imagery (W. Schmidt, J. Fastook and T. Hughes). Radiative solar heating of these heavily crevassed ice streams is also being analyzed (T. Pfeffer). In Greenland a study of tidal flexure on Jakobshavn Glacier has been completed and the results published in the Journal of Geophysical Research.

UNIVERSITY OF MINNESOTA

(R.LeB. Hooke and P.J. Hudleston, Department of Geology and Geophysics)

The Barnes Ice Cap was visited briefly in late April and early May, 1980. Hole-parallel strain rates were measured to a depth of over 200 m in borehole T020, 2 km from the ice divide at a point where the ice cap is about 380 m thick. Preliminary analysis indicates that hole-parallel strain is approximately independent of depth.

A stake line on the ice surface was resurveyed to obtain horizontal and vertical velocities. The latter do not appear to have changed appreciably over the past three years. They are still lower (less upward or more downward) than Holdsworth measured in 1970-71, but higher than required to maintain an equilibrium profile with a balanced mass budget. That this situation has persisted for some years is indicated by a roughly 2 m increase in thickness of the ice cap over the past decade at T020.

Laboratory studies of the sliding of ice over an irregular bed have been initiated, using an apparatus, designed and built at Minnesota, that can simulate conditions on a 20 x 25 cm rock surface at the base of a glacier 150 m thick. Artificial glacier beds with various geometries can be made from concrete and used in the apparatus.

In other activity P.J. Hudleston studied structures defined by foliation patterns in Storglaciären, Kebnekaise, Sweden.

STATE UNIVERSITY OF NEW YORK AT BUFFALO

(C.C. Langway,Jr., Geological Sciences)

GREENLAND FIELD ACTIVITIES – 1979

Two SUNY/Buffalo participants were involved in the GISP-79 drilling and ice core processing at Dye-3, from June 25 to August 31, where a depth of 224 m was reached. Two others spent from June 26 to July 6 gathering glaciological data and collecting chemical samples at 32 stations along a traverse route 30 km upstream from Dye-3.

GREENLAND FIELD ACTIVITIES – 1980

Core drilling at Dye-3 began on June 11 at 224 m and terminated on August 11 at 901 m. Nine people from SUNY/Buffalo were involved in the 24-hour/day operation. A total of 677 m of core was recovered and studied. Core recovery rate varied to a maximum of about 30 m/d. Quality of the ice core was uniformly excellent at the drill barrel breakout point but deteriorated with time below the 350 m depth.

A cold trench (-10°C) and a surface warm laboratory van were used to analyze the ice core in the field. Studies included continuous stratigraphy and logging, and selected sampling for crystallographic, ultrasonic velocity, air volume and bubble pressure measurements, as well as uniaxial compression, shear, and indentation hardness tests. A total of 663 samples were analyzed for F^-, Cl^-, NO_3^-, and SO_4^{2-}. Continuous recordings of temperature, pressure, relative humidity, radiation, precipitation, wind speed and direction were made at a meteorological station operated during the field season. Surface snow samples and shallow cores were collected along a 30 km traverse route upstream from Dye-3 and snow accumulation was measured.

Ice core not consumed or shared by the Swiss, Danish or U.S. teams was returned to Buffalo for further laboratory tests.

GREENLAND FIELD ACTIVITIES – 1981

By June 1, 1981, the core drill had penetrated to 1000 m depth. This ice core and the remaining approximately 1000 m will be treated in the field like the upper 901 m. 18 people from SUNY/Buffalo are participating in the GISP-81 field season. Ice cores remaining after the 1981 field season will be returned to Buffalo for further analyses.

SUMMARY OF LABORATORY ACTIVITIES

Since September 1978 research has been related to the remeasurement of sample increments studied in the field and new studies requiring more controlled laboratory conditions.

PHYSICAL AND MECHANICAL PROPERTY STUDIES

Important highlights of the studies completed or in progress are as follows:

- determination of freeze-on hypotheses for the Camp Century core debris-laden ice. The basal ice zone is characterized by an anomalous gas content, a relatively low debris concentration, extremely small ice crystals, and highly preferred vertical crystal orientations.

- discovery of substantial modification of debris-laden ice following freeze-on. A distinct difference exists between the textural features and gas contents at Camp Century and Byrd Station.

- identification by SEM of surface textures characteristic of englacial debris.

- refinement of the use of total gas content as an indicator of past ice sheet elevation. The discovery of seasonal and annual variations in total gas content place important constraints on the interpretation of the total air profile. Recent total gas measurements show that the change in surface elevation at Camp Century is limited to approximately 600 m rather than the 1200 m previously estimated.

- correlation of Camp Century ice crystal fabrics with the flow regime. Between 900 and 1000 m the crystal fabrics develop into a single maximum pattern with a high concentration of vertically oriented c-axes; this development of a strongly preferred orientation is in agreement with the present flow models for Camp Century. The fabric model is being revised in order to incorporate results of high pressure deformation experiments.

- identification of a drastic change in the Camp Century crystal size corresponding to the Wisconsin-Holocene transition. Whereas crystal size reduction was formerly thought to be purely a rheological phenomenon, there is now a strong indication of a direct or indirect climatic influence.

- comprehensive analysis of the Milcent and Crete ice core physical properties including stratigraphic melt features, total gas content, air bubble size and concentration, and crystal size and orientation. The development of anisotropy at the bottom of the Milcent core has been compared to the isotropic conditions in the upper 350 m at Crete.

- development of an ultrasonic technique to measure the anisotropy of polycrystalline polar ice cores. Calibration of the ultrasonic velocity measurements with fabrics from the Milcent, Crete, Camp Century and Dye-3 cores demonstrated a sensitivity of this technique to changes in average crystal orientation.

- recognition of the high stress-strain environment of the Ross Ice Shelf streams manifested in the properties of the J-9 core including small crystal size and highly elongated, lineated, necked and ruptured air bubbles; contrasting with Weertman's concept of bubble coalescence under high shear strain.

- identification of a relationship between pore close-off density and temperature. Pore close-off density was previously considered a constant and a recognition of its variation with temperature is of fundamental importance to the interpretation of any air volume data.

- development of a flow model of large ice sheets from laboratory mechanical tests conducted under hydrostatic pressure and from the bore hole inclination measurements made at Byrd Station and Camp Century. Velocity profiles with depth calculated from both sites are in good agreement with those from bore hole inclination measurements. The velocity profile calculated for the Dye-3 location gives a surface velocity very close to already available geoceiver values. The depth-age relationships calculated by these velocity profiles for Byrd Station and Camp Century are in good agreement with those previously obtained by core analyses.

- completion of a deformation mechanism map for polycrystalline ice based on grain size. This map depicts a grain size/stress field and is considered more complete and appropriate than earlier mechanism maps which describe stress/temperature fields, particularly in glaciers where the temperature of ice is nearly a constant value but grain size varies.

- development of a research program and completion of theoretical considerations for laboratory tests on the mechanical properties (under hydrostatic, tensile and compressive stress) of selected sections of ice cores over the profiles of the Camp Century, Byrd Station and Dye-3 cores. Special "Instron" testing equipment is being used both in the field and laboratory to complete this study. An investigation has started into the tensile and compressive flow behaviour of the new Dye-3 ice core as a function of in situ stress as the ice core is being recovered in the field during GISP-81 and on adjacent samples in the laboratory as a function of time after recovery.

- use of ultrasonic equipment to perform on-site measurements of the wave velocities on selected samples of the Dye-3 core as a function of stress/temperature/strain rate as it is being recovered. Adjacent samples will be measured in the laboratory to investigate the effect of relaxation as a time dependent function. The wave velocity will be correlated with a careful direct measurement of the fabrics, crystal size and impurities from the same samples. These data will be compared with the earlier results from Camp Century, Byrd Station, Milcent and Crete.

- construction of shear testing apparatus to investigate samples from the bottom ice at Camp Century which has a characteristic fabric related to a deformational mechanism associated with its proximity to the basal interface. This will provide valuable information on flow behaviour at the near bottom of a large ice sheet. The near bottom Dye-3 ice core will be similarly investigated. Experimental results will be correlated with direct measurements of fabrics, grain size and debris size/distribution in terms of dislocation theory.

