Frozen Ground

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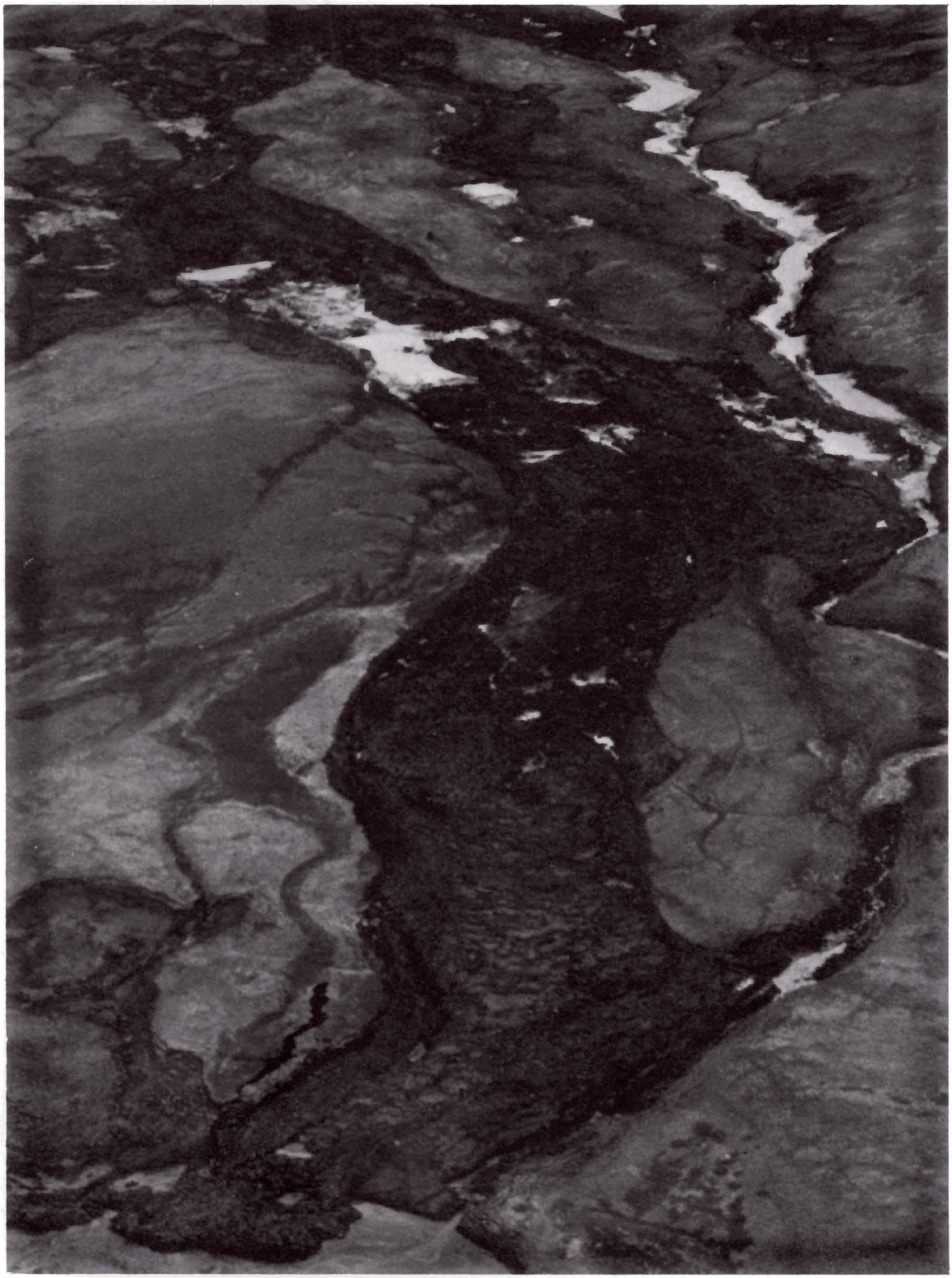

International Permafrost Association

The International Permafrost Association, founded in 1983, has as its objectives fostering the dissemination of knowledge concerning permafrost and promoting cooperation among persons and national or international organizations engaged in scientific investigations and engineering work on permafrost. Membership is through adhering national or multi-national organizations. The IPA is governed by its officers and a Council consisting of representatives from 20 adhering bodies having interests in some aspects of theoretical, basic and applied frozen ground research (including permafrost, seasonal frost, artificial freezing and periglacial phenomena). Working Groups organize and coordinate research activities. The IPA became an Affiliated Organization of the International Union of Geological Sciences in July 1989. The Association's primary responsibility is the convening of the international permafrost conferences. The first conference was held in West Lafayette, Indiana, USA in 1963; the second in Yakutsk, Siberia, 1973; the third in Edmonton, Canada, 1978; the fourth in Fairbanks, Alaska, 1983; the fifth in Trondheim, Norway, 1988; the sixth in Beijing, China, 1993. The seventh is planned for Yellowknife, Canada, in 1998. Field excursions are an integral part of each Conference, and are organized by the host country.

Officers of the Association (Executive Committee)

President	Vice President	Vice President	Secretary General
Cheng Guodong, China	Hugh M. French, Canada	Nikolai N. Romanovskii, Russia	Jerry Brown, USA

Members

Argentina	Finland	Netherlands	Spain
Belgium	France	Norway	Sweden
Canada	Germany	Poland	Switzerland
China	Italy	Russia	United Kingdom
Denmark	Japan	Southern Africa	United States of America

Standing Committees

Finance Committee	Advisory Committee on Working Groups	Editorial Committee

Working Groups

Data and Information	Periglacial Processes and Environments
Terminology	Cryosols
Global Change and Permafrost	Foundations
Mountain Permafrost	Seasonal Freezing and Thawing of Permafrost Areas

Cover: *Active-layer detachment slides in the valley of Black Top Creek, Fosheim Peninsula, Ellesmere Island, Canada. These slope failures, the largest of which are more than 600 m long, formed as a result of particularly rapid thaw during the summer of 1988. Under a warmer climate, the frequency of such events could increase, affecting slope development and sediment loads in rivers. A visit to this site is planned as part of a field trip and symposium on Ellesmere Island in July 1996 as one of the activities of the Working Group on Periglacial Processes and Environments. (Photo taken in 1989 by A.G. Lewkowicz; contact him for details on the 1996 meeting.)*

FROZEN GROUND
The News Bulletin of the International Permafrost Association

Number 15 **June 1994**

Frozen Ground, the News Bulletin of the International Permafrost Association (IPA), is published semi-annually. The IPA is a non-governmental association of national organizations representing 20 countries or groups of countries. The success of the bulletin is dependent upon the willingness of IPA participants to supply information for publication. Copy date for issue No. 16 is 15 October 1994. Please ensure that working group and member country reports are submitted in good time for publication. News items are also very welcome from any IPA participant or others, as are interesting photographs for the cover (please furnish 8"×10" black and white glossy prints). To submit news items or photos please contact the appropriate individual listed on page 31, or the Secretary General.

Issue No.15 of *Frozen Ground* was compiled by Jerry Brown with the assistance of Alan Heginbottom of the Editorial Committee. Production is courtesy of the Cold Regions Research and Engineering Laboratory, Hanover, New Hampshire, USA. Copies of *Frozen Ground* are available in Canada from Alan Heginbottom, Geological Survey of Canada, 601 Booth Street, Ottawa, Ontario; in Russia from Nikolai Grave, National Permafrost Committee, USSR Academy of Sciences, Fersman Street 11, 117312 Moscow; in the United States from Jerry Brown, P.O. Box 9200, Arlington, Virginia 22219-0200; and elsewhere from Council members.

EXECUTIVE COMMITTEE REPORT

It has been a busy time for the IPA, its Working Groups and the Executive Committee. The post-Conference proceedings volume was edited and published; it includes the summaries and papers from the special thematic sessions. The annotated bibliography on permafrost and climatic change was revised and edited and is in press. A new data rescue project has been proposed: the Global Geocryological Database (GGD). An implementation proposal and plans for a Fall 1994 workshop for the GGD are under development with members of the Data and Information WG at a meeting in Southampton, UK. The Global Change WG completed a review paper and several members participated in a St. Petersburg, Russia, meeting on monitoring changes in tundra biota. Additions and revisions were made to the multi-language glossary; a special Swedish version was published and a new draft of the Russian–English dictionary was prepared and copies distributed in English and Russian for comment. Members of the Foundations WG met in Edmonton and developed long-range plans. The Cryosols WG organized its summer field program to the Kolyma lowlands to compare international soil classification and mapping approaches. The Periglacial WG continued planning for the September symposium and field trip on slope deposits in France and for workshops on active layer modeling and monitoring. The Mountain Permafrost WG prepared its input to the IPCC report. A revised draft of the permafrost map was produced and final revisions are underway, with publication anticipated in late 1994.

As agreed upon by the Council in Beijing, the Executive Committee allocated funds to Working Groups based on individual requests to support and stimulate many of the above activities. Thus far in 1994, approximately $7,000 (US) was committed or transferred to Working Groups. This total exceeded the $5000 approved and was based on the worthy proposals and the present financial situation. Members have been timely in paying their annual dues, with 12 of the 20 members having met their 1994 obligation at this time. Notable were members paying for the first time, including Argentina, Sweden, Switzerland and Southern Africa. A complete financial report for 1994 will be presented in December, at which time we will have more information on several pending proposals to support the Secretariat and data activities. The Secretary General has received a request from Kazakhstan to become a Member. Several others have requested individual membership.

The IPA has been actively pursuing its international liaison activities, particularly in support of the Beijing resolution on global change. The major effort was preparation of a draft section for the Intergovernmental Panel on Climate Change (IPCC) Second Assessment Report and its Working Group II section on the Cryosphere. Input was collated from several working groups, individuals and published literature. The IPA–IPCC permafrost draft report is reproduced in its entirety in this issue of *Frozen Ground*. An explanation of the IPCC process is also included (p.15). Readers are encouraged to comment on this draft and send changes and additions to the Secretary General. The IPCC reports are scheduled for publication in late 1995 after thorough international expert review. In addition to the IPCC activities, we have been in close contact with the International Arctic Science Committee (IASC), the International Association of Geomorphologists, the International Society of Soil Science, the International Geosphere-Biosphere Programme (IGBP), and several IUGS projects, including the project on Earth Processes in Global Change and the COGEOENVIRONMENT and its Workshop on Geo-indicators, which will be attended by IPA Vice President Romanovskii in July in Newfoundland, Canada.

Finally, the Executive Committee is meeting in the United Kingdom in early July in conjunction with the Data and Information Working Group meeting on data rescue. We will review present IPA and liaison activities and develop plans for the 1995 Council meeting in Berlin during INQUA. Results of those discussions will be circulated to members and reported in the December issue of *Frozen Ground*. We wish everyone a successful summer field season and fall meetings.

REPORTS OF WORKING GROUPS

Recent Activities of the Working Groups

Essentially all Working Groups were actively pursuing their stated program goals over the past six months. Summaries of these activities are reported below. Allocation of funding by the IPA Executive Committee in response to WG requests is included in the appropriate reports. Purposes and membership of the WGs are reported in *Frozen Ground* No. 14. For further information on individual WG activities, contact the Chair or Secretary at the addresses given on page 32.

Data and Information

R.G. Barry, Chair (USA); J.A. Heginbottom, Secretary (Canada)

Members of the Working Group and the Executive Committee have prepared a proposal to organize and develop a Global Geocryological Database (GGD). The initial focus of the GGD is on data rescue in both hemispheres, leading to a more systematic archiving and distribution of relevant permafrost and seasonally frozen soils data. The draft proposal was distributed to all IPA Adhering Bodies and Working Groups in April for comments and endorsements. Development of the GGD will be coordinated closely with the World Data Centers and other international organizations, including the Global Resources Information Database (GRID). The Russian component, following the recommendation of the Beijing Council meeting to establish a data recovery activity in Russia, has already begun to develop its component of the GGD. The Minister of Environmental Protection and Natural Resources has endorsed the proposed GGD and established a base for it in the Federal Center of Geoecological Systems (FCGS).

A small planning meeting to develop GGD activities and its funding is scheduled at the GeoData Institute, University of Southampton, 30 June–1 July. Another small workshop is being planned to be held in Europe in October or November 1994. Funding for the GGD both within each country and for IPA will be required, and several proposals are under consideration for workshops, training, and data identification and rescue. A review of ongoing data acquisition will also be undertaken as part of the GGD with the assistance of other IPA WGs. A description of the proposed GGD activities will be available soon and will be published in the December 1994 issue of *Frozen Ground.*

The Working Group provided material for the IPA contribution to the draft Second Assessment Report of the IPCC (see p. 21–22). Major emphasis for closing gaps in knowledge and uncertainties focused on the need to assess past data and organize a comprehensive effort to monitor geocryological conditions and processes, both of which are linked to the GGD.

The annotated bibliography of permafrost and climate change by E.A. Koster, M.E. Nieuwenhuijzen and A.S. Judge was revised and final editing was accomplished; a supplemental list of recent references was added as an appendix by Ann Brennan. The bibliography is scheduled for publication in June 1994 in the series Glaciological Data as Report GD-27, World Data Center-A for Glaciology, Boulder, Colorado.

IPA funds totaling $3000 have been provided for assistance in publishing the annotated bibliography, WG support, and travel to the Southampton meeting.

Terminology

R.O. van Everdingen, Chair (Canada); V. Konishchev, Secretary (Russia)

Several additions were made to the eight-language index (English, French, German, Italian, Norwegian, Russian (plus transliteration), Spanish, and Swedish) of permafrost and ground ice terms, and final corrections made to all but the German version. Printouts of the current draft are available at cost from the Chair ($5.00 US, per language, or $30.00 for the eight-language set). A Swedish version of the index was published by Lund University (see *Publications*, page 27, for more information).

