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# Symposium on Permafrost Geophysics

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be arranged easily, and the participants have ample opportunity to get to know one another and to discuss problems of mutual interest. The Ottawa Workshop was organized under the chairmanship of Professor D. I. Gough of the University of Alberta, Edmonton, Canada.

**References**

Chapman, S. and J. Bartels, 1940, Geomagnetism; Chapter 22, Electromagnetic Induction within the Earth: Oxford University Press.

Rikitake, T., 1966, Electromagnetism and the Earth's Interior: Elsevier Publishing Co.

Electromagnetic Induction in the Earth and Planets, Workshop review papers presented at University of Edinburgh, September 1972: Phys. Earth Planet. Interiors, v. 7, no. 3, 1973, 398 p.

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# Symposium on Permafrost Geophysics

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The Canadian National Committee for the International Hydrological Decade (IHD) and the Permafrost Subcommittee of the National Research Council of Canada, Associate Committee on Geotechnical Research (ACGR) held a point Symposium on Permafrost – Hydrology and Geophysics in Calgary, Alberta on February 26 to 28, 1974. The hydrology section was sponsored and organized by the Canadian National Committee for the IHD. The geophysics section was sponsored and organized by the Permafrost Subcommittee of ACGR. This report will review the geophysical part of the symposium.

Fourteen invited papers were presented during the last day and a half of the symposium. The purpose of the presentations was to give an up-to-date account of geophysical techniques that have been tried in the northern regions of Canada and Alaska. Emphasis was placed on results of application of various techniques, rather than on model studies and equipment feasibilities and systems. This emphasis was appropriate in view of the specific nature and present interest in the subject and the interaction between hydrologists, geologists and engineering geologists.

The opening paper, "Geophysical Parameters of Permafrost" by L. S. Collett indicated that the electrical, seismic and gravity methods were the most useful methods applicable in the frozen ground environment. This is because electrical resistivity and elastic properties of earth materials exhibit the greatest change in frozen soils and rocks between 0°C and −10°C. The ratio between ice and water depends on the temperature gradient, porosity, dimensions of the pores, concentration of salt solutions and mineral composition of the soils and rocks. The gravity method is useful to detect ground ice and for estimating the thickness of excess ice but is of little use for the detection of the presence or absence of permafrost. The freezing of insterstitial water in rocks and soils has little or no effect on the magnetic permeability and radioactive parameters.

In the following paper entitled "Temperature and Heat Flux Measurements through Permafrost as a Geophysical Tool" by A. M. Jessop and A. S. Judge several points were brought out. The process of drilling a well disturbs the temperature in the ground around the well. The extent of this disturbance depends on many factors, including the temperature of the drilling fluid, the porosity of the surrounding rock, the thermal conductivity of the rock, and the duration of circulation of the drilling fluid. Of the two examples presented, a series of temperature profiles show that after six to eight years the temperatures are still continuing to return to equilibrium levels. At equilibrium level for the one example at Reindeer in the Mackenzie Delta, the temperature profile approximates two straight lines with different gradients, the change in gradient coinciding with the freezing boundary. The other example at Winter Harbour on Melville Island in the Arctic Archipelago shows very little change in the temperature gradient at equilibrium. The difference in behaviour between these two wells is accounted for by the fact that at Reindeer the porosity of the penetrated section was very high, and the ice contained in it was melted.

At Winter Harbour the porosity was very low, and although any ice around the hole was probably melted, there was so little that it was quickly refrozen after drilling. If temperatures are measured at sufficiently close intervals of time, porosity of the host-material can be determined and the material itself identified. This factor is complicated by the salinity of the water. The narrow zone of high temperature gradient above 0°C at depth usually marks the bottom of the frozen layer. This zone will always be on the high side of the hole due to disturbance by drilling. In the Beaufort Sea, the authors state that by a knowledge of heat flow, past and present surface temperatures, and the properties of the earth materials concerned, it is possible to make a prediction of the depth of permafrost at any location. The weakness in this process is our knowledge of past conditions.

The third paper "Electrical Resistivity Profile of Permafrost" by P. Hoekstra relates the experience of the author who has worked in the Fairbanks, Alaska region on the study of permafrost. In the application of electromagnetic geophysical techniques, it is concluded that conduction currents (resistivity) dominate to about $10^5$ Hz and displacement currents (dielectric constant and dielectric loss) above $10^5$ Hz. For the solution of geotechnical problems, $10^6$ Hz is perhaps the upper limit of useful frequencies. Resistivity values for several saturated soils and one rock type as a function of temperature (−15°C to 10°C) are shown in graphic form. Resistivity variations of the various horizons near Fairbanks are also presented.