- publication of the first study of the sub-ice material from Camp Century where it is reported that petrologically the cobbles can be correlated with the Rinkian mobile belt of Greenland's west coast. Using Rb-Sr dating techniques, it is tentatively concluded that the cobbles are approximately 3,000 Ma old rocks that were reset to 1100 Ma during the Carolinidian orogeny.

- establishment of the significance of ice melt features as a signal of climatic change. When undisturbed ice cores are recovered to depths as great as 900 m and the core properly examined, melt features are still readily visible to the naked eye and the coherence with stable isotope measurements is very good for low and high frequency climatic events.

GLACIOCHEMISTRY STUDIES

Important highlights of the studies completed or in progress are as follows:

- confirmation of pollutant Pb and SO_4^{2-} in Greenland snow. The initial discovery of Pb aerosols in Greenland was questioned and reinterpreted as representing geographical, not temporal, changes in concentration.

- identification of Zn as an additional pollutant element. Modern Zn concentrations are a factor of three greater than in snow deposited before the Industrial Revolution.

- identification of 1900 A.D. as the time before which there was no significant input to Greenland snow from anthropogenic emissions.

-identification of continental dust, sea salts, and volcanic aerosol sources from R-mode factor analysis of seasonal and annual concentration variations.

- detection of historical volcanic events in Greenland ice by chemical analysis. The eruptions of Laki and Asama-Yama (1783), Askja (1875) and Krakatoa (1883) are marked by extremely high concentrations of Zn, Cd, SO_4^{2-}, Pb, Cu, K and specific conductance. Two extended periods of high levels of Cd and Zn in the Camp Century core have been detected with implied explosive volcanism centered at 65,000 and 8,000 B.P., in accord with the North Atlantic sediment records.

- detection of seasonal variations in concentrations of Zn, Cd, Pb, Cu, K and specific conductance in Greenland ice. Previously, long-term seasonal variations had been demonstrated for Na, Mg, Ca and Al.

- the first reported measurements of NH_4^+ in Greenland snow and ice. Measurements of NA_4^+ and SO_4^{2-} on the same samples show that whereas most SO_4^{2-} in pre-1900 Greenland deposits was neutralized by NH_4^+, only about 20% of the modern SO_4^{2-} is neutralized by NH_4^+, implying that the increase in the acidity of precipitation is a global phenomenon.

- detection of seasonal variations in sea salt concentrations in Ross Ice Shelf snow, permitting detailed dating of samples. Because of the low annual accumulation rates, the oxygen isotope dating technique is unusable over most of Antarctica. Previously, dating had been limited to fallout horizons or to the relatively imprecise ^{210}Pb technique for most areas of Antarctica.

- determination of Ross Ice Shelf vertical strain rates by chemical analysis. Measurements of the thinning of annual layers at depth in Ross Ice Shelf cores reflect the combination of vertical strain and possible changes in past snow accumulation rates. Assuming a constant accumulation rate, measured thinning rates determined by detailed chemical analysis, are in accord with surface glaciological measurements of the principal strain rates.

- modelling of the surface distribution of Na concentrations on the Ross Ice Shelf. Coupled with accumulation and strain rates and ice velocities the model predicts the Na-depth profile expected in ice shelf cores.

- delineation of the glaciochemical regimes concept for sea salt concentrations on the high plateaus of Antarctica; the source areas were dominantly the lower latitude oceans.

- reinterpretation of the Little America V chemistry profile of Langway et al. Comparison of observed Na-depth profiles and those predicted from model surface concentrations and observed flow and accumulation parameters indicated a steady-state flow of ice from West Antarctica, rather than a recent surge. The Little America V profile is interpreted as representing shelf ice in the 0-120 m depth interval, and ice from 550 km away in West Antarctica below the 150 m depth. While this interpretation is in contradiction to the steady-state hypothesis of Crary et al. recent steady-state calculations based on newly measured parameters are in excellent agreement.

- the first reported measurement of plutonium isotope concentrations in Greenland and Antarctic snow. A complete history of bomb-produced nuclides and ^{238}Pu from the disintegration and "burn-up" of the SNAP-9A satelite in 1964 are recorded in both profiles. On the Antarctic samples, measurements were extended to include ^{137}Cs, ^{90}Sr and ^{3}H.

- determination of the horizontal variability in concentrations of seven elements on scales of a few meters to several kilometers.

- the addition of the anions Cl^-, F^-, NO_3^-, SO_4^{2-}, and Br^- to the suite of elements routinely measured by ion chromatography. Previously, anion data existed for Greenland precipitation only for Cl^- and SO_4^{2-}.

NORTHWESTERN UNIVERSITY

(G.E. Birchfield and J. Weertman, Department of Geological Sciences)

Two greatly simplified paleoclimate models have been developed in order to investigate changes in the atmosphere, hydrosphere, cryosphere and on the earth surface accompanying the major changes of climate that have occurred over the last 500,000 years. The driving force for the changes is the Milankovitch earth orbit perturbations. The models are being modified and expanded to help in:

- determination of the features or processes responsible for the apparent sensitivity of the climate system to orbital insolation anomalies.

- identification of processes which are capable of responding on time scales of the order of 10^3 - 10^5 years.

- assessment of the role of ice sheet-atmosphere interactions in the growth and decay of the continental ice sheets.

- assessment of the role of the deep ocean as a potential heat reservoir that exchanges heat with the atmosphere-cryosphere on the time scale of 10^4 - 10^5 years.

- determination of the essential elements of the climate system responsible for the appearance of the 100,000 year major glaciations.

In another study the role of subglacial water under Antarctic ice streams in stabilizing or destabilizing the West Antarctic Ice Sheet is being investigated.

UNIVERSITY OF WISCONSIN AT RIVER FALLS

(R.W. Baker, Dept. Plant and Earth Sciences)

In order to investigate the effects of variations in the degree of preferred crystallographic orientation and ice crystal size on creep, nineteen samples of anisotropic glacier ice were deformed in simple shear. Samples for this study were collected along the margin of the Barnes Ice Cap, Baffin Island, NWT, Canada, and were tested in a university cold room. Results indicate that the length of time required for samples to reach the minimum value of strain rate decreases as ice crystal size increases: an increase in crystal fabric development from isotropic to one with a strong single maximum results in an enhancement of minimum strain rate by a factor of four; and a doubling of the ice crystal size results in about a nine-fold increase in minimum strain rate. The relationship among minimum octahedral shear strain rate $\dot{\gamma}$ min, crystal size d, fabric intensity f, octahedral shear stress T, and absolute temperature T, is:

$$\dot{\gamma}\ \text{min} = B d^{\ell} f^{m} T^{n} \exp(-Q/RT)$$

where B = 3.178×10^{-12} $mm^{-\ell}$ bar^{-n} yr^{-1}, ℓ = 3.145, m = 0.977, n = 3.0, R is the gas constant, and Q = 18.8 kcal/mole.

Multiple stress experiments — simple shear with simultaneous uniaxial compression — are presently being conducted on isotropic glacier ice to test the possibility that stress configuration may influence minimum strain rate.

GEOTECHNICAL SECTION
DIVISION OF BUILDING RESEARCH
NATIONAL RESEARCH COUNCIL OF CANADA
Ottawa, Ontario, Canada

The effects of snow and frozen ground must, at times, be considered in the design, construction and operation of structures, including buildings. The importance of this for Canada was appreciated by Dr R.F. Legget, the first Director of the Division of Building Research (DBR). As a Chairman of a National Research Council of Canada (NRCC) Associate Committee on Soil and Snow Mechanics, he organized in 1947, together with Prof. J.T. Wilson, Chairman of the NRCC Associate Committee on Geodesy and Geophysics, a Conference on Snow and Ice. This was the first of a series to be sponsored by the Associate Committee on Soil and Snow Mechanics. Amongst the 70 participants were Sir Charles Wright, Pat Baird, Link Washburn, Walter Wood and Graham Rowley. One of the objectives of the meeting was to stimulate interest in snow and ice problems. To it Dr Legget and Major M.G. Bekker reported some of the results of a post-war fact finding mission to Europe, including an initial contact with the British Glaciological Society.