The next version of the Russian–English permafrost dictionary, prepared by Nikolai Romanovskii, V. Konishchev and G. Rosenbaum, containing over 3000 geocryological and related terms, was circulated on diskette and in hard copy for comments in early 1994. The Chair provided some editing and transformed the file into a WordPerfect database to enable production of both Russian–English and English–Russian versions. A limited number of paper copies of the English–Russian version are being circulated for review and comment. Romanovskii plans to have the next

version available in June; it will contain draft definitions for selected terms.

Poster papers for both the multi-language index and Russian–English dictionary will be presented in July at the 15th Polar Libraries Colloquy, Cambridge, UK. Plans for a WG meeting have been postponed. There is a growing need to organize an internationally acceptable index of geocryological terms for indexing data sets and bibliographic collections. This topic will be explored with the Polar Librarians and several global data organizations.

In addition to WG members listed in *Frozen Ground* No. 14, the following are corresponding members: R.G. Barry (USA), E. Buk (Argentina), S.A. Harris (Canada), L. King (Germany), B. Ladanyi (Canada), M. Seppälä (Finland), D. Trombotto (Argentina), T.S. Vinson (USA), Zhou Youwu (China), C. Tarnocai (Canada).

IPA funds totaling $1000 were allocated for computer and personnel support to the Chair and Ex-Officio member Romanovskii for work on the index and dictionary.

Global Change and Permafrost

F.E. Nelson, Chair (USA); A.E. Taylor, Secretary (Canada)

The Chair, Secretary and members contributed several major sections to the IPA–IPCC report (see page 16). These were based, in part, on the paper from the special session on permafrost and climate change which has now appeared in Volume 2 of the Beijing conference proceedings. The WG plans to participate in the development of the IPA Global Geocryological Database and will assist in reviewing recent data acquisition programs. As part of the US Global Change Arctic System Science (ARCSS) program, the Chair, several US researchers and the IPA Secretary General have been reviewing and documenting past data sets from Arctic Alaska as part of a data rescue effort. Results of these efforts will be shared with the GGD and others.

The Chair and WG Member Oleg Anisimov attended a March workshop in St. Petersburg, Russia, on the International Tundra Experiment (ITEX). ITEX is an experimental field program to assess the effects of climate change on tundra biota. Air and soil temperatures are modified by use of open chambers placed on the tundra. A field manual provides guidance on sampling methods and data documentation. Sites have been established in all Arctic countries and several mid-latitude alpine locations. Several ITEX sites in Alaska, Canada and Russia have been measuring active layer thicknesses. Based on the IPA presence at the ITEX workshop, it was agreed that a chapter on active layer measurements would be included and the IPA WG Chair would prepare a draft chapter for inclusion in the 1994 manual. Additional information on ITEX can be obtained from the MAB/ITEX Secretariat at the Danish Polar Center, Strandgade 100H, 1401 Copenhagen K, Denmark.

IPA funds in the amount of $325 were provided for a CD-ROM drive. In addition, funding for attendance at the ITEX meeting in St. Petersburg was approved for the Chair, but was not required as other funds became available.

Mountain Permafrost

W. Haeberli, Chair (Switzerland); F. Dramis, Secretary (Italy)

A report was compiled on Glaciers and Permafrost in Mountain Areas for IPCC Working Group II. It was authored by W. Haeberli (lead author) together with F. Dramis, A. Weidick and S. Hastenrath. Although the assessment deals with (a) background information, (b) the evolution during the past 100 years and perspectives for the coming century, (c) impacts on physical and socio-economic systems, and (d) recommendations and mitigation strategies, the submitted report mainly deals with the development of knowledge since the last IPCC assessment. Sections from the report dealing with mountain permafrost have been incorporated into the IPA report to the IPCC (pages 20–21). The full text submitted for the IPCC cryosphere chapter was distributed to IPA Council Representatives and Working Group Chairs for comments and is available from W. Haeberli.

In conjunction with WG goals, the proposed IPA-IPCC recommendations and the IPA Global Geocryological Database, the WG is now collecting information with respect to ongoing activities and future plans for modeling, mapping and monitoring mountain permafrost.

In addition to WG members listed in *Frozen Ground* No. 14, the following have agreed to be full members: D. Trombotto (Argentina), J. Sollid (Norway), and N. Caine (USA); and as Corresponding Members: A.E. Corte (Argentina), K. Lieb (Austria), Michèle Evin (France), D. Barsch and L. King (Germany), N.N. Romanovskii (Russia) and J.R. Giardino (USA).

No IPA funding has thus far been requested for 1994 activities.

Periglacial Processes and Environments

A.G. Lewkowicz, Chair (Canada); C. Harris, Secretary (United Kingdom)

The first meeting of the WG on Periglacial Processes and Environments since the Beijing Conference will be in Reims, France, from 4–9 September 1994. This meeting will involve a Symposium on Periglacial Slope Deposits and Processes and a field trip to examine grèzes litées (stratified slope deposits) in western France. The meeting is co-sponsored by the Commission on Frost Action Environments of the International Geographical Union and the Association Française du Pergélisol and is being organized by Jean-Claude Ozouf and Jean-Pierre Lautridou of Centre de Géomorphologie du CNRS, Caen (Tel. 31 45 57 18; Fax 31 45 57 57). More than 30 international registrants are expected to attend.

The WGs on Periglacial Processes and Environments and Global Change and Permafrost are planning several activities at prominent conferences. Through the Snow, Ice and Permafrost Committee of the American Geophysical Union (AGU), they will offer a special session on "Permafrost and the Changing Climate" at the Annual AGU meeting to be held in San Francisco in December 1994. Through the presentation and analysis of field data and modeling results, this special session will address the three important roles played by permafrost in the presence of a changing climate: 1) selective recorder of climate change, 2) agent of environmental changes that affect ecological and human communities, and 3) facilitator of further climate change. These diverse aspects of permafrost were discussed in the special session of the Sixth International Conference on Permafrost in Beijing and contributed to the IPA report to the IPCC (see pages 19–20).

The proposed December 1994 AGU special session on permafrost is the first of two; the second is planned for December 1995 in conjunction with a proposed IPA-sponsored two-day workshop focused on "Monitoring of Permafrost and Frozen Soils: Implications for Studies of Periglacial Processes Under a Changing Climate." The workshop will address diverse frozen ground properties, as well as thermal characteristics, and will be more oriented toward periglacial processes. Whereas the special session will provide a venue for presentation of a large number of papers by many workshop participants and other interested parties, the workshop will provide for longer and more comprehensive papers. The primary objectives of the 1995 workshop and special sessions will be to review the state-of-the-art in monitoring frozen ground in the field and in the laboratory, to share information on recent advances in measurement and analysis methods, to compare modeling results with field data, and to identify priorities for future research. Papers presented at the workshop will be submitted for publication in a special issue of *Permafrost and Periglacial Processes.*

No IPA funding has thus far been requested for 1994 activities.

Cryosols

D.A. Gilichinsky, Chair (Russia); C.L. Ping, Secretary (USA)

The WG is organizing a joint field study of permafrost soils in the Lower Kolyma, from 26 July to 9 August 1994. To date, the following scientists from six countries are planning to participate in the study; C.L. Ping, J.M. Bockheim, J.M. Kimble, J.P. Moore, R. Aherns, D.K. Swanson, and W. Eisner from the USA; C.A.S. Smith and C. Tarnocai from Canada; B.J. Jakobson from Denmark; G.G. Mazhitova, S. Gubin, I. Sokolov, Y. Naumov and A. Oganyesyan from Russia; and Chen Chi and Zhao Lin from China. The group will assemble in Magadan and fly on a charter flight to Cherskiy. The group will be divided into two teams; one will work in a 5- × 10-km^2 area south of Cherskiy to map permafrost landforms and associated soils, and the other will work on three transects to study soil and permafrost distribution and characteristics and sample soils from representative landforms and vegetation communities. These joint studies will provide the WG the opportunity to compare international field procedures in soil mapping, description, and sampling methods. A soil–permafrost map is expected to be produced as a result of this activity, and soil samples will be shared among collaborators. The field program is co-sponsored by IPA, USDA–Soil Conservation Service, the Alaska–Yukon Society of Professional Soil Scientists, Department of Indian and Northern Affairs of Canada and Agriculture Canada, and the Russian Academy of Sciences. Results will be shared with Commission V: Soil Genesis, Classification and Cartography of the International Society of Soil Science and its Chairman, Dr. Hari Eswaran.

The USDA Soil Conservation Service will use this opportunity to collect soil samples in order to expand its database on Cryosols and to test the newly proposed Gelisol Order with input from circumpolar participants. This new order for soils with permafrost was recently proposed by the International Committee on Permafrost-Affected Soils (ICOMPAS) for incor-

poration in the US Soil Taxonomy (ST). The new order includes soils containing permafrost within 2 m of the surface. The Gelisol order is intended to address deficiencies in ST and to recognize the extent (13% of the world's soils) and importance of permafrost-affected soils on a global basis. The dominant process in these soils is cryopedogenesis, which includes cryoturbation or disruption of the profile by frost action. Patterned ground is specified at the family level. New soil temperature classes are proposed for use at the family level to differentiate soils according to their susceptibility to permafrost recession following a disturbance. The introduction of a Gelisol order in ST is intended to facilitate soil-based technology transfer in the circumpolar and alpine regions of the world. Gelisols would constitute a twelfth order in ST and would include soils covering an area of 18 million km^2, exceeded only by the Aridisols. Persons wishing to receive the first circular of ICOMPAS and to receive regular mailings may contact: Dr. James Bockheim, Department of Soil Science, 1525 Observatory Drive, University of Wisconsin, Madison, WI 53706-1299. Telephone: 608-263-5903; Fax: 608-265-2595; e-mail: bockheim @calshp.cals.wisc.edu.

ICOMPAS is working with the Cryosols WG. James Bockheim and John Kimble (SCS) are co-organizing the Symposium on "Permafrost-Affected Soils" to be held in Seattle, 13-18 November 1994, as part of the Annual Meeting of the Soil Science Society of America. In addition to invited papers, papers and posters were solicited that describe morphology, genesis, classification, and use of permafrost-affected soils as well as those which dealt with unifying concepts and long-term data sets (see p.30 for conference information).

IPA funds totaling $2000 were provided to partially support Russian and Chinese travel and logistics for the summer's Kolyma field project.

Foundations

J.W. Rooney, Chair (USA); K.Flaate, Secretary (Norway)

Members of the Working Group met in Edmonton, Canada, on 6 and 8 March 1994, in conjunction with the 7th International Cold Regions Engineering Specialty Conference. These included J. W. Rooney, K.Flaate, R.G.Tart, and L. Khrustalev, who had been visiting in Alaska, and Freezing and Thawing WG members B. Ladanyi and K. Senneset. Other participants included S. Grechishchev and E. S. Melnikov from Russia; K. Jones, D. Sego, D. Hayley and H. M. French from Canada; and C.W. Lovell and R.L. Sher from the USA.

Working Group plans were reviewed (see *Frozen Ground* No. 14 for WG purpose and background). It was agreed to undertake a state-of-the-practice report as a series of articles prepared by Canadian, Chinese, Russian, and US authors. Topics to be included are: 1) Foundation investigation programs in permafrost, 2) Pile foundations in permafrost, and 3) New foundation methods and designs. Deadline for the first drafts was set for 1 December 1994.

It was agreed to undertake a series of seminars or workshops in connection with selected technical conferences once or twice a year over the next several years and to prepare special reports to be published in a volume for the Seventh International Conference on Permafrost. Subjects include: 1) Foundation experience (failure case histories); 2) New foundation designs, 3) Drainage and ground deformation considerations, and 4) Foundations for linear transportation systems.

The Russian participants (Grechishchev and Melnikov) presented an outline for a monograph on "Geocryological Conditions of Oil-Gas Provinces within the Permafrost Zone and Problems of Design and Environment." Writing responsibilitiies would be shared among Russian, Canadian and US authors. It is planned that details will be presented and discussed in Magadan in September during the special session on Permafrost and Engineering Geology at the Second International Conference on Arctic Margins (see p. 29 for conference information).

IPA funds totaling $800 were provided for travel support of the Russian WG member to participate in the Edmonton WG meeting.

Seasonal Freezing and Thawing of Permafrost Areas

A. Phukan, Chair (USA); B. Ladanyi, Secretary (Canada)

Secretary Ladanyi and K. Senneset represented the Working Group at the Foundations WG meeting in Edmonton. No IPA funding has thus far been requested for 1994 activities.

NEWS FROM MEMBER COUNTRIES

Argentina

The Argentina Committee for the IPA has 28 members. In 1994, the Adhering Body was able to pay its dues to the IPA for the first time. At a 23–27 November 1992 meeting on Geocryology and Paleoclimates of Northern Patagonia in Puerto Madryn, a series of papers was presented on basic and applied research, including some dealing with road construction in Patagonia. Members of this Argentina Committee presented papers at the XII Argentina Geological Congress in Mendoza, 15–20 October 1993, and the Symposium and Workshop on High Latitude Processes in Buenos Aires, 13–17 December 1993. A.E. Corte completed the Spanish contribution to the IPA multi-language index of terms.

Members of the Argentina IPA Committee completed a several year program on the significance of active layer freezing and thawing and permafrost behavior on the hydrology of the Central Andes. Work on a periglacial basin originally started in 1982, but most of the activities have been since 1990. Meteorological stations at 1450, 2240, 2505 and 3565 meters indicate a lapse rate of 0.6°C/100 m, with precipitation increasing 17 mm/100 m. During the last 13 years, the annual mean temperature of the Aquaditas underwent a clear increase. Glacier ice has diminished significantly. Discontinuous permafrost occurs above the 3000–3500 m zone and occupies 77% of the study area. Geophysical and temperature soundings in this zone indicate the active layer is about 2 m thick and the permafrost is 72 m thick. Below the sporadic permafrost zone, 17% of the area has seasonal frost. Mean annual flow of the Rio Blanca in 1992 was 500 L/s. It is estimated that the flow from the nearby Argostura basin must be equal or greater. Permafrost aquifers and residual flow produce significant winter flows. Rock glaciers and covered glaciers yield clear discharge. Winter flows have a higher solute concentration. Total solutes are greater in discharge from metamorphic areas than volcanic areas.