M. S. King, T. S. Bamford and P. J. Kurfurst in "Ultrasonic velocity measurements on frozen rocks and soils" describe an apparatus for measuring compressional and shear-wave velocities on core samples in their frozen state under uniaxial compression (2000 lb/in²). The data for two limestones and two sandstones show a very rapid increase in velocity when the temperature is reduced below 32°F. The compressional velocities are also greater than the shear velocities. The compressional-wave velocities on the two limestones show a hysterisis effect for descending and ascending temperatures. Shear-wave velocities also show this hysterisis effect. For the one limestone (Warminster), the electrical resistivity also shows the same hysterisis effect as was found for acoustic velocities. A corresponding freezing-point depression was not detected with the sandstone samples.

The last paper in the first session on physical properties of permafrost pertains to "Application of remote sensing to permafrost studies" by C. Tarnocai and J. Thie. Remote sensors do not significantly penetrate the surface of the soil but detect radiation reflected or emitted from the surface of the land or vegetation canopy. Understanding the relationships and dynamics of ecosystems is the key to the interpretation of permafrost. The near-surface permafrost affects the surface pattern of the terrain, vegetation, drainage and soils. Multispectral remote sensing data provide more information than does conventional panchromatic photography. Perennially frozen peat landforms (palsas, peat plateaus and polygons) were clearly identifiable on multiband photography as well as on panchromatic imagery and could be mapped with great accuracy. Perennially frozen alluvial soil can also be separated from unfrozen soil by the use of vegetation cover since on alluvial soils permafrost was found under spruce forest cover, while it was absent under willow cover. ERTS satellite imagery could map peat plateaus (100 m diameter) in large organic complexes in the southern zones. Frost-heaved stone-fields, peat polygon areas and peat plateaus could be detected in the arctic and subarctic environments. The more broken landform of the Precambrian Shield proved to be too complex for successful permafrost mapping. High and low altitude infrared scanning (3-5 μm and 8-14 μm) showed very little promise for detection of permafrost but contained valuable information relating to soil moisture. SLAR imagery was of no value for the detection or delineation of permafrost.

The papers in the next two sessions on the final day of the symposium were presented to give an overview of the methods and techniques that have been used in the continuous and discontinuous permafrost regions and off-shore. In the sixth paper by W. J. Scott and J. A. Hunter on "Seismic and electrical methods in permafrost detection", surveys were carried out at five test sites in the Mackenzie Valley. In DC resistivity soundings, thickness determinations can only be made when the lateral extent of permafrost is more than 10 times its thickness. Thick segregated ice can sometimes be identified in soundings in areas of thick permafrost. VLF (Very Low Frequency, 15-20 kHz) measurements using the Radiohm principal are not useful for detecting permafrost in the thin discontinuous zone because the skin depth is greater than the permafrost thickness. VLF method is able to differentiate areas of thick from thin permafrost. Seismic refraction profiling is useful in areas of discontinuous permafrost for mapping the areal extent of frozen and unfrozen ground. Seismic velocities can be used in thin continuous permafrost zones to delineate material types in unconsolidated overburden and massive ice lenses. Uphole wavefront methods can map permafrost boundaries in areas of thermal disturbance. The application of reflection methods has not been successful in mapping permafrost structure.

In the seventh paper "Geoprobe EM R-14: A new multi-spectral EM induction system for delineating depths of permafrost zones" by M. K. Ghosh and P. G. Hallof, an inductive EM system is described which makes use of a large multi-turn loop lying on the ground. It operates on 14 pre-selected frequencies from 5 Hz to 45,000 Hz. A receiver measures the amplitudes of the vertical ($H_z$) and horizontal ($H_R$) magnetic components. Provision is also made to measure the orthogonal electric field (E) by measuring the voltage induced between two iron stakes driven into the ground 400 feet apart. Phase is also measured between $H_z$ and $H_R$

components with respect to the E-field. Samples of theoretical curves are given including some thicknesses of permafrost on Melville and Cameron Islands in the Arctic Archipelago and a sedimentary section at Bowmanville, Ontario.