Following the Conference, Dr Legget arranged for Dr Marcel de Quervain to spend a year in Canada evaluating research needs. He also initiated in DBR a program of snow and ice research. Dr de Quervain's report, published in 1950, has provided important guidance to that work, particularly during the first years.

SNOW

Very little was known in Canada in 1947 about the properties of snow or even of the variation that could be expected across the country in the average characteristics of the snow cover. Mr G.J. Klein, of the NRCC Division of Mechanical Engineering, initiated a snow survey at several locations in southern and northern Canada about that time as part of an investigation of aircraft skis. Snow cover properties were measured with a set of instruments developed especially for that program and which were widely known as the "Canadian snow kit". The snow survey was taken over by the DBR Snow and Ice Research Group, and became its first project.

Although the Group was set up to investigate snow and ice problems of particular concern to construction, its interests at the beginning were very broad. This was due, primarily, to the negligible research being done on these materials and the considerable need for information concerning them. As the activity had to start with no laboratory facilities, emphasis was placed on field work. In addition to the snow survey, studies were carried out on the compressibility of snow, methods of determining its water content, correlations between snow cover properties and weather and climate and the influence of snow cover on heat flow from the ground.

ICE

A cold room completed in 1954 allowed a start to be made on a program of ice engineering research and on an extensive study of the properties of ice. The temperature of the room could be controlled to better than ± 0.1 °C over the range of 0 to -50°C.

The ice engineering program has had two major objectives: to establish the capability to predict the force ice covers may impose on structures under given conditions; and to determine the load that can be safely placed on or transported over ice covers. It was early decided that to validate methods for predicting ice forces would require expensive measurement programs on full size structures subject to natural ice conditions. This assumption has been fully supported by events. In spite of extensive theoretical and laboratory studies, a major limitation for exploration and development of resources in ice-affected waters is still the lack of a proven basis for predicting ice forces.

It was realized that better knowledge of the strength and deformation properties of ice was required in order to properly design field experiments and to interpret results. A program of investigation of these properties was initiated in the cold room. Most measurements have been made on columnar grained, fresh water ice, an ice type that is common on lakes and rivers. Measurements have been made as well on granular and frazil ice types.

Particular attention has been given to the deformation behaviour of ice in the first 1% of strain, as this is the range associated with most engineering problems. Investigations have been carried out on the creep rate under compressive and tensile stresses, the characteristics of crack formation and the nature of the failure process, the stress strain behaviour for nominal constant strain rate, and the elastic and delayed elastic behaviour. This work has clearly demonstrated that careful and accurate control of ice quality, temperature, stress, strain rate and specimen geometry is required to obtain reproducible results. It has also shown the very significant effect of testing machine stiffness on test results. In recent years increasing attention has been given to the properties of sea ice because of growing engineering activity in ice-affected marine waters.

Because of the great variability in the properties of naturally formed ice and ice covers and in the interaction between ice covers and structures, particular emphasis has been placed on field investigations. These have included an investigation of the failure of a water reservoir, the failure of an ice control structure, the behaviour of ice about bridge piers and current studies of the interaction between the ice cover and a dock at an Arctic site.

A major requirement for design of structures subject to ice action is to specify the conditions that will be associated with maximum forces. This requires an appreciation of the factors that control when an ice cover will form, its rate of growth, its maximum thickness and its break-up. In response to this need, analyses were carried out on existing records of date of freeze-up, date of break-up and maximum ice thickness. This analysis, combined with measurements of the heat transfer coefficients at water and snow surfaces and detailed observations of ice formation on lakes, has provided a basis for estimating maximum expected thickness on a regional basis. Observations were also made on the formation of frazil ice and its effects, and on the use of dust for advancing break-up of ice covers. This work has now been largely curtailed because of the growing interest and activity of hydrologists and hydraulic engineers in this important problem area for Canada.

Extensive use is made of ice covers for supporting loads, particularly by the pulp and paper industry. An important program has been to record this experience as well as that on the transport of loads over ice and the use of ice covers as platforms for supporting engineering and other activities. This work has provided input for manuals for the use of ice covers by aircraft and by government employees. More recently attention has been given to the development of the design basis for platforms for supporting heavy loads over long periods such as offshore drilling activity. A parallel problem that is also receiving attention is the uplift force exerted by ice on structures such as pile foundations, when subjected to an increase in water level.

PERMAFROST

More than one-half of Canada is underlain by permafrost. Although the early explorers noted the presence of perennially frozen ground in Canada more than 250 years ago, it was not until difficulties were experienced on major northern construction works during the Second World War that it received attention. At that time there was little organized knowledge of the subject anywhere, let alone in Canada. Recognizing its importance to the development of northern Canada, permafrost studies were begun at the DBR in 1950 to gain a better understanding of this terrain condition and the special problems it creates for engineering design and construction. Early studies showed the need for information on the nature and distribution of permafrost, for the development of site evaluation and selection techniques and for the improvement of design and construction criteria for foundations and engineering facilities. Much of the early work involved extensive field investigations but since 1970 the permafrost studies have been about evenly divided between field projects and laboratory research on frozen ground.

Between 1952 and 1960, a station was operated at Norman Wells, N.W.T. for about 6 months each year to support field studies in the Mackenzie River valley. In subsequent years, DBR studies in this area and the northern Yukon have been conducted from Inuvik, N.W.T. A small station, established at Thompson, Manitoba, in 1966, is operated throughout the year to support field studies in the discontinuous permafrost zone where some of the more difficult engineering problems occur. Laboratory studies at DBR include investigations, of the physical, thermal, strength and deformation properties of frozen and thawing soils and model studies of foundations in permafrost.

A major program to collect information on the occurrence and distribution of permafrost in Canada was begun in 1953. Between 1962 and 1968 field surveys to determine the southern limit were made across Canada. About 1969, studies on its occurrence and distribution were initiated in other parts of the permafrost region. Attention has been given to the transition between the discontinuous and continuous permafrost zones with studies at various locations in northern Manitoba, the District of Keewatin, N.W.T. and the Yellowknife area. The distribution of permafrost in alpine and high altitude areas is being investigated in the Canadian Cordillera, Gaspe and Labrador. Studies have also been undertaken on the nature and distribution of permafrost on Devon Island and at Alert, N.W.T. the northern part of the continuous zone. An updated Permafrost Map of Canada (first issued in 1967) was published in collaboration with the Federal Department of Energy, Mines and Resources, in 1978.

It was recognized at an early stage that the basic factors affecting the distribution and stability of permafrost must be understood in order to improve the ability to predict its occurrence. Field observations were made in 1959 and 1960 at Norman Wells to obtain information on the components of the heat exchange at the ground surface. Because of the complexity of permafrost occurrence and distribution in the discontinuous zone, a long-term program of investigations was initiated at Thompson in 1967 on the effects of climatic and terrain factors.

Failures or unsatisfactory performance of structures founded on perennially frozen materials can be attributed, in many cases, to poor siting or lack of information on subsurface conditions, particularly with respect to the amount of ice in the ground and the ground thermal regime. The applicability of air photo interpretation methods for preliminary site surveys and route selection, with particular emphasis on evaluating surface features as an aid to predicting subsurface conditions, was confirmed by a field evaluation carried out in northern Canada in 1951. Considerable experience in site investigation methods was gained in 1954 when DBR staff participated in a special survey of the Mackenzie Delta area to select a suitable site for the new town of Inuvik. A detailed study carried out over a wide area at Thompson, Manitoba, in the late 1950's and early 1960's, showed that many strong correlations could be made in the discontinuous zone between the occurrence of permafrost and ground ice and terrain factors such as vegetation, relief, drainage, soil type and snow cover. The pronounced effect that bodies of water have on the occurrence of permafrost and on the ground thermal regime was investigated in the early 1960's in the Mackenzie Delta area and northern Manitoba.