The final report for IGCP Project 297; Geocryology of the Americas, has been prepared. Some results of the project were published in eight reports in Volumes 1 and 2 of the Sixth ICOP. These and other papers in 1993 included the following topics: geochemistry and geocryology, periglacial hydrology, ice wedges, freezing point depression effects on calcium carbonate, regional geocryology, cryogenic weathering, geophysical investigations, palsa-like mounds, and cryogenic soils.

Submitted by A.E. Corte

Canada

For some 30 years, the Permafrost Subcommittee of the National Research Council of Canada (NRCC) was central to many aspects of coordination of permafrost research in Canada. The parent body of the Permafrost Subcommittee was the NRCC's Associate Committee on Geotechnical Research (ACGR). This committee, which was founded in 1945 to coordinate and stimulate research on the engineering and physical aspects of the terrain of Canada, was one of a number of advisory committees set up by the NRCC after World War II to consider scientific and technical problems of country-wide concern. The ACGR carried out much of its work through a number of subcommittees, which were expected:

> *To define problem areas in their assigned field, advise the Associate Committee on research needs, follow through actively in promoting research, and assist in the publication and application of the results of research.*

Given that about half of Canada is underlain by permafrost, it was natural that the committee should pay particular attention to this subject. In 1958 the ACGR sponsored the first conference held in Canada devoted solely to the subject of permafrost. That conference, attended by 33 people from Canada and the USA, clearly showed the growing interest and concern developing in Canada regarding permafrost, the technical problems it presented for northern development, and the limited scientific understanding available to address these questions.

As a result the Permafrost Subcommittee was formed in 1960. It was always a very active body, and highly effective in stimulating research on basic aspects of permafrost and related engineering activities, and in developing communication among individuals in universities, industry and government who had interests in the subject. It played a leading role in the development of the knowledge and capability concerning this very challenging ground condition, primarily through sponsoring conferences and seminars, and the publication of reports and books.

Over the years, the Subcommittee organized six general conferences (one international) and 10 specialized workshops or seminars, on topics as diverse as permafrost geophysics, engineering, pipelines, the active layer, global climate change, subsea permafrost, and saline permafrost. The proceedings of these conferences and

Robert Ferguson Legget

1904–1994

Dr. Robert F. Legget, founding director of the Division of Building Research (DBR), National Research Council of Canada, died in Ottawa on 17 April 1994, in his 90th year. Dr. Legget chaired the NRCC Associate Committee on Soil and Snow Mechanics (later to become Geotechnical Research) from 1946 to 1966. He founded the DBR in 1947, after 11 years in engineering practice and 11 years of teaching at Queen's University, Kingston. He retired from the NRCC in 1969.

It was his vision and determination that brought into being Canadian expertise in permafrost engineering and also contributed so much to the development of Canadian permafrost science. While at DBR, he hired scientists and engineers such as Roger Brown, Hank Johnston, and John Pihlainen, who carried out much of the early work on permafrost distribution, description and basic properties.

He also supported strongly various institutional arrangements in permafrost, such as the Permafrost Subcommittee, the international conferences, the Canadian conferences and seminars, and the publication of scholarly works on permafrost subjects.

seminars have been made available through the publication series of the ACGR. The Subcommittee also sponsored the publication of "Permafrost Terminology," by R.J.E. Brown and W.O Kupsch (1974), "Permafrost Engineering Design and Construction," by G.M. Johnston (1981) and "Glossary of Permafrost and Related Ground Ice Terms" (1988). This last publication is still in print, in English and French editions, and may be obtained from Bitech Publishers, Vancouver (see inside back cover).

From its inception in 1960 until his untimely death in 1980, the late Roger Brown served as the research advisor to the Subcommittee, and much of its effectiveness was due to his enthusiasm and energy. The proceedings of the 4th Canadian Permafrost Conference were dedicated to his memory, and the volume includes a brief biography and a list of his publications. Roger served under a series of chairmen, including Ross Mackay and Hugh French, both of whom are well known within the IPA. Roger was succeeded as research advisor by Henry (Hank) Johnston, who was followed in turn by Sivan Parameswaran and then by Harry Baker, all on the staff of the Division of Building Research at the NRCC. In 1988, Don Hayley took over as chairman of the Subcommittee; Don currently chairs the Canadian National Committee for the IPA.

Membership of the Subcommittee was made up of engineers and scientists from industry, consulting firms, universities and government agencies. The technical specialties represented by the membership have included geotechnique, exploration geophysics, geothermics, hydrology, geomorphology and climatology. Many well-known Canadian permafrost workers served on the committee over the years—too many to name individually.

Not only was the Subcommittee active within Canada; it also played a strong role internationally. It acted as the coordinating committee for Canadian participation for the First and Second International Conferences on Permafrost (ICOP) in the USA (1963) and the USSR (1973). The Subcommittee was later responsible for putting together the Organizing Committee for the Third ICOP, held in Edmonton in 1978. The Subcommittee coordinated visits to Canada by permafrost researchers from the USSR, China and Japan, and visits of Canadian permafrost delegations to the USSR (1966, 1978) and China (1977, 1987). It was also involved in the development of the IPA itself, and in discussions of Canadian membership in the IPA.

In 1990, the NRCC, as part of a major review and reorganization of its operations, concluded that the Associate Committees had served their purpose. Many of the technical areas of interest represented by them now are represented by active professional societies. In a move to support the activities of these societies, the NRCC has passed to them the responsibilities of providing national advice on research needs and directions, and for representing Canada in the international arena. The ACGR was therefore disbanded in 1991 and, with its disappearance, the Permafrost Subcommittee and the other subcommittees were also disbanded. In the case of geotechnique, the Canadian Geotechnical Society has taken responsibility for many of the functions of the former ACGR, with the Cold Regions Division being responsible for permafrost and frost action. The international coordination functions of the Permafrost Subcommittee have passed to the Canadian National Committee for the IPA, which is sponsored jointly by the NRCC and the Geological Survey of Canada.

Acknowledgments

A speech given by Lorne Gold at the opening ceremony of the Third ICOP, Edmonton, 1978, and an unpublished report on the ACGR prepared by Michael Bozozuk (1990) formed the basis of this short account of the Permafrost Subcommittee.

Submitted by J. Alan Heginbottom
Secretary, Canadian National Committee
for the International Permafrost Association

China

The Workshop on Remedial Techniques for the Qinghai-Xizang (Tibet) Highway in Permafrost Regions was held on 13–15 April 1994, at the State Key Laboratory of Frozen Soil Engineering, LIGG, Chinese Academy of Sciences. Thirty experts and scientists participated in this workshop. Several valuable proposals for the remedial scheme and design principles for the highway were presented and discussed. This workshop is one of the most important preparations for carrying out the remedial project on the Qinghai-Tibet Highway.

Progress on the permafrost and global climate change research program is as follows:

- Chapters for the China report to the IPCC "Evaluation of the influence of climate change on environment in China" have been prepared as follows: Chapter 11: The influence of climate change on permafrost zones in China; Chapter 12 The influence of climate change on glaciers in China; and Chapter 13: The influence of climate change on snow cover in China.
- The ground temperature monitoring system along the Qinghai-Tibet Highway has been set up.
- A 100-m-deep and a 200-m-deep bore hole for monitoring ground temperature will be set up on the Qinghai-Tibet plateau in 1994.
- Investigation of the concentration of CH_4 and CO_2 will be carried out along the Qinghai-Tibet Highway.

Volume 2 of the Proceedings of the Sixth ICOP, containing 98 reports, papers and poster abstracts, was shipped in late April to every registered participant, except accompanying persons. Any participant who has not received Volume 2 should contact the Chinese Organizing Committee.

Submitted by Zhu Yuanlin

Italy

In October 1993, Professor and Mrs. Troy L. Péwé visited members of the International Permafrost Association in Italy. Professor Péwé presented invitational lectures on the origin and distribution of permafrost as well as of the history and status of the IPA at universities in Naples, Rome, and Camerino. Students of Professor Francesco Dramis are actively studying rock glaciers in the Alps and periglacial mass movement in the central Apennines, especially at Campo Imporatore. Recent work indicates modern permafrost may be present in the central Apennines.

Submitted by T.L. Péwé

Russia

The Annual Meeting of the Scientific Council on Earth Cryology was held 25–28 April 1994, in Pushchino, Moscow Region at the Institute of Soil Science and Photosynthesis of the Russian Academy of Sciences. Twenty-six papers were discussed at the Plenary Session. The main subject of the meeting was Global Climate Warming and Permafrost.

Nine sessions of contributed papers (67 papers) dealt with permafrost age and evolution (northern part of European Russia, Transbaikal area, high mountainous regions of the Earth); stability and protection of permafrost; prediction of air temperatures by the different

Participants attending the annual meeting of the Russian Scientific Council on Earth Cryology, 25–27 April 1994 in Puschchino, Moscow Region. The meeting was hosted by the Institute of Soil Science and Photosynthesis, and Professor V.G. Kefeli, Director, D.A. Gilichinsky and Institute staff. (Photograph provided by N.A. Grave.)

climate scenarios; remote sensing to observe the dynamics of the permafrost and northern ecosystems; trace gases and carbon in soils; thermokarst lakes in tundra; and construction problems related to gas, oil and mining developments. Other papers were devoted to the problem of geothermal stability in Siberia; to the technogenic impact on permafrost, to the geomorphological processes in permafrost such as thermokarst and slope failure; the development of sea and lake shorelines; frost heaving processes; methods of assessment of ice content and stability of the frozen soil, the depth of the active layer; geophysical control of the structure and composition of the frozen soil; and seasonal thaw and freezing of the ground.

A meeting resolution was passed which approved the activities of the Council and proposed the main research problem areas:

- Evolution of the cryolithozone
- Monitoring of the cryolithozone
- Study and prediction of global changes in the environment, climate, and cryolithozone
- The ecology and recommendations for rational land management on permafrost
- Fundamental and applied research in the processes of soil thawing and freezing
- Elaboration of the theory of stability in the thawing and freezing of soil associated with the anticipated climate warming

It was recommended that the Scientific Council on Earth Cryology organize a Russian conference in 1995 and invite scientists and specialists from abroad. The subject of the conference was: "Evolutionary Geocryological Processes in the Arctic Regions and Problems of Global Changes of the Environment and Climate in Permafrost Areas."

IPA should be asked to assist in involving the scientists and specialists to participate and present papers on the above-mentioned problems.

Several of the activities discussed above are conducted under Program 18 "Environment and Global Climate Change" and its permafrost component which includes:

- The assessment or estimate of the influence of climate change on the cryolithozone
- The monitoring of the cryolithozone
- Methods and measures to protect construction and the environment in the North.

Numerous institutes, universities and private contractors are involved, including those of the Russian Academy of Sciences and its Permafrost Institute, the Institute of Northern Development, the Institute of Geography and the Institute of Soils and Photosynthesis at Moscow State University and the Faculties of Geography and Geology, VSEGINGEO, and PNIIIS. The program is financed by the Ministry of Science under the direction of Yuri Israel and Academician George Golitsin. The permafrost program is directed by Academician P.I. Melnikov and the Scientific Council on Earth Cryology.

Experimental sites for monitoring changes in air and ground temperatures were established in northern West Siberia and two sites were established in Yakutia in cooperation with Japanese, Canadian and US specialists. Based on measurements from experimental sites, engineering methods to protect construction are being developed including use of thermopiles, thermosyphons, insulations, and special foundations using horizontal cooling of frozen basements.

Submitted by Nikolai A. Grave

Stanislav Grechishchev, VSEGINGEO, reported on investigations during 1993 as follows.

- The results of 15-year studies of geocryology–climatic conditions at the stations Marre-Sale (Yamal) and Parisento (Gydan) were analyzed.
- Rates of shoreline movement along the Kara Sea were observed.
- The ice–thermal regime of lakes for eight years was analyzed.
- The estimation of possible changes of ground temperature was undertaken for the Global Change Program.
- The mathematical model "Shlier" of physico-chemical and mechanical processes in freezing–thawing water-saturated soils was produced.
- The temperature depression at the freezing front versus the freezing velocity was studied.
- Methods of echo-geological surveying and monitoring in ore fields in permafrost areas were developed.
- New publication—Investigations of Engineering-Geocryological and Hydrogeological Conditions of the Upper Horizons of Permafrost Ground in Oil–Gas Regions (E.S. Melnikov, S.E. Grechishchev, A.V. Pavlov, Ed). 280 pp.

Spain

A special invitational visit was made by Professor T.L. Péwé to Madrid, Spain, to lecture on the background of the IPA to the new IPA group in Spain. Many scientists and engineers are greatly interested in the subject of past and present permafrost and other periglacial phenomena, not only in Spain but in Antarctica, the

Back row, left to right: Prof. David Palacios, University Complutense, Madrid, Chairman, Spanish Committee, IPA; Prof. Juan Antonio Gonzales Martin, University Autonoma de Madrid, Vice-Chairman, Spanish Committee; Prof. Antonio Fernandez, University National A. Distancia, Member, Spanish Committee.
Second row, left to right: Ana Alvarez, Ph.D. student; Luis M. Tanarrow, Ph.D. student; Prof. Ana L. Martin, University of Mexico; Prof. Troy L. Péwé, Arizona State University, Past-President, IPA.
Front row: Marta Gil, Ph.D. student. (Photograph by T.L. Péwé, 25 October 1993.)