A paper on "The detection of ground ice by gravity profiling" by V. N. Rampton and R. I. Walcott demonstrates the use of the gravity method at five different sites in an area of ice-cored topography. Bouger anomaly profiles using an average density of 2.0 Mg $m^{-3}$ for thick frozen unconsolidated sediments and 0.9 Mg $m^{-3}$ for ice provide a quick method of assessing the relative amount of ice along a profile. The thickness of ice and the elevation were inversely proportional to the Bouger anomaly along each profile. The average amount of excess ice in the topography along the profiles is obtained by removing linear trends, obtaining the Bouger density of the topography, and calculating the proportion of frozen saturated sediment and ice required to produce this density. The above technique is unable to detect changes in the amount of excess ice that have a linear trend over the complete profile or a uniform slab underlying the complete profile.

The ninth paper moves offshore to describe "A seismic refraction method to detect sub-seabottom permafrost" by J. A. M. Munter and G. D. Hobson. The Geological Survey of Canada has been conducting experiments for the detection of offshore permafrost by seismic methods in the Mackenzie Delta region of the Beaufort Sea. A low velocity layer (sea-water and unfrozen sediments) overlying a high velocity layer (permafrost) constitutes a model amenable to interpretation by the seismic refraction method. Using single-ended refraction profiling, depths of penetration beneath the sea bottom in excess of 100 metres has been achieved in shallow waters to a depth of 35 metres.

The tenth paper "Airborne E-Phase resistivity surveys of permafrost" by R. V. Sellman, J. D. McNeill and W. J. Scott discusses the potential of the airborne Barringer E-Phase system for mapping ground resistivities at three frequency ranges: Broadcast Band (BCB), Low Frequency (LF) and Very Low Frequency (VLF). The areas in Canada included five sites along the Mackenzie Valley, between Tuktoyaktuk and Fort Simpson and in a discontinuous permafrost zone in central Alaska, near Fairbanks. Each frequency senses the ground to different depths depending on the resistivity. The most obvious direct interpretation that the apparent resistivity data permit is the distinction between thawed and frozen zones in fine-grained sediments (Fairbanks). In the Involuted Hill area, near Tuktoyaktuk, the VLF contour map clearly indicates the location of areas of deep thaw associated with present or recenty drained thaw lakes. The topographic high areas and Involuted Hill in which massive ground ice occurs were clearly defined by high resistivities. The area near Norman Wells at Heart Lake provides an example where resistivity contrasts between various ground conditions are small. Local high values appear to be associated with sandy areas and alluvial materials along streams. The surveys indicate that the airborne system can be a useful regional reconnaissance tool from which data on ground conditions and permafrost distribution can be inferred, valuable to planning drilling programs and engineering site evaluation. The degree of sophistication of interpretation of airborne E-Phase data is much dependent on the amount of ground truth available.

The next paper by G. W. Smith and G. Rempel on "Review problems of exploration geophysics in permafrost" discusses the seismic method for oil and gas prospecting in permafrost regions. The presence of permafrost distorts the "seismic picture" of the lower geological horizons. Seismic reflections from depth do not provide data for the delineation of the upper permafrost section nor of its distorting effects. The most important problem for the reflection seismic method is the variable nature of permafrost both vertically and horizontally. Most of these variations are due to heat sources such as bodies of water. The velocity discontinuities near the surface due to the thaw bulbs under water bodies may be quite abrupt, and acting as vertical reflecting interfaces often cause reverberating surface waves which obscure the energy reflected from depth. Unique to permafrost regions are the "frost breaks" that are visible on many records where dynamite is the seismic source. Large flood plains may leave residual, alternating layers of frozen and unfrozen sediments which can cause reverberations and energy dissipation. Without adequate knowledge of the distribution of permafrost for the correction of seismic reflection anomalies, there is the ever present danger of drilling non-existent structural prospects.

R. Burns and J. M. Hamilton presented a paper on "Some geophysical and hydrological aspects of permafrost in the Cornwallis Island Area, N.W.T.". Apparent resistivity data bear a distinct correlation with topographic altitude. Before isostatic rebound occurred throughout this region, the coast line was 135 m above its present position. The vaues of apparent resistivities above 135 m are in general higher than they are at lower altitudes. The average mean resistivity above 135 m is 20,000$\Omega$ m, at 135 m is 10,000$\Omega$ m and from 135 m to 40 m the range is from 4,000 to 450$\Omega$ m. The authors suggest that the correlation between apparent resistivity and present altitude is due to the fact that the portion which was submerged by the glaciated ice load contains minute amounts of brine in the pore spaces of the rock. Subsequent drilling experienced loss of fluid in the hole which was attributed to a permeable zone which occurred at a depth where rock temperatures were about −2.1°C which is the melting point of seawater.