As it is absolutely necessary to determine subsurface conditions at construction sites, and especially the extent and type of ground ice, considerable attention has been given to the improvement of drilling and sampling equipment and techniques to obtain undisturbed samples of frozen materials for examination and testing. Geophysical equipment (seismic refraction and electrical resistivity) and air-borne infrared sensors have been used for determining the presence of permafrost. Because permafrost is a thermal condition of the ground, DBR has emphasized in its field work the development of equipment and methods for measuring ground temperatures, particularly for remote areas. Probes and associated equipment have been developed for measuring the thermal conductivity of frozen and unfrozen materials both in the laboratory and in the field. "Down-hole" instruments, such as dilatometers and penetrometers are being evaluated for determining the strength properties and deformation behaviour of frozen soils in situ.

DBR has instrumented many types of structures in northern Canada to monitor their long-term performance and compare it with design predictions. Pile-supported structures, including buildings, bridges, wharfs and large oil storage tanks, are under observation. Roads, airstrips, buildings and oil tanks, built of or supported on gravel fills are also under observation. The performance of several insulated highway test sections is being monitored to evaluate this technique for reducing the quantity of fill required and for preventing thawing of ice-rich permafrost. Detailed studies were undertaken between 1958 and 1970 to assess the effect on permafrost of dykes constructed for a hydro-electric power project in northern Manitoba. Anchorages in permafrost for structures that are subjected to uplift forces, e.g. guyed power transmission towers, have also been studied.

The transportation of oil and gas by large diameter pipelines in permafrost areas poses special stability problems. Assistance was given to industry in field and laboratory studies of the behaviour of warm-oil pipelines in permafrost in the early to mid-1970's. DBR is now involved in laboratory studies of frost heave problems associated with chilled gas pipelines.

Laboratory work was undertaken to complement the field studies and to gain a better understanding of the physics and mechanics of frozen ground. Particular attention is being given to the settlement and consolidation properties of thawing soils, the strength properties and deformation behaviour of frozen ground and the influence of ice and unfrozen water contents. Development of sample preparation and test techniques form a large part of the work since there are no standard methods for the testing of frozen soils.

Model studies of foundations in frozen ground were begun in the laboratory about 1975. Emphasis has been placed on studying various types of piles (steel, wood, concrete) subjected to short- and long-term static and dynamic loading to evaluate adfreeze bond strength, bearing capacity and creep characteristics. Model studies of a chilled gas pipeline are underway to evaluate heat and moisture transfer and frost heave aspects.

FROST ACTION

Seasonal freezing of the ground causes many problems in Canada including freezing of buried utilities and the heave of structures. A program of soil temperature measurements at various locations was begun by DBR in 1949 to establish correlations between ground temperatures, soil type, snow cover and the climate. A laboratory frost action program was started in 1953 to study the phenomenon of soil freezing, particularly the conditions under which discrete crystals of ice form during the freezing process. Observations of break-up of roads were made each spring in the early years.

The mechanism of ice lensing in soils has been studied at DBR for many years as a basis for establishing reliable methods of assessing the frost susceptibility of a soil. Particle size, pore size and rate of heat extraction are all important to the heaving process. Recent laboratory studies indicate that the frost heave rate is directly related to overburden pressure and temperature. New techniques have been developed to measure the temperature of specimens during heaving.

In some situations thermal insulation provides an economical way to avoid damage due to frost action. In the early 1960's field studies were initiated to evaluate the use of insulation under roads, around foundations of unheated structures and beneath the floors of skating and curling rinks and cold storage plants, and to develop reliable and economical design and operational methods. Field studies were begun in 1966 on the amount and variability of "frost-grip" forces that are transmitted to steel, concrete and wood columns by the growth of ice lenses in the soil, and on uplift forces on long concrete walls and plates or footings.

AVALANCHES

DBR initiated an avalanche research program in 1957 when assistance was provided to the Federal Department of Public Works in locating avalanche sites on the Trans Canada Highway through Rogers Pass, B.C., and in specifying the defence system that should be established. Investigations have continued since that time on the characteristics of avalanches and the development of defence systems. Considerable support is provided annually, by DBR, for special courses on avalanche hazard evaluation and avalanche engineering. The avalanche research unit is based in Vancouver, B.C., and its research is carried out primarily in the Rogers Pass region.

SNOW LOADS

Specifying snow loads on structures is a major design problem in Canada. DBR conducts field surveys and carries out much of the research that is necessary to establish this information for the National Building Code of Canada.

COMMITTEES

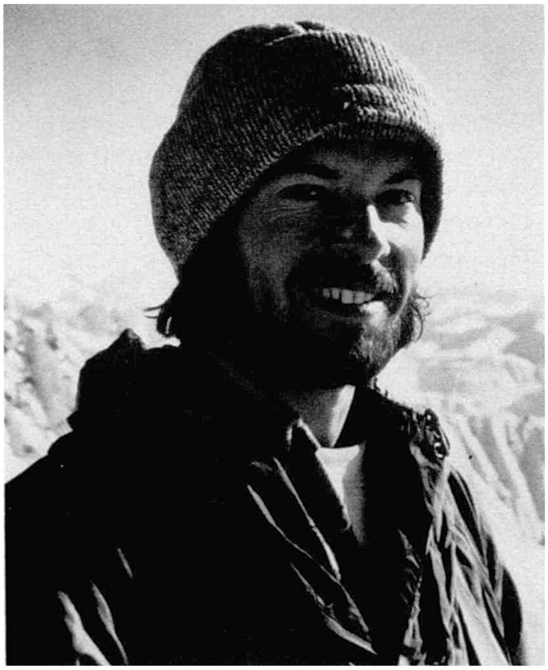
One of the major ways in which DBR works with others on snow, ice and permafrost problems is through the Subcommittees of the Associate Committee on Geotechnical Research (formerly the Associate Committee on Soil and Snow Mechanics). Over the years these Subcommittees have sponsored seminars on the thermal regime in permafrost, permafrost geophysics, ice engineering, ice pressures, avalanches, snow removal, bearing capacity and other important topics. These seminars have provided useful summaries of the state-of-the-art and a record of important developments in Canada since 1947. The research staff of the Division's Geotechnical Section act as technical advisers to the Subcommittees and participate actively in the organization and programs of their symposia.

There has been a remarkable growth in glaciological research over the past 33 years. The Geotechnical Section of DBR is probably the only group in Canada that has had an active glaciological research program through this whole period. Although the group doing this work is small, it has been able to contribute effectively to the growth of knowledge, both through its research program and participation in committee and society activities. The recent acquisition of a close-loop testing machine will open up new opportunities for investigating the strength and deformation properties of ice; current oil and gas exploration activities in ice-affected waters are providing opportunities for participation in major scale field experiments; the growth of activity in the mountains of western Canada is increasing the need for information and expertise concerning avalanches. Through this work, the group will continue to contribute to the development of glaciology and to solutions to problems associated with snow and ice and permafrost.

A list of publications presenting the results of DBR research on snow, ice and permafrost can be obtained by writing to the Geotechnical Section, Division of Building Research, National Research Council of Canada, Ottawa, Ontario, K1A 0R6, Canada.

Lorne W. Gold,
Associate Director, DBR

Peter MacKeith (1949-1980)



Peter MacKeith was killed in a climbing accident on Old Snowy, in the Alaska Range, on 26 April 1980. Peter had nearly completed his doctorate in geophysics at the University of Alaska, where he was carrying out research on the response of glaciers to volcanic heating on Mt. Wrangell and Mt. Redoubt. The 1980 field season would have been his fourth in the Wrangell Mountains, and he was making rapid and ever-increasing progress in understanding the complex, multi-faceted problems that exist there. Peter himself was a many-sided character with an extraordinary breadth of talents and interests, so many, in fact, that the success of his research remains something of a mystery. A partial list of his current activities would include one or two engineering design projects, active support of Alaskan mountaineering and presidency of the Alaska Alpine Club, and above all, photography. As a photographer, Peter was truly an artist. His sensitive, well-composed and well-processed photographs won prizes, delighted his friends, and still bring cheques in the mail from users in widely scattered places.