US and Mexico, where members of the Spanish committee are working.

An enthusiastic group of Spanish researchers (see photo) conducted a day-long field excursion west of Madrid with Dr. Péwé to view inactive mass movement periglacial phenomena and Quaternary loess deposits with strikingly developed paleosols.

Submitted by T.L. Péwé

United Kingdom

A Geocryology Workshop, the first scientific meeting to be organized by the British National Committee of the International Permafrost Association, was held on 29 March 1994 at the University of Cardiff. The workshop was attended by 16 members, and papers were delivered on a wide range of permafrost-related topics. Papers by Brian Whalley (Belfast) and by Rick Shakesby, John Matthews and Danny McCarroll (Swansea) described new data on the origin of rock glaciers and protalus ramparts. Iain Sutherland (Cardiff) and Colin Ballantyne (St. Andrews) each described studies of rapid periglacial slope adjustments in Norway; Graham Elliot (Reading) illustrated the potential of radiocarbon dating in determining past rates of solifluction and Adrian Humpage (Cardiff) discussed shallow active layer detachment slides on Ellesmere Island, Canada, as analogues for British Quaternary clay slides. Colin Lloyd (Institute of Hydrology) outlined new hydrological research in Spitsbergen, Stephen Gurney (Reading) presented data on cryogenic mounds in Quebec, and Ed Derbyshire (Royal Holloway, London) demonstrated the value of periglacial stratigraphy in palaeoenvironmental reconstruction on the Tibetan Plateau. Three papers were concerned with laboratory studies: Ron Jones (Nottingham) discussed frost heaving of clay soils; Julia Branson (Southampton) described experimental simulation of needle ice growth; and Charles Harris (Cardiff) presented preliminary results of large-scale laboratory simulation of solifluction currently being undertaken in the cold labs of the CNRS, Caen, France. Finally,

Participants attending the first scientific meeting organized by the British National Committee of the International Permafrost Association, held in Cardiff, 29 March 1994. From left: Ron Jones, Iain Sutherland, Adrian Humpage, Brian Whalley, Colin Ballantyne, Rick Shakesby, Mike Clark John Matthews, Julia Branson, Ed Derbyshire, Danny McCarroll, Steve Gurney, Colin Lloyd, Graham Elliot and Charles Harris.

the importance of establishing a cold regions data bank and the work of the Data and Information Working Group of IPA were discussed by Mike Clark (Southampton).

This workshop was highly focused and informal and generated much discussion. It was agreed that further such meetings should be held, possibly on an annual basis, under the auspices of the British National Committee of the IPA.

Submitted by Charles Harris
Chairman, British National Committee of the IPA

United States

On 14 March 1994 Secretary of Interior Bruce Babbitt gave the oath of office to Dr. Gordon Eaton, who will serve as the 12th Director of the US Geological Survey. Dr. Eaton, an earth scientist, was most recently the Director of the Lamont-Doherty Earth Observatory, and previously an employee of the USGS, President of Iowa State University, and Provost and Vice President at Texas A&M University. Dr. Eaton succeeds Dr. Dallas Peck, who has returned to his research in the Geological Survey. The USGS has the federal government's largest civilian mapping program and the largest water resources scientific and data program, is responsible for the national assessment of energy and minerals resources, and conducts basic and applied research on a wide range of earth science and earth hazard programs. The agency has 10,000 employees working in nearly 200 field offices and headquarters. In addition to its long history of permafrost reserach, the USGS is supporting the IPA map project and is providing expert assistance and experience for the development of the IPA Geocryological Database project.

Troy Péwé reports that in August 1993, 25 scientists interested in evidence of periglacial and glacial features on Mars attended a workshop and field trip in Fairbanks, Alaska, sponsored by the NASA Lunar and Planetary Institute. The meeting was most notable for its field setting and the fact that it brought together researchers from the planetary and earth science communities who have special interests in cold-climate processes and landforms. Many of these planetary scientists had never before observed periglacial (permafrost) and glacial ice in the field. Three of the four days of field trips were headed by T.L. Péwé and R.D. Reger using Guidebook No. 1 of the Fourth International Conference on Permafrost. A second printing was issued in 1993. Other field leaders were J. Begét and D.M. Hopkins. Field trip leaders presented invitational papers at the workshop.

Troy Péwé also reports on the field trip following the Sixth ICOP, 10–15 July 1993. Nine US participants attended the post-conference excursion to southern China. The first stop was the outstanding archeological display of life-sized terra cotta figures of soldiers from the time of Emperor Qin (221–206 B.C.). Large, new exposures of loess were seen in road cuts leading to the bridge across the Wei River at Xian.

The highlight of the trip was the visit to the spectacular and unique, limestone tower–karst topography at Guilin in the Guongxi Zhuang Autonomous Region of southeast China. The first day was spent inspecting several of the more than 3000 caves in Devonian limeston. One day was spent floating down the Li River on a flat riverboat, through the world-famous karst "forest" of stone peaks eroded in tilted Devonian limestone. This mystic landscape has been reproduced on silkscreens, paintings, and ceramics for more than 1000 years. After Guilin, a day was spent in the large ancient city of Gangzhou (Canton) on the Pearl River.

Eric G. Johnson, Executive Committee Secretary, Technical Council on Cold Regions Engineering (TCCRE), reports on the success of the 7th International Cold Regions Engineering Specialty Conference held 6–9 March 1994 in Edmonton, Alberta, Canada. The conference was sponsored by the Canadian Society for Civil Engineering, the Canadian Geotechnical Society, and the American Society of Civil Engineers. One-hundred-eighty engineers and scientists from many countries attended, including Russia and China. Besides presentation of papers, the conference included forums on research and education from which summarizing documents will be prepared. Planning is underway for the 8th International Cold Regions Engineering Specialty Conference with the University of Alaska–Fairbanks for August 1996. The next meeting of TCCRE will be during the National ASCE Convention in Atlanta, 7–9 October 1994. The following committees will meet: Executive Committee, Programs, Frozen Ground, Publications, Awards, Research, Education, and Design and Construction. Work continues on the monographs on Arctic Foundations, Roadways and Airfields, and Materials, and on updating the Cold Climate Utilities Manual.

During the 7th Specialty Conference, TCCRE's Education Committee participated in sessions to identify cold regions subjects that might be included in a standard undergraduate civil engineering curriculum. Results will be reported in a paper for the *Journal of Cold Regions Engineering*. For information contact Education Committee, Chair Larry Bennett (tel. 907-474-6121).

The Committee on Frost Action of the Transportation Research Board held its annual meeting on 10 January 1994 in Washington, D.C. Presentations included: Update on the MN/ROADS project (Melrae Succio), New "n" factor computations (Richard Berg), Cold weather impacts on bridges (Leroy Hulsey), CRREL FERF load cart (Robert Eaton), Underground bridging (Billy Connor), New airfield test section (Vincent Janoo), and Geofoams (John Howath), among other presentations and discussions of research needs.

David Esch, of the Alaska Department of Transportation and Public Facilities, reports two active studies related to permafrost. The benefits (K-factors) of ground tire rubber as insulation for permafrost or frost heave are being studied by John Zarling (University of Alaska–Fairbanks) using thermal conductivity measurements. Development of a string of soil saturation sensors to measure perched water on top of frozen soil layers is underway with Gerald Christenson, MPC, Gig Harbor, Washington.

K.R. Everett, Ohio State University, F.E. Nelson, Rutgers University, Y. Shur, University of Alaska, and Jerry Brown report on a joint US–Russian active layer project which has several Russian sites on Yamal Peninsula (M. Liebman), Gydan Penisula at Parisento (A. Pavlov and N. Moskalenko) and Anadyr (A. Kotov) and in Alaska. The main sites are located at Barrow, Prudhoe Bay and several places along the pipeline road. Late summer active layer thicknesses have been probed on 1- × 1-km grids, 100- × 100-m grids or transects for 1992 and 1993. Barrow thaw is the least (22 and 30 cm), Anadyr is intermediate (59 and 51 cm), and Yamal (86 and 93) and Parisento (81 and 93 cm) have the deepest thaw. Observations will continue in 1994 with additional sites added in both Siberia and Alaska. Measurements will be incorporated into the International Tundra Experiment (ITEX).

Virgil Lunardini reports that CRREL had two holes drilled in permafrost in central and northern Alaska in winter 1993–94. A small amount of undisturbed core was recovered, with sampling obtained throughout. Further coring is planned. Temperature measurements will begin in July 1994, in 3-inch-diameter PVC pipe, filled with silicone fluid.

Bob Eaton reports that a new traffic loading machine is being procured for the CRREL Frost Effects Research Facility (FERF). The machine will make it possible to apply the equivalent of 20 years of truck traffic in six months. The effect of moisture upon subgrade support will soon be evaluated in the FERF, testing four soil types representative of the United States. This work is part of a cooperative international effort being sponsored by the Federal Highway Administration.

Vincent Janoo, CRREL, reports that the Federal Aviation Administration has contracted with the Corps of Engineers for a five-year study to evaluate airfield pavement design methods. An instrumented section on the main runway of the new Denver Airport will have the following parameters measured: dynamic strain, thermal-induced strains, layer deflections, and temperature and moisture with depth. The structural capacity of the pavements will be periodically characterized with a Heavy Weight Deflectometer. Data will be collected remotely via modem and downloaded into a database. Results will be used to develop a design procedure which will account for the seasonal temperature and moisture changes.

Nancy Liston reports that the CRREL Technical Library has relocated to its new home in the new four-story Technical Information Analysis Center. The library collection includes over 20,000 books, 160,000 micrographics, 760 journal titles, in some cases dating from the mid-1950s, and a technical report collection of more than 100,000 documents. A room has been dedicated to the micrographic and paper collection of the 48-volume COLD Bibliography. The new facility was dedicated in June 1994.

Compiled by Jerry Brown

OTHER NEWS

Estonia

The International Science Foundation (ISF) has awarded a grant to Rein Vaikmae, Institute of Geology, Estonia Academy of Sciences, entitled "Oxygen18 and deuterium variations in permafrost and ground ice as a source of paleoclimatic information." The goal of the proposal is to understand how the climate system, and particularly the global cryosphere, has responded to incoming solar radiation over the last 30 000 years. Specific objective is to reconstruct long-term variations of some fundamental climate variables, such as temperature and concentrations of greenhouse gases.

The main task of this project is to collect samples from ground ice wedges of different age and texture in West Siberia and Kolyma Lowland. The results of preliminary studies have enabled us to distinguish ice wedges of different ages in both these areas, from early Pleistocene up to late Holocene. A great number of samples are needed to obtain detailed isotope profiles from permafrost which would be comparable to those from glacier profiles and thus enable one to make correct correlations. The following investigations are planned. First, an expedition to Siberia in the middle reaches of the Kolyma River; ice wedge complexes (Duvanny Jar, Zelyony Mys) in that region are among the largest in the world. Samples will be taken for isotope analysis from the vertical profile of ice wedges and from layers of different age in ice wedges. Secondly, samples taken during this expedition and also those collected in earlier years, but still unanalyzed, will be analyzed in the Laboratory of Paleoclimatology of the Institute of Geology. Analytical basis of the proposed programme includes: stable isotopes (Finnigan MAT Delta E mass spectrometer for ^{18}O and D analyses); dating (^{14}C, TL, OSL, ESR methods); water chemistry (ion chromatography); and pollen.

Comparison of the isotope profiles from permafrost regions with the deep ice core isotope profiles in Greenland, Arctic Canada and Eurasian archipelagos (Svalbard, Severnaya Zemlya) will enable one to estimate the distribution of ^{18}O and D in the precipitation of the Northern Hemisphere at various periods over the last climatic cycle. This, in turn, provides modelling groups with information needed for better estimation of the climatic changes at various time slices over the last climatic cycle.

The Working Group report on Changes in Permafrost Conditions under IGCP Project 253: Termination of the Pleistocene is under review and will be reported in the next issue of *Frozen Ground.*

Submitted by Rein Vaikmae

Kazakhstan Membership

The Institute of Geography of the Kazakhstan Academy of Sciences in Almaty has requested information on membership in IPA. In a letter of inquiry, Drs. I.V. Seversky and A.P. Gorbunov indicated that the International Center on Geoecology of Mountain Countries of Arid Regions (ICGM) has been founded. The Centre includes a Division of Geocryology which has experience in multi-year research investigations in the mountains of Central Asia and Kazakhstan. Also indicated was an interest in cooperation with the IPA Database project. For further information about the Center contact : Institute of Geography, Pushkin St. 99, Almaty 480 100, Republic of Kazakhstan. Fax: 7 3272 63 69 73.

INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE

IPCC: An Update

by Martin Beniston

At its plenary meeting held in Zimbabwe, 11–13 November 1992, the IPCC decided to revise its working structure in order to meet the challenges of an updated series of IPCC reports, scheduled for 1994 and 1995. Substantial reports were prepared by these Working Groups on issues related to global climate change in time for the Second World Climate Conference (Geneva, October/November 1990). Updated reports were prepared by all Working Groups in 1992.

Now that the Framework Convention on Climate Change (FCCC) has been ratified and has just recently come into effect, there are specific scientific, technological, and political issues related to the implementation of the Convention which require an adequate flow of information between scientists and governments. The ultimate objective of the Convention and any resulting legal instruments is to stabilize greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate. Such a level should be achieved within a time frame sufficient to allow ecosystems to adapt naturally to climate change, to ensure that food production is not threatened, and to enable economic development to proceed in a sustainable manner.

It is clear that in the last phrase pertaining to the need for ecosystems to adapt naturally to climate change poses a challenging task to define what is the natural adaptability of ecosystems (thresholds, response functions), and what is the measure of climate change which can be tolerated by natural systems. The work currently undertaken in the drafting of the IPCC WG II Second Assessment Report will go some way toward answering such questions.