A new technique of using radar frequencies for sounding in permafrost was presented by W. J. Scott, K. J. Campbell and A. S. Orange entitled "EM pulse survey method in permafrost". This paper describes the results of an experiment in the use of an impulse-radar system to study sub-surface conditions in permafrost terrain. A description is given of the pulse system. The dominant frequency of the pulse appears to be about 100 Mhz with significant lower-frequency components. Tests were made at two sites and although the results were not too conclusive, it did point out inherent difficulties in using high frequency EM reflections to delineate massive ice. The tests were carried out when the active layer was present. It is felt that such work, carried out when the active layer is frozen, offers some reasonable chance of success.

The fourteenth and final paper in the symposium describes the "Use of wireline well log information to determine the presence of permafrost" by E. T. Connolly. Thanks to the efforts of the Canadian Well Logging Society, information on well logs has been standardized. Information on temperature borehole logs include the bottom-hole temperature, the temperature when each logging device entered the borehole, the time circulation stopped, the time drilling stopped, the time the tool was on bottom, the temperature observed by a maximum-reading thermometer plus the temperature recorded on the run. With these data, an accurate time-temperature plot can be determined. By combining data from several logging runs at different depths in a well bore, and plotting them against time, one can establish a fairly accurate geothermal gradient for a particular location. Then, by extrapolating this temperature gradient back to the mean annual ground temperature for the location, the depth of permafrost can be estimated at the point at which the temperature gradient crosses the 30° to 32°F temperature point on the plot. Resistivity and sound velocity wireline logs exhibit high values in perennially frozen ground. Unfortunately, the borehole does not have frozen material or soils in its immediate vicinity due to a thaw zone as a result of the drilling. The result is to distort the resistivity and velocity log readings, so that the detection of the base of permafrost tends to be distorted by these methods. Recently logging firms have begun to use normal resistivity spacings in the order of twenty feet to detect the presence of permafrost at a further distance from the well hole. A combination of wireline well logs now make it possible to determine the presence and depth of permafrost in arctic wells with reasonable accuracy.

On the last evening of the symposium, a meeting was attended by 60 participants from industry, government and universities and chaired by L. S. Collett on the "Future problems of permafrost geophysics". Problems of permafrost relating to the industry in the fields of petroleum and mineral exploration, construction, pipelines and drilling were discussed. Excellent notes on these discussions have been prepared by Dr. M. S. King, University of Saskatchewan. Arrangements have been made with Dr. R. J. E. Brown, NRC, to publish these notes by Dr. King and extended abstracts of the papers presented at the symposium in a Technical Memorandum of the National Research Council.

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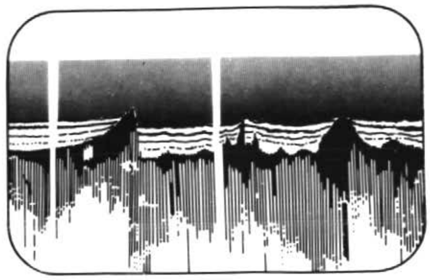

# The Ocean '74 Conference

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**Summary**
Ocean '74, the fifth IEEE International Conference on Engineering in the Ocean Environment, was held in Halifax, Nova Scotia, August 21 to 23, 1974, under the chairmanship of O. K. Gashus of Nova Scotia Technical College. This was the first time that the annual conference was held outside the USA. 529 people from many different countries attended: 125 papers by authors from 10 different countries were presented.

The major portion of the work presented was oriented toward electrical and electronic engineering but the Technical Program Committee did seek papers from other disciplines to exemplify the multidisciplinary nature of oceanography. The work in temperate and Arctic waters was the main emphasis of the conference and the largest session dealt with "Engineering and Physics of Sea Ice". Other subject areas included: 1. Seismic reflection methods and geological instrumentation and techniques, 2. Positioning at sea, 3. Acoustic applications, techniques, instrumentation, and scattering, 4. Data acquisition, communications, telemetry, and signal processing, 5. Instrumentation, sensing in the ocean environment, and pressure