Although Peter was a student and only 30 at the time of his death, he had already mastered several professions besides his photography. His undergraduate training at Cambridge provided him with degrees in engineering and electrical sciences, and he was a talented designer with experience at Hewlett-Packard, the Scott Polar Research Institute, the Institute of Oceanographic Sciences, and the University of Alaska. His designs included thermal drilling equipment, radio echo sounding equipment for use on Roslin Glacier, Mt. Wrangell, Variegated Glacier and elsewhere, and a time lapse camera for velocity studies on Variegated Glacier. His master's degree in optics and diploma in physics from Imperial College gave him considerable expertise in remote sensing. He was interested in the application of remote sensing to geological problems and was preparing himself exceptionally well in this area. His understanding of the techniques of obtaining remotely sensed data and of the physical principles involved, combined with an intimate knowledge of field problems based on extensive personal experience, was a rare and valuable combination. He was a gifted and patient experimenter who left behind well-organized notebooks.

Peter's interest in glaciology, mountaineering, and basic adventure took him to many places over a dozen years: Svalbard, East Greenland, Afghanistan, Baffin Bay (where he was associated with the North Water Project), South America, and Alaska. His trips and climbing expeditions were always documented with fascinating photographs. His approach to mountaineering is well summarized by his friend Carl Tobin:

> "Peter was a person who went into the mountains exclusively for enjoyment. His climbs were not ambition-ridden or frenzied, but were rather more like elaborate encounter sessions, where friends could share each others presence without society's handicaps. Safety and fulfillment were his goals. He never expected to die climbing."

There were many sides to Peter and few of his friends or family knew all of them. Some characteristics were obvious: he was energetic, he could do things, and he always did them well. He was a creative seamster who made his own tent and other equipment for himself and for his mountain projects. He was a good cook, both at home and in the field. He abhorred factory made bread. He was fond of good music and played the French horn; he made lasting and probably much needed contributions to the music appreciation of some of his Alaskan friends. Peter grew to love Alaska and wanted to make it his home. He is sadly missed in Fairbanks and in his native London.

C.S. Benson
W. Harrison

SECOND SYMPOSIUM ON APPLIED GLACIOLOGY

US Army Cold Regions Research and Engineering Laboratory
Hanover, New Hampshire, 23-27 August 1982

SECOND CIRCULAR

The Society will hold a Second Symposium on Applied Glaciology in New Hampshire, USA, in 1982; the first symposium on this subject was held in 1976 in Cambridge, UK. Registration will take place on Sunday 22 August, and sessions will be from Monday 23 to Friday 27 August. There will be a visit to CRREL on Wednesday afternoon 25 August.

ORGANIZING COMMITTEE

A.J. Gow (Chairman)
B.S. Yamashita (CRREL)
W.F. Weeks
H. Richardson

PAPERS COMMITTEE:

S.C. Colbeck (Chairman)
S. Ackley
R. Frederking
B. Salm
J. Schwarz
P. Schwerdtfeger
H. Richardson

1. PARTICIPATION AND PAYMENT

This circular includes a booking form for registration and accommodation. The form should be sent to the address given below before 1 May 1982 with the appropriate deposits, as indicated. (Registration fees cover organization costs, distribution of preprints of summaries to participants, the visit to CRREL and the Clambake.) Payments should be made in £ sterling or US$ –

by sterling cheque payable to: International Glaciological Society Symposium and sent to the Secretary General at the Society's address:
by sterling Bank transfer to: International Glaciological Society Symposium, Account no.54775302, and sent to the National Westminster Bank Ltd., 56 St. Andrew's Street, Cambridge CB2 3DA, England;
or, for people resident in the U.S.A., by US$ check payable to: IGS Symposium, c/o S.C. Colbeck, CRREL, Hanover, NH 03755, U.S.A.

Registration fees:

Participants ....£40.00/US$ 85.00
Students ....£26.00/US$ 55.00
Accompanying persons aged
18 or over ....£16.00/US$ 35.00

LAST DATE FOR REGISTRATION BOOKINGS: 1 MAY 1982

2. TOPICS

The Symposium will be concerned with the following topics:

1. engineering problems associated with river, lake and sea ice;
2. engineering problems associated with ground ice, icebergs and glaciers;
3. properties and behaviour of snow, ice and ice cover;
4. snow removal, control and processing;
5. avalanche control and snow pressure;
6. ice accretion;
7. modelling techniques in applied glaciology.

3. PROGRAMME

A detailed programme will be given in the Third Circular. On Sunday evening, 22 August, there will be an informal party; on Wednesday afternoon 25 August there will be a visit to the Cold Regions Research and Engineering Laboratory, and on Thursday evening 26 August the Clambake will be held. Various local tours will be arranged for those interested, and may be booked when registering on Sunday 22 August. A one-day tour for accompanying persons will be arranged to nearby Vermont; the cost of this, with lunch, is included in their registration fee.

4. ACCOMMODATION

Accommodation, meals and meetings will be at The Sheraton Motor Inn, West Lebanon, N.H. Prices per night will be as follows:

Single occupancy – $50.00
Double occupancy – $56.00 (i.e. $28/person)

Note – all rooms have a private bathroom and two double beds.

These prices also include taxes but no meals. The restaurant serves reasonably priced meals and snacks. A deposit of £23.00, or $50.00 for people resident in USA, must be paid when booking accommodation. This deposit is returnable if notice of cancellation is received before 1 July 1982.

5. TRANSPORTATION

Information about access to Lebanon from Boston will be provided in the Third Circular. We are hoping to arrange a special group tour: air London-Boston (21 August), overnight in Boston, private bus to the hotel in West Lebanon. (Return journeys to be arranged individually with our travel agent.) If you are interested in this group arrangement, please write to the Secretary General for further information.

6. PAPERS

(i) Submission of papers
Those participants who would like to contribute to the Symposium should first submit a summary of their proposed paper in English; this summary should contain sufficient detail to enable the Papers Committee to form a judgement on the likely merit of the proposed paper, but should not exceed three pages of typescript. Summaries must be submitted on paper of international size A4 (210 x 297 mm) with wide margins and double spaced lines. Summaries should be sent to: Secretary General, International Glaciological Society, Lensfield Road, Cambridge CB2 1ER, England.

LAST DATE FOR SUBMISSION OF SUMMARIES: 1 DECEMBER 1981

(ii) Selection of Papers
Each summary will be assessed by the members of the Papers Committee, acting independently of each other, taking into account technical quality and relevance to the theme of the Symposium. The Papers Committee will then invite a strictly limited number of papers for presentation and thorough discussion at the Symposium (not necessarily confining themselves to authors who have submitted summaries). It is hoped to notify authors of papers during March 1982.

(iii) Distribution of Summaries
The summaries of the accepted papers will be sent before the Symposium by surface mail to all participants who have registered in good time.

(iv) Submission of Final Papers and Publication
The Proceedings will be published in the Annals of Glaciology by the International Glaciological Society. Papers presented at the Symposium will be considered for publication in these Proceedings, provided they have not been submitted for publication elsewhere. Final typescripts of these papers should be submitted to the Secretary General, International Glaciological Society, Lensfield Road, Cambridge CB2 1ER, England, by 21 June 1982. They should be written in English and prepared in accordance with the instructions that will be sent to authors when they are notified about acceptance of papers for the Symposium. The maximum length for papers will be 5000 words or the equivalent length including any illustrations. Papers longer than this and late papers will be excluded from the Proceedings volume. The papers will be refereed according to the usual standards of the Society before being accepted for publication. Speedy publication of the Proceedings will depend upon strict adherence to deadlines.

LAST DATE FOR SUBMISSION OF FINAL PAPERS: 21 JUNE 1982

7. DISPLAY SPACE

There will be a limited amount of space available for displays of photographs and maps related to the theme of the Symposium. Those participants who wish to use such space are asked to write to the Secretary General of the Society in Cambridge, giving details of the material they wish to display and the area required.

8. SOCIAL EVENTS

(i) ICEBREAKER
on the evening of Sunday 22 August there will be an icebreaker in the Sheraton Inn.

(ii) CLAMBAKE
The Clambake (a seafood banquet) will be held on Thursday 26 August. In addition to being the main social event of the Symposium, it will also be the Annual Dinner of the International Glaciological Society. Members of the Society and others not attending the Symposium will be welcome: tickets may be purchased at the registration desk on Sunday 22 August.