The IPCC is in a privileged position to provide the scientific input to the legislators and governments who will in time implement the FCCC. Much of the information will be contained in new, updated scientific reports which will be available in a preliminary form by 1994 (for WG I), and in a finalized form by 1995 (all WGs). The new IPCC structure, designed to meet the needs of both the scientific community and of governments, is as follows:

WG I: Scientific Assessment of Climate Change
WG II: Impacts, Adaptation, and Mitigation Strategies
WG III: Economic and Cross-Sectoral Issues

Under the Chairmanship of Bert Bolin, each WG now has a co-chair from an industrialized country and one from a developing nation, in order to make the IPCC more representational and involve countries from the developing world more fully in the scientific and decision-making processes. Within WGII, four subgroups have been set up to provide input into specific themes to be included in the 1995 report, as follows:

Subgroup A: Energy and Industry Issues; Co-Chairs: Japan and India
Subgroup B: Oceans and Coastal Zones; Co-Chairs: The Netherlands and Venezuela
Subgroup C: Natural Terrestrial Ecosystems and Forests, Hydrology, Cryosphere, Mountains; Co-Chairs: Switzerland and Argentina
Subgroup D: Managed ecosystems and forests, Agriculture, Arid/Semi-arid Zones, Water resources; Co-Chairs: France and Tunisia

Subgroup C has the responsibility of highlighting the present state of knowledge on the impacts of climate change on natural and unmanaged systems with an emphasis on terms included in Article 2 of the Climate Convention. Dr. Blair Fitzharris, Otago University, New Zealand, is the lead author for the section on the Cryosphere and is being assisted by specialists and organizations knowledgeable of snow, ice and permafrost in different regions of the world. The draft assessments will undergo expert peer review starting in summer 1994.

General information on the current work of IPCC WGII is published in the form of an ad- hoc Newsletter edited in Switzerland. Further information on WGII-C activities and requests for copies of the Newsletter can be obtained from the author:

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Permafrost and Climate Change: The IPA Report to the IPCC

Introduction

The IPA agreed to assist the Intergovernmental Panel on Climate Change (IPCC) Working Group II in revising the cryosphere section of *Climate Change 1992: The Supplementary Report to the IPCC Impacts Assessment*, and specifically those sections concerned with permafrost and related consequences of climatic-induced changes. For the IPCC analyses, permafrost is considered as part of the cryosphere, along with snow and ice. The following draft contains information relevant to Section VIII, *Terrestrial Component of the Cryosphere,* of the 1992 report, including progress since the 1992 assessment, information gaps, and responses to close information and data gaps. It has been submitted to the Working Group II-C for inclusion in the Second IPCC Assessment Report scheduled to be published in 1995 (see p. 15). Sections of the draft are based on contributions from IPA Working Groups members, the draft WG II-C report (Fitzharris 1994) on the cryosphere, and published literature. Readers are encouraged to submit comments, revisions and additions to the IPA Secretary General within the next several months.

Background

Permafrost underlies as much as 25% of the earth surface and affects natural and managed ecosystems and terrains in both hemispheres, including forests, grasslands and rangelands, mountains and wetlands, and their hydrologic systems. In addition to permafrost regions, seasonally frozen soils occupy large regions of the temperate zone. Permafrost, a negative temperature condition of the substrate, has important linkages with the atmosphere/biosphere/earth system that are manifested in at least three ways: 1) interpretable records of past climate changes are preserved in the thermal and stratigraphic profiles of permafrost; 2) permafrost translates climatic changes by perturbing ecological, agricultural and geomorphic subsystems and engineered structures and systems; and 3) permafrost modifies and amplifies climate change through release and/or sequestration of carbon and trace gases.

Research on the interactions between permafrost and climatic change has accelerated dramatically in recent years; a large volume of literature has been published on this general topic, much of it very recently. Despite this focus, notable deficiencies in knowledge persist, many of which have barely begun to be addressed in a systematic manner. This review concentrates on results from recent publications and those needed to resolve uncertainties in knowledge. In the interests of brevity, only selective, recent references are cited; more comprehensive treatments of the literature are contained in two IPA-sponsored publications (Koster et al., 1994; Nelson et al., 1993).

Permafrost Thermal Regimes and Distribution

Research in deep boreholes in Alaska (Lachenbruch et al., 1989; Harrison, 1991; Zhang and Osterkamp, 1993), Canada (Taylor, 1991), and elsewhere (see references in Koster et al. 1994) has shown a distinct but spatially heterogeneous warming trend during the past century. The distribution of borehole sites from which data have been made available is, however, far from optimal. Although intraregional variations can be substantial, observations on an areal coverage are very poor in most of the high latitude and high altitude regions of the Earth that are underlain by permafrost. This situation should be addressed by a comprehensive inventory of relevant shallow and deep borehole locations, accompanied by an effort to log, analyze, and archive past and future data collected from them.

Similarly, few data sets incorporating long-term or high-frequency temperature observations are generally available from shallow permafrost or the active layer in high latitudes. Subsurface variations in temperature often depart substantially from those air temperatures measured at the height of standard observational screens, owing to variable substrate thermal properties, surface cover or topoclimatic factors. In addition to archiving and making available existing data sets in a manner similar to that suggested for deep holes, systematic collection of standardized ground-temperature measurements at a large number of circumarctic locations, chosen on the basis of being representative of local or regional conditions, is required. Establishment of an observational network, including soil temperature and moisture measurements, is a critical prerequisite to unambiguous detection of climatic change and its effects on permafrost. Integration with ongoing programs, including the International Tundra Experiment (ITEX), is essential to monitor changes and more fully understand and predict the interactions between the atmosphere, vegetated landscapes and the underlying permafrost terrain.

Projects are underway in Canada to map permafrost distribution at intermediate (regional) scales. The inadequate representation of the atmosphere–cryosphere coupling noted in the 1992 IPCC Supplementary Re-

Compiled and edited by Jerry Brown, IPA Secretary General, P.O. Box 9200, Arlington, Virginia 22219-0200, USA.

port arises from a lack of surface physical property characterization, and from overly simplistic land–atmosphere interaction algorithms. Collection of observational data about such questions should be given high priority. In Canada, a long-term (decadal) program has been launched to meet data needs and monitor changes in the near-surface environment in the Subarctic. A multi-instrument latitudinal transect along the Mackenzie Valley has been initiated, with thaw tubes installed at more than 60 sites (Nixon and Taylor, 1994); other instrumentation includes air temperature monitored at screen height and at the ground surface using inexpensive data loggers, which will enable quantification of the air/ground coupling through, for example, calculation of n-factors.

On Alaska's North Slope, a detailed sampling design to monitor active-layer thickness and soil properties in a series of 1-km × 1-km grids has been implemented along two transects inland from the coast at Barrow and Prudhoe Bay. Thermal verification of mechanically probed thaw depths is an integral component of all stages of the project. This study and others under the Arctic System Science (ARCSS) program will ultimately result in a model that will forecast spatial and temporal variations in active-layer thickness using output from general circulation models. Similar measurements are underway in Canada and Russia; the Fifth ITEX Workshop, held in St. Petersburg, Russia, in March 1994, resulted in agreement to include active layer observations at ITEX sites.

Efforts to model the response of permafrost to climatic warming, although begun more than ten years ago, are not numerous in the literature. Several soil-permafrost models have been developed for Arctic Alaskan sites. Kane et al.(1991), and Hinzman and Kane (1992), used a finite-element, two-dimensional, heat conduction model with phase change to predict soil temperatures under various warming scenarios over a period of 50 years. Waelbroeck (1993), using Barrow climate and soil moisture and temperature data, developed and validated a physical climate–soil model to be used for predicting changes of net primary production and decomposition in tundra ecosystems. Both models reaffirm the importance of soil moisture in controlling active layer thickness, a parameter difficult to measure across the complex tundra landscapes.

Little is currently known about the rapid degradation and loss of permafrost in the subpolar regions that is frequently cited as an artifact of climatic warming. In areas where the permafrost is currently discontinuous, long-term warming may ultimately lead to its eradication. In continuous permafrost, the most likely result is a thickening of the active layer. In both cases, initial degradation will be contemporaneous with the alteration of the climatic signal as indicated by Kane et al. (1991) but, as the thaw plane penetrates more deeply, so lag times will increase. Although a few studies have documented retreat and disappearance of permafrost using sequential air photography, little detailed information is available about long-term trends involving thickening of the active layer, development of taliks, or about the temporal scale at which such phenomena occur. Simulations performed by Riseborough and Smith (1993) suggest that rate of thaw and ultimate disappearance of a relatively thin (4.5 m) permafrost profile at a subarctic site in central Canada would be highly dependent on interannual climatic variability.

There has been inadequate attention devoted to coupling models of permafrost evolution and response with general circulation models (GCMs) or other major climate change scenarios. Recent efforts, including those of Nelson and Anisimov (1993), have been made to map the distribution of permafrost at small geographic scales, under various scenarios of climatic change using the "frost-index" approach. Results from these studies suggest that there will be substantial poleward migration of the discontinuous and continuous permafrost zones. These studies only treated degradation of near-surface permafrost, however, and more attention must be given to the role of latent heat associated with ablation of ground ice. Simulations conducted by Riseborough (1990), for example, indicate that areas with abundant ground ice, such as western Siberia (Burns et al., 1993), will retain substantial amounts of permafrost that is not in equilibrium with new temperature conditions imposed at the surface.

Paleoclimate approaches in both Russia and China continue to offer analogues for proposed changes in distribution of permafrost. Several regional summaries are presented with details available in the literature.

In China, permafrost distribution has altered substantially over the Quaternary as the climate has changed. Four major periods are recognized (Wang, 1989; Fitzharris, 1994).

Last Ice Age (18,000 years B.P.): At that time, the southern boundary of the high latitude permafrost in Northeast and North China was at 36°–40°N, about 8°–10° south of the present boundary. Temperatures were 10–12°C colder than present. This indicates a sensitivity of 0.8° lat/°C. Within this zone, the lower elevation of mountain permafrost decreased about 800–1000 m, suggesting a sensitivity of 100 m/°C. At the northeast edge of the Qinghai-Xizang (Tibet)

Plateau, the lower limit of mountain permafrost was 2200 m, compared with the present-day 3300–3400 m. Here the sensitivity was 160 m/°C. On the northern slope of the Himalaya the limit was 3900 m, 700 m lower than present and a sensitivity of 78 m/°C.

Warm Holocene Period (8500–3000 years B.P.): The average temperature in the east was about 2.5°C higher than that at present, with a temperature rise of 4–5°C in winter, but only about 1°C in summer. The southern boundary of predominantly continuous permafrost in Northeast China was located about 50°–52°N, having shifted 1.5° lat. The sensitivity of the southern boundary was 0.6° lat/°C.

Little Ice Age (300–200 years B.P.): The southern boundary of permafrost in Northeast China moved 2° further southward to 46°N, the mean annual temperature dropped 3°C and the gradient value was 0.6°lat/°C. The southern limit of permafrost on the Qinghai-Xizang Plateau was at 4400 m (present-day limit is 5000 m). The sensitivity is estimated as 166 m/°C. The lower elevation of permafrost was at least 300 m lower than at present. The extent of the plateau permafrost was much greater than that in the Holocene Period.

Present Time: Over the last century, in North China, the permafrost temperature has risen 0°–0.5°C, the thickness has decreased by 5–10 m and the southern boundary of permafrost has receded from the semi-arid zone to the semi-humid marginal region in the north and east. The southern boundary of the isolated permafrost zone in the Songnen Plain has receded northwards by nearly 2° lat, reaching 48°N.

The southern boundary of permafrost in Northeast China will be at 48°N by the year 2030 and the predominantly continuous permafrost zone will have receded to 52°N, similar to that in the Great Warm Period. With the exception of the Changbai Mountains, there would be no high-altitude permafrost. On the Qinghai-Xizang Plateau, it is estimated that with an increase in air temperature of 3°C, the permafrost limit will be at 4600 m. Since in the northwestern part of the Plateau, the elevation is generally higher than 4700 m, plateau permafrost will not be much affected. However, if air temperature should increase by 5°C, the permafrost limit would rise to 5700 m at the northern boundary and to 5800 m at the southern limit. These elevations are just at the elevation of the broad plateau surface; thus continuous permafrost would disappear except in the northwestern part of the Plateau and the areas around the Fenghuo Mountains.

In Russia, reconstructions of the permafrost zone in the Holocene climatic optimum and in the last Interglacial are used as paleoanalogues of warming (Velichko and Nechaev, 1992; Velichko et al., in press). The mean annual air temperature increase in the Holocene climatic optimum was 2–3°C, and in the latest Interglacial 6–8°C. With a rise in temperature of 1°C, permafrost will be partially preserved only to the east of the Pechora River. In the south of Yamal and Gydan the temperature of frozen ground will be 3–4°C higher than at present, and only discontinuous permafrost will remain. Continuous permafrost occurs north of 70°N. It remains to the east of the Yenisey at the same latitudes, but its temperatures will be an average of 2° higher than at present.

For a temperature rise of 2°C, continuous permafrost will disappear in the Russian European north. All the way from the Lower Ob to the Lower Hatanga and in the Anadyr lowland, only sporadic and discontinuous permafrost will remain. Continuous permafrost will exist only in the lowland of the Lena, Kolyma and Indigirka basins.

During a general rise in temperature of 1°C the temperature of the frozen ground will rise by 1–2°C in the north of Eurasia, and the active layer will increase by 20–30 cm. For a temperature rise of 2°C, the ground temperature will rise by 3–4°C and the active layer will increase by 40–50 cm. These changes will result in activation of solifluction, thermokarst and thermoerosion processes, an increase in bogs and changes of large tracts of forest within the permafrost areas.