General information about the Symposium may be obtained from:

The Secretary General,
International Glaciological Society,
Lensfield Road, Cambridge CB2 1ER,
England. Tel: Cambridge 355974

Detailed information about arrangements in Hanover may be obtained from:

A.J. Gow,
CRREL, P.O. Box 282,
Hanover, NH 03755, U.S.A.

DATES TO REMEMBER

1 December 1981 – Last date for submission of summaries for consideration.
1 May 1982 – Last date for reservations: registration, accommodation.
21 June 1982 – Last date for submission of final versions of accepted papers, for consideration for publication in the Proceedings.

Registration, Accommodation

SECOND SYMPOSIUM ON APPLIED GLACIOLOGY

23-27 August 1982, Hanover, New Hampshire, U.S.A.

A. REGISTRATION FORM

(please type or print in black ink)

Name of participant:

....
(family name) (initials)

Address: ....

....

Accompanied by (indicate age if under 18)

Name: ....

Name: ....

I send registration fee/s as follows:

(i) Participants ....
£40/US$85 each £..... / $.....

(ii) Students (bona fide) ....
£26/US$55 each £..... / $.....

(iii) Accompanying persons ....
£16/US$35 each £..... / $.....

(There is no registration fee for accompanying persons under the age of 18)

TOTAL REGISTRATION FEE/S
= £..... / $.....

B. ACCOMMODATION FORM

Please reserve the following accommodation for the nights of 13-17 August 1982, for which I enclose a deposit of £23/US$50 per person.

Hotel - * shared accommodation preferred.
* single accommodation preferred.

TOTAL DEPOSITS FOR ACCOMMODATION

FOR .... PERSON/S = £..... / $......
* delete as appropriate

TOTAL PAYMENT (sections A, B)

Sent by cheque/Bank transfer, to Cambridge/Hanover = £..... / $.....

Mail to:
Secretary General,
International Glaciological Society,
Lensfield Road,
Cambridge CB2 1ER, England.

BEFORE 1 MAY 1982.

See page 1 of the Second Circular for methods of making payment.

RECENT MEETINGS (of other organizations)

INTERNATIONAL SYMPOSIUM ON ICE

A Symposium, sponsored by the International Association for Hydraulic Research and co-sponsored by the International Glaciological Society, the International Association of Hydrological Sciences and the World Meteorological Organization, was held at the Château Frontenac, Quebec City, Canada, on 27-31 July 1981. Business meetings of the IAHR included the working groups on Ice Forces, Ice Jams, Thermal Regimes and Ice-testing Methods. Participants were able to attend sessions of POAC-81 taking place in a neighbouring hotel at the same time. The preprint volume contained 57 of the 63 papers scheduled for presentation and a further 8 short notes. The final proceedings volume will contain all papers and discussion and can be ordered from Prof. B. Michel, Dept. of Civil Engineering, Université Laval, Cité universitaire, Québec, Canada, G1K 7P4 at a cost of $80.

Invited lecture: B. Michel - History of research on river and lake ice in Canada.
Invited lecture: L. Bengtsson - Experiences on the winter thermal regimes of rivers and lakes with emphasis on Scandinavian conditions.
L. Bengtsson - Heat losses from an open water surface at very low air temperature - a laboratory experiment.
G.D. Ashton - River ice suppression by side channel discharge of warm water.
V. Matousek - A mathematical model of the discharge of frazil in rivers.
T.O'D. Hanley & S.R. Rao - Acoustic detector for frazil.
F.D. Haynes, G.D. Ashton & P.R. Johnson - Performance of a point source bubbler under thick ice.
P. Tryde - Ice formation on the walls of a water tunnel excavated through rock in permafrost.
L. Votruba - Relations between climatic conditions and winter regime of water bodies.
Invited lecture: M. Drouin - Ice problems in the James Bay development.
D.M. Foulds - Peaking hydro generating stations in winter.
O. Györke, E. Decsi & E. Zsilak - Problems of ice release and flow conditions upstream of low-head river dams.
H.T. Shen & N.L. Ackerman - Wintertime flow and ice conditions in the upper St. Lawrence River.
T.E. Wigle, J. Bartholomew & C.J.R. Lawrie - Winter operations International Rapids section of the St. Lawrence River.
R. Boivin, O. Caron & M. Drouin - Influence de la couverture de glace sur les échanges d'eau douce dans un estuaire à marée: le cas de l'estuaire de la Grande Rivière, au début du remplissage du réservoir de LG 2.
K. Hirayama - Hydraulic resistance of ice cover.
M Jensen - Ice problems at Vittjärv power plant - measures and results.
Invited lecture: H. Parkinson - Ice conditions and problems on the Liard-Mackenzie River in north west Canada.
N.K. Gidas - Recherche sur les meilleures solutions contre les inondations de Matapédia causées par les débâcles.
F.M. Henderson & R. Gerard - Flood waves caused by ice jam formation and failure.
J.C. Tatinclaux & M. Gögüs - Stability of floes below a floating cover.
V. Kanavin - Fifty years of experience in the field of ice problems for river engineering.
R. Gerard - Ice scars as indicators of past breakup water levels.
N.L. Ackerman, H.T. Shen & R.W. Ruggles - Transportation of ice in rivers.
R.M. Vogel and M.J. Root - The effect of floating ice jams on the magnitude and frequency of floods along the Missisquoi River in northern Vermont.
Invited lecture: M. Skladnev - Achievements in ice engineering in the U.S.S.R.
D.J. Calkins, D. Sodhi & D. Deck - Port Huron ice control model studies.
S.F. Daly & D.M. Stewart - Force distribution in a fragmented ice cover.
G. Garbrecht & H. Fahlbusch - Formation of ice jams in the Elbe River - a case study.
N.D. Elhadi & K.S. Davar - Dispersion in a covered channel with varying roughness at the top cover.
N. Marcotte - Régime thermique et régime des glaces en rivière - étude de cas.
S. Petryk, U.S. Panu, V.C. Kartha & F. Clement - Numerical modelling and predictaability of ice regime in rivers.
C.D. Smith - Model study of ice movement at Idylwyld traffic bridge.
Invited lecture: Ö. Starosolszky - Thermal regime and ice forecasting for fresh-water bodies.
V. Balanin, V. Tronin, V. Malinovsky, Y. Sandakov & G. Ginzburg - Estimation of ice conditions and organization of shipping on rivers and reservoirs during the extended period of navigation.

S.M. Aleinikov, B.E. Lyapin, M.I. Zhidkikh, A.V. Panyushkin & N.G. Khraptyi - Protection of hydraulic structures from icing.
O.I. Gordeev & V.V. Degtyarev - Computation of trajectories of ice floes movement on the rivers.

I.N. Sokolov, Y.L. Gotlib, P.G. Dick & G.M. Ryabkin - Studies of ice action on pumped storage power plant structures.
I. Mayer - Ice hydraulics stability analysis.
Invited lecture: M.Mellor - Glacier mechanics.
S. Beltaos & A.M. Dean, Jr. - Field investigations of a hanging ice dam.
G.W. Timco - A comparison of several chemically-doped types of model ice.
D.A. Sandell - Carbamide ice growth in a large test basin.
M. Nakawo & R. Frederking - The salinity of artificial build-up ice made by successive floodings of sea water.
F.U. Häusler - Multiaxial compressive strength tests on saline ice with brush-type loading platens.
N. Urabe & A. Yoshitake - Strain rate dependent fracture toughness (K_{IC}) of pure ice and sea ice.
P.R. Kry - Scale effects in continuous crushing of ice.
N.K.Sinha - Comparative study of ice strength data.
P. Duval, M. Maître, A. Manouvrier, G. Marec and J.C. Jay - Primary creep and experimental method for testing ice in various conditions of strain rates and stresses.
L. Lainey & R. Tinawi - Parametric studies of sea-ice beams under short and long term loadings.
P. Oksanen - Friction and adhesion of ice.
H. Saeki, T. Ono & A. Ozaki - Mechanical properties of adhesion strength to pile structures.
L. Billfalk - Formation of shore cracks in ice covers due to changes in the water level.
N. Yoshimura & K. Kamesaki - The estimation of crack pattern on ice by the new discrete model.
R.T. Weiss, A. Prodanovic & K.W. Wood - Determination of the shear properties of ice rubble.
Invited lecture: L. Gold - Designing ice bridges and ice platforms.
G. Tsang - Fin boom ice gate for ice control and winter navigation.
P. Yee, T.E. Wigle & A. Hollmer - The Lake Erie - Niagara River ice boom - an operational experience.
R.Y. Edwards & R. Abdelnour - Model tests of level ice and multi-year ridges moving on to conical structures.
K.R. Croasdale & R.W. Marcellus - Ice forces on large marine structures.
C.J. Montgomery & A.W. Lipsett - Estimation of ice forces from dynamic response.
M. Määttänen - Ice-structure dynamic interaction - ice forces versus velocity - ice-induced damping.
J Karri & P. Jumppanen - Measurement of horizontal and vertical ice loads on pile type structures.