Mathematical simulations of changes in permafrost temperatures and thaw depths under an increase in annual average air temperatures of 2° and 4°C by Vyalov et al. (1993) provide additional evidence for responses in the Russian permafrost regions. Warming in the northern regions will merely result in slighlty greater thawing depths, with no radical changes in permafrost conditions. In the southern regions, more tangible effects will occur, with the shift to discontinuous permafrost and formation of taliks and degradation of ground ice. Eventually, if warming is long lasting over the geologic time scale, the permafrost line will recede northward by 500 km along the 70°E longitude and 1200 km along the 100°E longitude. Given a thawing rate of 100 mm per year, thawing of 10 m takes 100 years. During the warmer Holocene, thawing rate were estimated to be 7 to 60 mm per year, depending on latitude.

Geomorphic and Hydrologic Processes

The critical factor influencing the response of permafrost terrain to climatic change is the presence of ground ice and its effect on thermal and hydrologic properties of the terrain. Ground ice is generally concentrated in the upper few meters of permafrost, pre-

cisely the layers that will thaw first as permafrost degrades. Ice contents tend to be greatest in fine-grained, surficial materials and are generally low in coarse sands, gravels and bedrock. Wet valley floors tend to have higher ice contents than dry ridge tops, but these generalizations hide a very high degree of variation within any given soil type or terrain unit. Consequently, the permafrost landscape response to climate change can be expected to vary greatly even at a local scale. Accurate prediction of effects requires detailed information on ground ice contents, data that so far have been obtainable only from extensive drilling and ground-based remote sensing (e.g. ground-probing radar). The possibility of aerial or satellite-based remote sensing exists, but there is currently little research underway to solve this problem, even in major programs such as the Earth Observing System-Cryosphere System (EOS-CRYSYS) and the NASA Synthetic Aperture Radar Program (SAR).

As is the case with other disciplines, the influence of climatic change on the hydrologic cycle is poorly understood, in part due to lack of a historical database and lack of adequate process modeling (Kane, 1993). Excess water released during thaw will be lost by evaporation or drainage and will be accompanied by settlement of the surface. An analogy of the probable response can be found in areas where the ground surface or vegetation has been disturbed by human activities or forest fire. Hummocky topography with a deranged drainage pattern (thermokarst) develops as thawing ice-rich areas subside more than those with lesser ice contents. These effects are irreversible at time scales of less than centuries and would result in major changes in the hydrology and ecology of areas so affected. In areas of massive ground ice in Russia, past climatic warming has altered the landscape by producing extensive flat-bottomed valleys (alases) over hundreds of years. Positive feedback could also prolong permafrost degradation even if the climate ceased to change further. Ponds within an area of thermokarst topography could eventually grow into thaw lakes that would continue to enlarge for decades to centuries due to wave action and continued thermal erosion of the banks.

Overall evaluation of the sediment supply system in permafrost areas suggests that a warming phase will be accompanied in many areas by an increase in sediment transported to rivers and lakes (Woo et al., 1992). This sediment will be derived from slump activity, slow and rapid landsliding on slopes as well as surface erosion by running water. The direction of change in the transport capacity of rivers is less clear because of potential changes in the basin water balance, so that river beds could either aggrade or degrade. The increased sediment supply could also affect biota within aquatic ecosystems. Effects will also be noticed in coastal areas where rising water levels combined with a longer open-water season and greater storminess could increase rates of annual retreat in erodible ice-rich sediments.

Various thresholds may be crossed as the hydrological responses evolve towards the future climate (Woo et al., 1992). The freeze-thaw transition is of utmost importance in permafrost hydrology. Longer periods with higher above-freezing temperatures will reduce the storages of snow and ice, enhance rainfall at the expense of snowfall, and accelerate the rates of melt and evaporation. A moderate amount of winter warming may have little hydrological consequences because it will fail to raise the temperature to the thawing threshold. Another threshold condition is the unidirectional loss of ground ice. Once melted, this cannot be replaced in the near term. As indicated, ground ice melt also leads to thermokarst which changes the topography. Such thresholds, once crossed, create new hydrological environments with abundant ponds.

The hydrologic feedback on land surface and climate processes is also of importance. Snow and ice covers have high albedos and a reduced duration of their presence will significantly affect the radiation regime to cause further warming. Evapotranspiration is enhanced by a longer snow-free period and by vegetation growth, but plants may be stressed if high evaporation rates reduce the moisture supply. Ground thermal properties will be modified when the hydrologic status of the soil is altered. This may accelerate or retard ground thaw, which in turn has strong effects on movement of water in the permafrost terrain. Various feedbacks and thresholds operate at different time scales, with or without time lags.

As suggested above, there continue to be problems associated with prediction of the effects of future climatic change on permafrost terrain. First, the interactions of climate and many geomorphic processes are complex and inadequately understood. Second, there is relatively little research in this area, primarily because of a lack of trained personnel and long-term funding. Third, those links that are understood are not necessarily related to changes in mean temperatures or precipitation, or the outputs of GCMs. The impact of an overall rise in temperature throughout the summer will be profoundly different, for example, than having a higher amplitude change for a shorter period. Future variation in the frequency of extreme events, both of precipitation and temperature, are unknown, but many important geomorphic responses, such as landsliding

by detachment of the active layer (Lewkowicz, 1992), are dependent on climatic thresholds rather than linear trends.

Carbon and Trace Gases in Permafrost Systems

Ice-saturated permafrost presents an impervious layer to deep infiltration of water, thus maintaining water saturated and poorly aerated soils. Significant increases in active layer depth or loss of the permafrost is expected to cause drying of the upper soil layers in most regions, and enhanced decomposition of soil organic matter. Loss of a sizable portion of more than 50 Gt and 450 Gt carbon present respectively in the soils of arctic and all northern ecosystems, could cause an appreciable positive feedback on atmospheric rise of carbon dioxide. Marion and Oechel (1993) examined Holocene soil carbon balance along a latitudinal transect across Arctic Alaska and concluded that long-term trends in carbon storage will continue to act as a small sink. However, recent warming and drying have apparently shifted Arctic ecosystems from carbon sequestration (as occurred during the Holocene and historical past) to one of loss of carbon dioxide to the atmosphere (Oechel et al., 1993). Estimates of possible current losses of carbon dioxide from Arctic terrestrial ecosystem to the atmosphere range from 0.2 Gt of carbon (Oechel et al., 1993) to much higher values of winter time losses of carbon dioxide as reported for the Russian Arctic near Chersky (Zimov et al., 1993; see also Kolchugina and Vinson, 1993).

Large amounts of natural gas, mostly methane, are stored in the form of gas hydrates, although their distribution is not well known. In the Canadian Arctic Islands and Beaufort-Mackenzie region, analysis of thermal and geophysical logs indicates that 2×10^3 to 4×10^4 Gt of methane is stored as hydrate. Decomposition is occurring presently beneath 7.3×10^4 km^2 of the Beaufort Shelf in response to the increase of surface temperatures accompanying marine transgression; 10^5 m^3/km^2 may decompose over the next century (Judge and Majorowicz, 1992; Judge et al., 1994).

Although many publications concerned with methane emissions in the boreal and tundra region have appeared recently, very few data are available on the methane content of permafrost itself; samples obtained near Fairbanks (Kvenvolden and Lorenson, 1993) and the Prudhoe Bay area (Moraes and Khalil, 1993; Rasmussen et al., 1993) suggest substantial variability. If the amount of methane sequestered in permafrost is indeed large and climatic warming leads to widespread increases in active-layer thickness, the resulting positive feedbacks could be substantial.

Mountain Permafrost

The study of high mountain and plateau permafrost is in its infancy in most parts of the world. However, the occurrence of high altitude permafrost is widespread and early indications suggest its presence and degradation serve as a sensitive and early indicator of climate change; warming trends of the permafrost over the past decade has been documented in the Swiss Alps (Haeberli et al., 1993a). The following is extracted from the separate IPCC WGII report entitled "Glaciers and Permafrost in Mountain Areas" prepared by Wilfried Haeberli (lead author) and Francesco Dramis, Stephen Hastenrath, and Anker Weidick.

Perennially frozen slopes occur in many mountain ranges of the world (Cheng and Dramis 1992, Harris and Giardino 1993, King and Åkerman 1993, Qiu 1993). Ice-rich debris or morainic material especially exist under subcontinental to continental-type climatic conditions with elevated glacier equilibrium lines. Such supersaturated mountain permafrost exhibits pronounced creep movements, thereby forming large numbers of rock glaciers (Barsch, 1992; Calderoni et al., 1993; Sollid, 1992; Urdea, 1993).

Detailed investigations have recently been carried out in order to determine the direct influence of climate on mountain permafrost, especially air temperature records (Gavrilova, 1993) and global radiation input (Funk and Hoelzle, 1992; Schrott ,1993). Ground temperature is also strongly influenced by local factors somehow related with climate, such as thickness and duration of snow cover, type of vegetation, properties of organic layer and soil, characteristics of running water, etc. (Harris and Corte, 1992; Schmitt, 1993). These factors differently influence soil temperature and can interact in varying ways, making it difficult to predict the overall effect of changes (Koster, 1993).

Reactions of mountain permafrost to climatic changes should occur in the form of melting of the ground ice at the permafrost table, with or without changes in active layer thickness (direct response with time scale of several years), disturbance of temperature profiles within the permafrost (delayed response with time scale of decades to centuries), and displacements of the permafrost base (final response with time scale of centuries to millennia). Modification of permafrost distribution patterns and adjustment of geomorphic, hydrological and nivo-glacial surface processes are complex and take place over variable and extended time periods. First attempts are now being made to monitor the long-term evolution of high-mountain permafrost (Francou and Reynaud 1992, Haeberli et al. 1993b, Ødegård et al. 1992).

High-mountain permafrost must have been affected by recent warming, but its secular evolution is little known (Haeberli et al. 1993a). Monitoring long-term behavior of mountain permafrost in the Swiss Alps is carried out by aerial photogrammetry of permafrost creep, borehole measurements for permafrost deformation and temperature, data archiving from geophysical surface soundings for later repetition and qualitative analysis of infrared aerial photography (Haeberli et al., 1993b; Vonder Mühll and Schmid, 1993; Wagner, 1992). The permafrost investigated is typically several decimeters to more than 100 m thick and has mean annual surface temperatures between the melting point and about –3°C (Vonder Mühll and Holub 1992). Heat flow within the uppermost 60 m permafrost in bedrock indicates stable surface temperatures between about 1950 and 1980.

As a consequence of the exceptionally warm 1980s, annual rates of thaw settlement due to melting ground ice in European mountain permafrost may have more than doubled since the 1970s and tend to reach the decimeter range possibly due to a superposition of accelerated melting at the permafrost table onto effects of 20th-century warming (melting at the permafrost base). Permafrost temperatures collected from boreholes in several diverse regions point to warming trends for the most recent years (Haeberli et al., 1993b; Zhang and Osterkamp, 1993), even though no significant trend has been recognized elsewhere (Jin et al., 1993).

Agricultural and Engineering Effects and Practices

Many of the technologic, economic, and social implications of climate change in the North were recently reviewed for North America in Wall (1993; see also Parry, 1992). Both agricultural and engineering practices will be influenced by climate change, particularly in the continental discontinuous permafrost zone, as well as in mountainous areas.

For agriculture and land management practices in regions of discontinuous permafrost, changes in duration of growing season climate, as reflected in soil moisture and temperature will influence planting and productivity of crops. Although warming should result in a gradual retreat of discontinuous permafrost zone northward, anticipated changes in soil moisture and temperature are not adequately known and will depend on local and regional climate changes that are not expected to be uniform. Experience with land clearing in interior Alaska and in other northern regions, a possible analogue to warming, shows a rapid retreat of the permafrost table, improved soil drainage and a warming of the soil. Droughty soils may be experienced in some years and upward movement of salts occur.

Engineering design criteria will need to be modified to reflect deepening of the active layer over permafrost, and warming and ultimate disappearance of underlying marginal or discontinuous permafrost. Permafrost engineering commonly designs for the warmest year in the past 20 years of record (Esch, 1993). Vyalov et al. (1993) also conclude that permafrost preservation and thawing design criteria for climate warming scenarios will need to be changed depending on location. The potential adverse effects on transportation systems is illustrated for the permafrost zone in China covering an area of about 2 million km^2 and having more than 3000 km of railway and over 13,000 km of highway. Climate-induced thawing of permafrost will result in serious disruptions and costs from ground subsidence, side-slope slumpings, landslides, icings and ice mound growth.

The effects of human-induced surface disturbances and of constructed facilities on the thermal and physical stability of permafrost soils are variable, but generally predictable in a known or stable climate; this may not be the case with unknown future warming scenarios. Well-documented case histories of both agricultural and engineering projects are important ingredients for anticipating climate changes in managed ecosystems and engineering projects (Phukan, (1993).

Permafrost Data and Information

Recommendations on future data collection have been made in preceding sections. Data collected previously on permafrost, seasonal frost, ground ice conditions, and cold regions engineering and hydrology are widely dispersed across many countries, organizations and individuals. There are no national or international data centers holding archives of permafrost data that are publicly available. Many potentially valuable data sets for global change research are either held within the private sector and universities, or are in government agency archives where their public release has either not been authorized or funds are lacking to support their retrieval. Progress in identifying, acquiring, archiving, and distributing permafrost data is hampered by low recognition by funding agencies of the importance of permafrost studies in global change research, the concomitant lack of data, and the absence of formally designated centers for such data, other than WCD-A (USA) and D (China) for Glaciology.

A preliminary survey of holders of permafrost data was carried out by the WDC-A for Glaciology, based

largely on attendees at the Fifth International Conference on Permafrost in 1988 at Trondheim, Norway. Out of 125 responses to 340 letters 76 replies indicated that the individuals had data sets and 58 of these were willing to make them available through a coordination office. Some steps to retrieve and organize these data have been initiated (Barry and Brennan, 1993) and facilitated by the preparation of the IPA Circumarctic Map of Permafrost and Ground Ice Conditions (scale 1:10,000,000) and the revised Canadian permafrost map (scale 1:7,500,000) (Heginbottom and Dubreuil, 1993; Heginbottom et al., 1993). Åkerman (1993) undertook a regional survey of Nordic data and literature as part of the IPA circumarctic map compilation.

The IPA proposes to organize and develop the Global Geocryological Database (GGD) to support two principal international activities: (1) input to and validation for global climate change scenarios and (2) rational development and protection of terrain underlain by permafrost (IPA, 1994). Initial focus of the GGD is data rescue for both hemispheres in response to many national and international recommendations (Crane, 1993; GRID, 1994), and ultimately may lead to a more sys-tematic collection, storage and dissemination of relevant data through monitoring and research programs. The IPA/GGD proposes to facilitate this process through the use of the World Data Centers and other international organizations (IPA, 1994).

The emergence of powerful geographic information systems (GIS) makes possible integration of extremely large and disparate data sets, at a variety of geographic scales. Utilization of GIS technology will facilitate the mapping of permafrost and the study and simulation of permafrost dynamics; the success of such efforts is dependent, however, on increasing standardization of data-collection procedures, adequate funding for data collection and processing, and access to the various data sets. Critical to this effort is careful selection of appropriate factors that quantitatively describe variables in the several subsystems (soils, vegetation, climate, terrain) that can be treated together analytically.

As the initial steps in the IPA/GGD, a series of small data workshops to identify and prioritize permafrost data sets is planned for the remainder of 1994 and an international effort to organize funding is being explored.

In contrast to data, the published global literature on permafrost and related scientific and engineering activities is actively maintained by the *Bibliography on Cold Regions Science and Technology* the US Library of Congress (LC) and other library resources (Lay and Everett, 1992). Every five years, the International Permafrost Association encourages the publication of a cumulative permafrost bibliography, combining the citations in the LC database and those contained in the disciplinary citations. In the period covering 1988 through 1992 over 3000 publications are cited (Brennan, 1993). A special bibliography on permafrost and climatic change covering the period from about 1960 through 1993 contains several hundred annotated entries and an updated list of titles (Koster et al., 1994). A synthesis paper, summarizing presentations at the special permafrost/climate session of the Sixth International Conference on Permafrost, presents a summary of current knowledge and an extensive bibliography (Nelson et al., 1993). Conclusions drawn from review of this large body of literature are that only a relatively few studies deal with the response of permafrost to former, present or future climates and that only a few studies (mainly based on tentative simulation experiments) predict anticipated climate changes. A common weakness to most summaries of the permafrost and periglacial literature is lack of adequate analysis of the Russian and Chinese literature.

Many of these data and bibliographic efforts are complemented by the IPA Working Group on Terminology which has endeavored to prepare a multilingual index (at present comprising eight languages) and an English–Russian dictionary of about 3000 terms (van Everdingen, 1993). These efforts will reduce the potential confusion for interpreting results caused by terminological differences.

Responses to Close Information and Data Gaps

Preceding sections have identified gaps in knowledge related to how permafrost conditions have and will respond to climate changes and, indirectly, what the impacts of such changes will be. The following outlines specific activities that should be undertaken to improve understanding of natural processes, model predictions and lessen uncertainties on consequences of changes:

Monitoring: An internationally agreed upon network of representative sites should be established in cooperation with geophysical and ecosystem programs and measurements obtained to document trends and changes in the active layer, continental and mountain permafrost boundaries and thermal gradients. Standardized ground observations should be supplemented by remotely sensed spatial and temporal data acquisition and analysis.

Modeling: An agreed upon approach to coupled climate-vegetation-active layer modeling of permafrost response to climate scenarios should be further devel-

oped, field validated at a number of international sites, and coupled with general circulation models. Special modeling efforts should be devoted to high mountain and plateau environments. Sensitivity analyses should be an integral part of all model validation.

Process Studies: Field investigations on processes related to the degradation of permafrost terrains should be identified and additional studies conducted to establish environmental thresholds needed to initiate rapid and/or low level changes (erosion, slope deformation, creep, thermokarst, etc.). Special emphasis is needed on processes resulting in emissions and/or sequestration of trace gases from terrestrial and subsea soils and permafrost.

Case Studies: Continued observations on performance of engineered structures should be undertaken to assess the adequacy of design criteria under changing climates (pipelines, roads, foundations, water supplies, etc.). Case studies should include agricultural practices in the discontinuous permafrost zones to evaluate long-term trends in productivity as a function of anticipated increases in variability of growing season climate.

Data: The IPA Global Geocryological Database program in both hemispheres should be developed under international auspices and oversight to ensure ready access to past and current data for modeling, validation and establishment of responses and trends. Included should be a comprehensive inventory of shallow and deep boreholes and active-layer measurements and related data archiving.

Bibliographic: Emerging communication technologies should be fully exploited to gather, store and make available on a continuous basis the relevant published and gray literature. Special attention should be assigned to responsible organizations to assess the results of these publications.

National Programs: To improve transfer of knowledge, those countries possessing permafrost terrain and those having global change or climate change research programs related to permafrost and periglacial research and engineering investigations should identify those programs and report results regularly. The IPA should endeavor to maintain a record of these programs and their accomplishments. Readers are requested to provide additions for individual countries.

Argentina
Andean Permafrost and Hydrology

Canada
EOS-CRYSYS (Earth Observing System–Cryospheric System)
US–Canadian BOREAS
(Boreal Ecosystems–Atmosphere Study)

Japan
Joint Siberian Permafrost Program

Russia
Programme 18: Environment and Global Climate Change

United States
ARCSS/LAII (Arctic System Science/Land–Atmosphere–Ice Interactions)
US–Canadian BOREAS

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Cited and Selected References

Åkerman, H.J., 1993: Nordic permafrost: A bibliography. *Rapporter Och Notiser*, No. 77, Department of Geography, Lund University, Lund, Sweden, 17

Barry, R.G. and A.M. Brennan, 1993: Towards a permafrost information and data system. In: *Permafrost: Sixth International Conference, Proceedings.* South China University of Technology Press, Wushan, China, **1**, 23–26

Barsch, D., 1992: Permafrost creep and rockglaciers. *Permafrost and Periglacial Processes*, **3**, 175–188

Brennan, A.M. (compiler), 1993: *Permafrost Bibliography Update 1988–1992.* Glaciological Data Report, GD 26, WDC-A for Glaciology, University of Colorado, Boulder, Colorado, 401

Burn, C.R. and M.W. Smith, 1990: Development of thermokarst lakes during the Holocene at sites near Mayo, Yukon Territory. *Permafrost and Periglacial Processes*, **1**, 161–176

Burns, R.A., N.N. Goriainov, J.A. Hunter, A.S. Judge, A.G. Skvortsov, B.J. Todd and V.M. Timofeev, 1993: Cooperative Russian-Canadian geophysical investigations of permafrost on the Yamal Peninsula, Western Siberia. In: *Permafrost: Sixth International Conference, Proceedings.* South China University of Technology Press, Wushan, China, **1**, 66–71

Calderoni, G., M. Guglielmin, A. Lozej and C. Tellini,

1993: Research on rock glaciers in the central Italian Alps (Valtellina, Sondrio, northern Italy). In: *Permafrost: Sixth International Conference, Proceedings*. South China University of Technology Press, Wushan, China, **1**, 72–77

Chapin, F.S. III, R.L. Jefferies, J.F. Reynolds, G.R. Shaver, J. Svoboda and E.W. Chu (Ed.), 1992: *Arctic Ecosystems in a Changing Climate. An Ecophysiological Perspective*. Academic Press, New York

Cheng, G. and F. Dramis, 1992: Distribution of mountain permafrost and climate. *Permafrost and Periglacial Processess*, **3**, 83–91

Crane, R.G., 1993: Workshop on cryospheric data rescue and access, Pennsylvania State University, May 11–12, 1993. Glaciological Data Report, GD 25, WDC-A for Glaciology, University of Colorado, Boulder, Colorado, 275–294

Esch, D.C., 1993: Impacts of northern climate change on Arctic engineering practice. In: *Impacts of Climate Change on Resource Management in the North* (G. Wall, Ed.). Department of Geography Publications Series, Occasional Paper No. 16, University of Waterloo, Waterloo, Canada, 185–192

Fitzharris, B.B., 1994: *Impact Assessment Reports: The Cryosphere* (draft, Chapter 6), April 1994

Francou, B. and L. Reynaud, 1992: Ten-year surficial velocities on a rock glacier (Laurichard, French Alps). *Permafrost and Periglacial Processes*, **3**, 209–213

Funk, M. and M. Hoelzle, 1992: A model of potential direct solar radiation for investigating occurrences of mountain permafrost. *Permafrost and Periglacial Processes*, **3**, 139–142

Gavrilova, M.K., 1993: Climate and permafrost. *Permafrost and Periglacial Processes*, **4**, 99–111

GRID: International data directory of environments in the Arctic (IDDEA), 1994: Minutes of the Joint AEDD-IDDEA Steering Committee Meeting, San Francisco, California, December 9–10, 1993. GRID-ARENDAL, Norway

Haeberli, W., G. Cheng, A.P. Gorbunov and S.A. Harris, 993a: Mountain permafrost and climatic change. *Permafrost and Periglacial Processes*, **4**, 165–174

Haeberli, W., M. Hoelzle, F. Keller, W. Schmid, D. Vonder Mühll and S. Wagner, 1993b: Monitoring the long-term evolution of mountain permafrost in the Swiss Alps. In: *Permafrost: Sixth International Conference, Proceedings*. South China University of Technology Press, Wushan, China, **1**, 214–219

Harris, S.A. and A.E. Corte, 1992: Interactions and relations between mountain permafrost, glaciers, snow and water. *Permafrost and Periglacial Processes*, **3**, 103–110

Harris, S.A. and J.R. Giardino, 1993: Permafrost in mountain ranges of North America. In: *Permafrost: Sixth International Conference, Proceedings*. South China University of Technology Press, Wushan, China, **2**, 1019–1021

Harrison, W.D., 1991: Permafrost response to surface temperature change and its implications for the 40,000-year surface history at Prudhoe Bay. *Journal of Geophysical Research*, **96**, 683–695

Heginbottom, J.A., J. Brown, E.S. Melnikov and O.J. Ferrians, Jr., 1993: Circumarctic map of permafrost and ground ice conditions. In: *Permafrost: Sixth International Conference, Proceedings*. South China University of Technology Press, Wushan, China, **2**, 1132–1136

Heginbottom, J.A. and M-A. Dubreuil, 1993: A new permafrost and ground ice map. In: *Permafrost: Sixth International Conference, Proceedings*. South China University of Technology Press, Wushan, China, **1**, 255–260

Hinzman, L.D. and D.L. Kane, 1992: Potential response of an arctic watershed during a period of global warming. *Journal of Geophysical Research*, **97**(D3), 2811–2820.

International Permafrost Association, 1994: Proposal prospectus: Global geocryological database. IPA Secretariat, Arlington, Virginia

Jin, H., G. Qiu, L. Zhao, S. Wang and Z. Zeng, 1993: Thermal regime of alpine permafrost in the upper reach of Urumqi River, Xinjiang, China. In: *Permafrost: Sixth International Conference, Proceedings*. South China University of Technology Press, Wushan, China, **1**, 307–311

Judge, A.S. and J.A. Majorowicz, 1992: Geothermal conditions for gas hydrate stability in the Beaufort–Mackenzie area: The global change aspect. *Global and Planetary Change*, **6**, 251–263

Judge, A.S., S.L. Smith and J.A. Majorowicz, 1994: The current distribution and thermal stability of natural gas hydrates in the polar regions. In: *Proceedings of the Fourth International Offshore and Polar Engineering Conference, Osaka, Japan*. In press

Kane, D.L., 1993: Northern hydrology and water resources in a changing environment. In: *Proceedings of Symposium on Impacts of Climate Change on Resource Management in the North, May 12–14, 1992, Whitehorse, Canada*. Department of Geography Publications Series, Occasional Paper No. 16, University of Waterloo, Waterloo, Canada, 55–67

Kane, D.L., L.D. Hinzman and J.P. Zarling, 1991: Thermal response of the active layer to climatic warming in a permafrost environment. *Cold Re-*

gions Science and Technology, **19**, 111–122

King, L. and J. Åkerman, 1993: Mountain permafrost in Europe. In: *Permafrost: Sixth International Conference, Proceedings.* South China University of Technology Press, Wushan, China, **2**, 1022–1027

Kolchugina, T.P. and T.S. Vinson, 1993: Climate warming and the carbon cycle in the permafrost zone of the former Soviet Union. *Permafrost and Periglacial Processes*, **4**, 149–163

Koster, E., 1993: Global warming and periglacial landscapes. In: *The Changing Global Environment* (N. Roberts, Ed.). Blackwell, Cambridge, Massachusetts, 127–149

Koster, E.A., M.E. Nieuwenhuijzen and A.S. Judge, 1994: Permafrost and climate change: An annotated bibliography. Glaciological Data Report 27, WDC-A for Glaciology, University of Colorado, Boulder, Colorado. In press

Kvenvolden, K.A. and T.D. Lorenson, 1993: Methane in permafrost—preliminary results from coring at Fairbanks, Alaska. *Chemosphere*, **26**, 609–616

Lachenbruch, A.H. et al., 1989: Temperature and depth of permafrost on the Arctic Slope of Alaska. In: *Geology and Exploration of the National Petroleum Reserve, 1974–1982* (G. Gryc, Ed.), US Geological Survey Professional Paper 1399, 645-656

Lay, L.B. and L.T. Everett (Ed.), 1992: *Proceedings of the Fourteenth Polar Libraries Colloquy: International Sharing of Polar Information Resources, May 2–7, 1992.* Byrd Polar Research Center, The Ohio State University, Columbus, Ohio, 371