INTERNATIONAL CONFERENCE ON PORT AND OCEAN ENGINEERING UNDER ARCTIC CONDITIONS

The Sixth International Conference on Port and Ocean Engineering under Arctic Conditions (POAC-81) was held at the Hilton Hotel, Quebec City, Canada on 27-31 July 1981. Two volumes of the proceedings, with 98 of the 118 papers scheduled for presentation, were preprinted and a third volume will be published later with the balance of the papers and the discussion. Copies of the proceedings can be ordered from Prof. B. Michel, Dept. of Civil Engineering, Université Laval, Cité universitaire, Québec, Canada, G1K 7P4 at a cost of $120. Papers were grouped into sessions according to the following categories: icebergs, ice conditions, ice control measures, ice mechanics, interactions between ice and shore, marine foundations and scour, marine structures, meteorology and oceanography, navigation in cold regions, oil spills, remote surveillance and instrumentation, sea ice conditions, sea ice drift, wave and ice mechanics. Due to the number of papers three parallel sessions were held each day. The majority of papers focussed on problems encountered in the Arctic Ocean and the Labrador Sea. The following 14 invited papers were presented:

P Bruun - Design criteria for nearshore and offshore structures under Arctic conditions.
J. Déry - Design of wharves for winter operation in the St. Lawrence River.
J.-C. Dionne - Ice action on sea shores.
I. Holand - Risk assessment of off shore structures, design experiences and principles.
B. Johansson - Dome Petroleum operations in the Beaufort Sea.
H.R. Kivisild - Marine foundations.
J. Lewis - On the state of commercial Arctic marine transportation.
B. Michel - Advances in ice mechanics.
E. Palosuo - The biologically important areas in the Arctic Ocean
J. Ploeg - On the importance of defining wave climates.
E.F. Roots - Oceanography and meteorology in the Arctic.
J.R. Rossiter - Remote surveillance and instrumentation in sea ice.
A Soucy - Environmental impact of hydro plants in northern Québec.
T. Tabata - Friction measurements of sea ice on some plastics and coatings.

FUTURE MEETINGS (of other organizations)

FOURTH INTERNATIONAL CONFERENCE ON PERMAFROST

18-22 July 1983, Fairbanks, Alaska

The Fourth International Conference on Permafrost, organized by the National Academy of Sciences and the State of Alaska, will be held 18-22 July 1983 at the University of Alaska in Fairbanks.

ORGANIZING COMMITTEE:

Chairman - T.L. Péwé
Vice-Chairman - G.E. Weller

TOPICS

Papers dealing with all aspects of permafrost will be welcome. Papers will be accepted for formal presentation or for poster sessions. Details about the submission of abstracts and final papers will be given in the first bulletin.

Provisional themes for the meeting include:

1. Pipeline construction
2. Embankments
3. Deep foundations
4. Excavations
5. Mining and petroleum engineering
6. Municipal engineering
7. Site and terrain evaluation
8. Geotechnical problems
9. Geophysical exploration
10. Hydrates
11. Subsea permafrost
12. Distribution of permafrost
13. Frost heave and ice segregation
14. Physics and chemistry of frozen ground
15. Hydrology
16. Climate change and geothermal regime
17. Ecology of natural and disturbed areas
18. Planetary permafrost
19. Periglacial phenomena (geocryology)
20. Mechanics of frozen soil
21. Heat transfer processes
22. Other

Special symposia will be arranged and will be announced in subsequent bulletins.

English will be the official language of the Conference.

PUBLICATION

The proceedings of the conference will be published. Papers will be reviewed according to the usual standards before being accepted for publication.

FIELD TRIPS

Permafrost underlies 85% of Alaska and affects many aspects of daily life. The location of the Conference is therefore ideal for viewing numerous features of continuous and discontinuous permafrost, and construction techniques used to cope with it. Field trips of 3 to 5 days duration are planned to be held before and after the Conference. Local half-day trips will take place during the Conference. Fairbanks permafrost features of interest include frost heave sites, ice wedge exposures, experimental road construction, agricultural practices, strip mining, and tunnel excavation.

Proposed extended trips include the Alaska Railroad (construction techniques in mountainous and permafrost terrain, Mt. McKinley National Park); Fairbanks to the Prudhoe Bay oil field along the trans-Alaska pipeline; Fairbanks to the Mackenzie Delta by road (periglacial and glacial geology features); and Fairbanks to Anchorage by road through the Copper River Basin.

EXHIBITS

Displays of construction, transportation and geophysical equipment and scientific exhibits are planned.

COST

A full range of accommodations will be available, including hotels in Fairbanks and inexpensive housing in campus dormitories. A registration fee will be charged to cover the cost of conference documents and local field trips. Charter flights to Alaska may be available if there is sufficient interest.

PLANNING QUESTIONNAIRE

If you wish to receive the first bulletin please write to:

Louis De Goes, Executive Secretary,
Polar Research Board,
National Academy of Sciences,
2101 Constitution Avenue, N.W.,
Washington, D.C. 20418, U.S.A.

GLACIOLOGICAL DIARY

1981

4-5 November
Perspectives on Natural Resources Series: Symposium IV. The Arctic — Resource Development. Sir Sandford Fleming College, Ontario, Canada. (Dr S.H. Watts, Sir Sandford Fleming College, Frost Campus, P.O. Box 8000, Lindsay, Ontario, K9V 5E6, Canada)

1982

22-26 March
4th Northern Research Basin Symposium Workshop on the Effect of Distribution of Snow Cover and Ice on Stream Flow. Ullensvang Hotel, Hardanger Region, Norway. (D.H. Lennox, National Hydrology Res. Inst., Environment Canada, Ottawa, Ontario, K1A 0E7, Canada)

28 March - 5 April
South-American Regional Meeting on Glacigenic Deposits Neuquén (Neuquén) and San Carlos de Bariloche (Rio Negro) Argentina. (J. Rabassa, Departemento de Geografia, Universidad Nacional del Comahue, Av. Argentina 1400, 8300 Neuquén, Argentina)

13-16 April
The first 50 years — a look at the future, Joint Meeting, 39th Annual Eastern Snow Conference and 50th Annual Western Snow Conference, Reno, Nevada, U.S.A. (R.T. Brown, Chief Hydrographer Southern California Edison Co., P.O.Box 800, Rosemead, California 91770, USA)

.... June
Workshop on River Ice Hydraulics. University of Alberta, Edmonton, Alberta. (R. Gerard, Dept. of Civil Engineering, University of Alberta, Edmonton, Alberta, T6G 2G7, Canada)

17-19 May
Lake Agassiz Symposium, Geological Association of Canada. (J.T. Teller, Department of Earth Sciences, University of Manitoba, Winnipeg, Manitoba, R3T 2N2, Canada)

19-30 July
International Association of Hydrological Sciences, Exeter Assembly. Exeter, Devon, U.K. (The Organizing Committee, IAHS Scientific Assembly, Institute of Hydrology, Wallingford, Oxford, U.K.)

1-9 August (*)
INQUA Conference. Moscow, U.S.S.R. (I.P. Kartashov, Secretary General of the XI INQUA Congress, Geological Institute, USSR Academy of Sciences, Pyzhevsky 7, Moscow 109017, U.S.S.R.)

2-6 August
6th International Symposium on the Physics and Chemistry of Ice. Rolla, Missouri, U.S.A. (P.L.M. Plummer, Department of Physics and Cloud Physics, University of Missouri-Rolla, Rolla, Missouri 65401, U.S.A.)

16-20 August (*)
4th International Symposium on Antarctic Earth Sciences. Adelaide, Australia. (J.B. Jago, School of Applied Geology, South Australian Institute of Technology, P.O. Box 1, Ingle Farm, South Australia 5098, Australia)

22-28 August
11th International Congress on Sedimentology, International Association of Sedimentologists. McMaster University, Hamilton, Ontario, Canada. (IAS Congress, Department of Geology, McMaster University, Hamilton, Ontario, L8S 4M1, Canada)

23-37 August
Second Symposium on Applied Glaciology. Hanover, New Hampshire, U.S.A. (H. Richardson, Secretary General, International Glaciological Society, Lensfield Road, Cambridge CB2 1ER, England)

31 August — 2 September (*)
Ice Drilling Technology Workshop. University of Calgary, Calgary, Alberta, Canada. (G. Holdsworth, National Hydrology Research Institute, 4616 Valiant Drive N.W., Rm.101, Calgary, Alberta, T3A 0X9, Canada)

21-23 September
International Symposium on Hydrological Research Basins and their Use in Water Resources Planning. Bern, Switzerland. (M. Spreafico, Landeshydrologie,Postfach 2742, CH-3001 Bern, Switzerland)

* Correction to previous announcement

1983

18-22 July
Fourth International Conference on Permafrost. University of Alaska, Fairbanks, Alaska, U.S.A. (Louis de Goes, Executive Secretary, Polar Research Board, National Academy of Sciences, 2101 Constitution Avenue, N.W., Washington D.C. 20418, U.S.A.)

15-26 August
18th General Assembly of the IUGG. Hamburg, Federal Republic of Germany. (P. Melchior, Observatoire Royal de Belgique, Avenue Circulaire 3, B-1180, Bruxelles, Belgium)

1984

2-7 September
Symposium on Snow and Ice Processes at the Earth's surface. (Co-sponsored by the Japanese Society for Snow and Ice.) Sapporo, Japan. (H. Richardson, Secretary General, International Glaciological Society, Lensfield Road, Cambridge CB2 1ER, England)

NEWS

AWARDS

Her Majesty The Queen has approved the award of the Royal Geographical Society's Patron's Medal to Professor Valter Schytt, for contributions to glaciology and field work in the polar regions.

The Royal Geographical Society has made a special posthumous award to Jim Bishop for surveying fieldwork in the Karakorum and Antarctica.

Dr Peter Wadhams has been awarded the Bruce Medal of the Royal Society of Edinburgh for his studies of pack ice behaviour near Spitsbergen, the North Pole and off east Greenland.

Dr Richard P. Goldthwait, Professor Emeritus of Geology and founder and first director of the Institute of Polar Studies, has received The Ohio State University Distinguished Service Award for his contributions to science and the university.

Dr W. Barclay Kamb has been elected a Fellow of the American Association for the Advancement of Science.

RECENT DEATHS

On 13 August 1981, Louis Philippe, one of the oldest members of the staff of the Laboratoire de Glaciologie du CNRS, was tragically killed after being struck by a glider while filming on his holidays. Amongst his many achievements Louis Philippe had produced several educational films on glaciology: Glaciological Expedition to Spitsbergen, Seismic Exploration of Glaciers, From Falling Snow to Running Water, etc.

INTERNATIONAL ASSOCIATION OF HYDRAULIC RESEARCH

Members of the IAHR Committee on Ice Problems would like to be contacted by those having an interest in the work of the Committee or who have suggestions as to new Working Groups which might be formed. Countries represented on the Committee are the following:

Canada (M. Drouin and R. Gerard), Denmark (P. Tryde), Finland (M. Määttänen), Federal Republic of Germany (J. Schwarz), Hungary (E. Zsilak), Japan (H. Saeki), Norway (T. Carstens), Sweden (L. Bengtsson), USA (G. Ashton and G. Frankenstein) and USSR (V. Degtyarev and V.E. Lyapin).

COLD REGIONS SCIENCE AND ENGINEERING - GRADUATE STUDIES

A joint program is being offered by the Thayer School of Engineering at Dartmouth College and the U.S. Army Cold Regions Research and Engineering Laboratory, Hanover, New Hampshire. The program, leading to the master's degree in engineering or science, provides research and course work opportunities in the following areas.

Electronics and Instrumentation for Polar Environments: When measurement equipment is being designed for use in cold regions, certain special factors must be taken into consideration. These include portability, low temperature instability, unusual power drains, and severe weather conditions (blowing snow, icing, etc.).

Mechanical Design for Polar Environments: The need to drill, excavate and sample cold regions materials (snow, ice, permafrost) requires the development of specialized augers, drills and cutters for these applications. Equipment design must take into account material properties and extreme environmental operating conditions.

Environmental Engineering: Modern engineering must consider the protection of local environments. For example, the design and construction of pipelines, roads and wastewater treatment facilities in low temperature environments or in permafrost demand special treatment.

Materials Science: Engineering solutions to cold regions problems require the characterization and quantification of the response of snow, ice and frozen soil to mechanical, thermal, electrical, and other forcings. Therefore the fundamental properties of these materials must be well understood.

Hydraulics and Hydrology in Cold Regions: The presence of an ice cover on rivers and lakes and the formation and movement of ice in these bodies as a two-phase flow creates a set of problems not yet adequately addressed. Snow cover characteristics, the movement of water through snow, and snowmelt runoff prediction all require study.

Geophysics of Snow, Ice and Frozen Ground: The large scale behaviour of snow, ice and frozen soils in response to natural forcing fields must be understood. The movement of sea ice driven by winds and currents, the deformation of large ice sheets by gravity, and the freezing and thawing of lakes are some of the areas under investigation. Engineering mechanics, oceanography, physics and fluid mechanics are applied in the study of these problems.

Polar Marine Engineering: This area covers the influence of ice covers on structures, transportation systems, etc. in marine, river and lake environments. Icebreakers, ice forces on structures and icing on the walls of canal locks are all currently being investigated.

Financial assistance is available for well-qualified students. For admission requirements and more detailed information contact:

The Dean of Thayer School of Engineering,
Hanover, New Hampshire 03755, U.S.A.

NEW MEMBERS

Fenton, Mark M., Terrace Plaza, 4445 Calgary Trail South, Edmonton, Alberta, T6H 5R7, Canada.
Gemmell, J. Campbell, 28 Ashvale Place, 1st Fl. Right, Aberdeen AB1 6QA, Scotland, U.K.
Koivunen, Iiro Pentti, Verkkotie 10 D 7, 80160 Joensuu 16, Finland.
Offermann, Barbara A., P.O. Box 62333, Sunnyvale, California 94088, USA.
Warren, Stephen G., P.O. Box 449, University of Colorado, Boulder, Colorado 80309, USA.
Wintges, Theodore, Justastrasse 10/II/RGB, D-8000 Muenchen 19, Germany.
Yoshida, Minoru, Water Research Institute, Nagoya University, Furocho Chikusa-ku, Nagoya 464, Japan.

INTERNATIONAL GLACIOLOGICAL SOCIETY

Lensfield Road, Cambridge CB2 1ER, England

DETAILS OF MEMBERSHIP

Membership is open to all individuals who have scientific, practical or general interest in any aspect of snow and ice study. Payment covers purchase of the Journal of Glaciology and Ice. Forms for enrolment can be obtained from the Secretary General. No proposer or seconder is required.

ANNUAL PAYMENTS 1981

Private members	Sterling: £20.00
Junior members	Sterling: £ 6.00
Institutions, Libraries	Sterling: £40.00 for Volume 27 (Nos. 95, 96, 97)

Annals of Glaciology (conference proceedings volumes)—prices on application.

Note — Payments from countries other than Britain should be calculated at the exchange rate in force at the time of payment. If you pay by bank draft, rather than by personal cheque, please ensure that sufficient money is included to cover the bank charges. Thank you.

ICE

Editor: Simon Ommanney

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Annual cost for libraries, etc. and for individuals who are not members of the Society: Sterling £6.00.

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