Lewkowicz, A.G., 1992: Factors influencing the distribution and initiation of active-layer detachment slides on Ellesmere Island, Arctic Canada. In: *Periglacial Geomorphology* (J.C. Dixon and A.D. Abrahams, Ed.). John Wiley and Sons, New York, 223–250

Marion, G. M. and W.C. Oechel, 1993: Mid- to late-Holocene carbon balance in Arctic Alaska and its implications for future global warming. *The Holocene*, **3**, 193–200

Moorhead, D.L. and J.F. Reynolds, 1993: Effects of climate change on decomposition in Arctic tussock tundra: A modeling synthesis. *Arctic and Alpine Research*, **25**, 403- 412

Moraes, F. and M.A.K. Khalil, 1993: Permafrost methane content: 2. Modeling theory and results. *Chemosphere*, **26**, 595–607

Nelson, F.E. and O.A. Anisimov, 1993: Permafrost zonation in Russia under anthropogenic climatic change. *Permafrost and Periglacial Processes*, **4**, 137–148

Nelson, F.E., A.H. Lachenbruch, M-k. Woo, E.A. Koster, T.E. Osterkamp, M.K. Gavrilova and Cheng Guodong, 1993: Permafrost and changing climate. In: *Permafrost: Sixth International Conference, Proceedings.* South China University of Technology Press, Wushan, China, **2**, 987–1005

Nixon, F.M. and A.E. Taylor (1994) Active layer monitoring in natural environments, Mackenzie Valley, Northwest Territories. In: *Current Research.* Geological Survey of Canada, Paper 94–1B, 27–34

Ødegård, R.S., J.L. Sollid and L. Sørbel, 1992: Ground temperature measurements in mountain permafrost, Jotunhaimen, southern Norway. *Permafrost and Periglacial Processess*, **3**, 231–234

Oechel, W.C. and W.D. Billings, 1991: Effects of global change on carbon balance of Arctic plants and ecosystems. In: *Arctic Physiological Processes in a Changing Climate* (F.S. Chapin III, R. Jeffries, J.F. Reynolds, G.R. Shaver and J. Svoboda, Ed.). Academic Press, San Diego, 139–168

Oechel, W.C. and J.I. Harle (Ed.), 1994: Global Change and Arctic Terrestrial Ecosystems: An International Conference, 21–26 August 1993, Oppdal, Norway; Recommendations. Norwegian Institute for Nature Research, Trondheim, Norway, 53

Oechel, W. C., S. J. Hastings, G. Vourlitis, M. Jenkins, G. Riechers and N. Grulke, 1993: Recent change of Arctic tundra ecosystems from a net carbon dioxide sink to a source. *Nature*, **361**, 520–523

Parry, M., 1992: The potential effect of climate change on agriculture and land use. In *Advances in Ecological Research, 22: The Ecological Consequences of Global Climate Change* (F.I. Woodward, Ed.). Academic Press, 63–88

Phukan, A. (Ed.), 1993: *Proceedings of the Second International Symposium on Frost in Geotechnical Engineering, June 28–July 1, 1993, Anchorage, USA.* A. Balkema, Brookfield, Vermont, 191

Qiu, G., 1993: Mountain permafrost in central Asia. In: *Permafrost: Sixth International Conference, Proceedings.* South China University of Technology Press, Wushan, China, **2**, 1028-1030

Rasmussen, R.A., M.A.K. Khalil and F. Moraes, 1993: Permafrost methane content 1: Experimental data from sites in northern Alaska. *Chemosphere*, **26**, 591–594

Riseborough, D.W., 1990: Soil latent heat as a filter of the climate signal in permafrost. In: *Proceedings of the Fifth Canadian Permafrost Conference, Quebec.* Centre d'études nordiques, Université Laval/ National Research Council of Canada, 199–205

Riseborough, D.W. and M.W. Smith, 1993: Modelling permafrost response to climate change and climate variability. In: *Proceedings of the Fourth International Symposium on Thermal Engineering & Science for Cold Regions* (V.J. Lunardini and

S.L. Bowen, Ed.). US Army Cold Regions Research and Engineering Laboratory, Hanover, NH, Special Report 93–22, 179–187

Schmitt, E., 1993: Global climatic change and some possible geomorphological and ecological effects in Arctic permafrost environments, Isfjorden and Liefedefjorden, northern Spitsbergen. In: *Permafrost: Sixth International Conference, Proceedings*. South China University of Technology Press, Wushan, China, **1**, 544–549

Schrott, L., 1993: Die Solarstrahlung als steuernder Faktor in Geosystem der subtropischen semiariden Hochanden. Dissertation, Universität, 166

Sollid, J.L. and L. Sørbel, 1992: Rock glaciers in Svalbard and Norway. *Permafrost and Periglacial Processes*, **3**, 215–220

Taylor, A.E., 1991: Holocene paleoenvironmental reconstruction from deep ground temperatures: A comparison with paleoclimate derived from the ^{18}O record in an ice core from the Agassiz Ice Cap, Canadian Arctic Archipelago. *Journal of Glaciology*, **37**, 209–219

Urdea, P., 1993: Permafrost and periglacial forms in Romanian Carpathians. In: *Permafrost: Sixth International Conference, Proceedings*. South China University of Technology Press, Wushan, China, **1**, 631–637

van Everdingen, R.O., 1993: A multi-lingual index of permafrost terms. In: *Permafrost: Sixth International Conference, Proceedings*. South China University of Technology Press, Wushan, China, **1**, 638–642

Velichko, A.A. and V.P. Nechaev, 1992: The estimation of permafrost dynamics in northern Eurasia within the global warming 1992. *Proceedings of the Academy of Sciences*, **324**, 667–671

Velichko, A.A., O.K. Borisova, E.M. Zelikson and V.P. Nechaev, In press: Permafrost and vegetation response to the global warming in northern Eurasia. In: *Biotic Feedbacks*. Oxford University Press, New York

Vonder Mühll, D.S. and W. Schmid, 1993: Geophysical and photogrammetric investigation of rock glacier Muragl 1, Upper Engadin, Swiss Alps. In: *Permafrost: Sixth International Conference, Proceedings*. South China University of Technology Press, Wushan, China, **1**, 654–659

Vonder Mühll, D.S. and Holub, 1992: Borehole logging in alpine permafrost, Upper Engadin, Swiss Alps. *Permafrost and Periglacial Processes*, **3**, 125–132

Vyalov, S.S., A.S. Gerasimov, A.J. Zolotar and S.M. Fotiev, 1993: Ensuring structural stability and durability in permafrost ground at global warming of the Earth's climate. In: *Permafrost: Sixth International Conference, Proceedings*. South China University of Technology Press, Wushan, China, **1**, 955–960

Waelbroeck, C., 1993: Climate–soil processes in the presence of permafrost: A systems modelling approach. *Ecological Modeling*, **69**, 185–225

Wagner, S., 1992: Creep and alpine permafrost investigated on the Murtèl rock glacier. *Permafrost and Periglacial Processes*, **3**, 157–162

Wall, G. (Ed.), 1993: *Proceedings of Symposium on Impacts of Climate Change on Resource Management in the North., May 12–14, 1992, Whitehorse, Canada.* Department of Geography Publications Series, Occasional Paper No. 16, University of Waterloo, Waterloo, Canada, 253 + appendices

Wang, K. and T.J. Lewis, 1992: Geothermal evidence from Canada for a cold period before recent climatic warming. *Science*, **256**, 1003–1005

Wang, S., 1989: Formation and evolution of permafrost on the Qinghai-Xiang Plateau since the late Pleistocene. *Journal of Glaciology and Geocryology*, **11**, 75–81 (in Chinese with English summary)

Woo, M.-K., A.G. Lewkowicz and W.R. Rouse, 1992: Response of the Canadian permafrost environment to climatic change. *Physical Geography*, **13**, 287–317

Zhang, T. and T.E. Osterkamp, 1993: Changing climate and permafrost temperatures in the Alaskan Arctic. In: *Permafrost: Sixth International Conference, Proceedings*, South China University of Technology Press, Wushan, China, **1**, 783- 788

Zimov, S.A., I.P. Semiletov, S.P. Daviodov, Yu.V. Voropaev, S.F. Prosyannikov, C.S. Wong and Y.-H. Chan, 1993: Wintertime CO_2 emission from soils of northeastern Siberia. *Arctic*, **46**, 197–204

PUBLICATIONS

The Swedish Contribution to the International Permafrost Association (IPA) Multilingual Index of Permafrost Terms, by H. Jonas Åkerman. Lunds Universitets Naturgeografiska Institute, Lungi, Sweden, *Rapporter Och Notiser*, no. 78, 1993.

Nordic Permafrost: A Bibliography, by H. Jonas Åkerman, Department of Physical Geography, Lunds Universitets Naturgeografiska Institute, Lungi, Sweden, *Rapporter Och Notiser*, no. 77, 1993.

Permafrost and Climate Change: An Annotated Bibliography, by E.A. Koster, M.E. Nienwenhuijzen and R.S. Judge. Glaciological Data Report GD-27, World Data Center for Glaciology, CIRES, University of Colorado, Boulder, Colorado 80309 ($10.00, hard copy or diskette).

Proceedings, 7th International Cold Regions Engineering Specialty Conference. Contact: Doris Hryan, Centre for Frontier Engineering Research, 200 Karl Clark Road, Edmonton, Alberta T6N 1E2, Canada. Fax: (403) 450-3700 ($50.00 Can.).

Proceedings, Fourth Canadian Conference on Marine Geotechnical Engineering, 27–30 June 1993, 3 volumes ($100 Can., plus handling). Video tape of fourteen keynote addresses and invited speakers ($60.00) also available. Contact: C-CORE, Memorial University of Newfoundland, St. Johns, Newfoundland A1B 3X5, Canada. Phone: (709) 737-8354, Fax: (709) 737-4706.

Proceedings, International Conference on The Development of the North and Problems of Recultivation. Extended abstracts from 8–14 July 1991 conference held in Syktyvkar, Komi, Russia. BPRC Miscellaneous Series M-334. Available from Byrd Polar Research Center, The Ohio State University, Columbus, Ohio 04321-1002.

Gas Pipelines, Oil Pipelines, Civil Engineering in Arctic Climates. Proceedings of a Seminar, P.J. Williams (Ed.). Carleton University, 173 p., 1993. $40.00 Can., postage included). Enclose check/money order to: Geotechnical Science Laboratories, Carleton University, 1125 Colonel By Drive, Ottawa, Ontario K1S 5B6, Canada.

International Tour of Permafrost-Affected Soils: The Yukon and Northwest Territories of Canada, 1993, by C. Tarnocai, C.A.S. Smith, and C.A. Fox. Centre for Land and Biological Resources Research, Agriculture Canada, Ottawa K1A 0C6, Canada.

International Correlation Meeting on Permafrost-Affected Soils: Guidebook–Alaska Portion, July 1993. J.P. Moore, D.K. Swanson, C.A. Fox, and C.L. Ping. Agriculture and Forestry Experiment Station, University of Alaska, Palmer, Alaska 99645.

Viable Microorganisms in Permafrost, David Gilichinsky, Ed. In English, containing reports by Russian, US and German investigators. Contact David Gilichinsky, Institute of Soil Science and Photosynthesis, Russian Academy of Sciences, 1242292 Pushchino, Moscow Region, Russia.

Proceedings, XX Polar Symposium, Man Impact on Polar Environment, 3–5 June 1993, Lublin, Poland. Polar Club of Polish Geographical Society, Committee on Polar Research, Polish Academy of Sciences. Contact: Institute of Earth Sciences of Maria Curie-Sklodowska University, Akademicka 19, 209-033, Lublin, Poland.

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Journal of Glaciology and Geocryology

Selected Frozen Ground Titles

Volume 15, No. 3 (September 1993)

Research Progress of Chinese Geocryology Viewed from 6th International Conference on Permafrost, Cheng Guodong and Xu Xuezu

Information about the 17th International Geographical Conference and the Global Change Research as well as the Postgraduates Training in the Geography Department of Universities in USA, Shi Yafeng

Outline of the Workshop on the Study of Global Bio-Geospheric Chemical Cycling Record in Arctic and Antarctic Ice Cores, Qin Dahe

Pleistocene Glaciations in Qinghai-Tibet Plateau Explanation with Astroclimatology, Xu Qingqi

A Study of Glacial Runoff Regime in Central Tien Shan During 1989–1990, Vladimir B. Aizen et al.

Formation and Distribution of the Sorted Circles at the Head Area of Urumqi River, Liu Gengnian and Lui Yuefeng

Characteristics of Shear Creep of Frozen Fine Sand, Mi Haizhen, Wu Ziwang, Ma Wei et al.

Study of the Influence of Moisture Migration on Temperature Field During Freezing Process of Pave-

ment Proper in Cold Regions, Lian Leming and Shi Jinyan

Research of the Frostheaving Project Survey, Huang Jinghsan

A Significant Breakthrough in Landbased Record of Ice Age Climates, Li Peiji

Book Review

The Monitoring of Glacier, Climate, Runoff Changes and the Research of Cold Region Hydrology in Qilian Mountains, Su Zhen

Volume 15, No. 4 (December 1993)

Temperature Return and Determination of Equilibrium Temperature, Wang Baolai

Landform and Origin of Hanasi Lake, Altay Mountains, Feng Min

The Change of Permafrost under Roadbed with Asphalt Pavement along the Qinghai-Tibet Highway, Wang Shaoling and Mi Haizhen

A Different View of Quaternary Glaciation and Environment in Tanzhesi Area of Western Mountain, Beijing, Guo Xudong and Yan Fuhua

Glacio-Hydrological Characteristics of Gozha Glacier on South Slope of the West Kunlun Mountains, Cao Zhentang

MST-88 Multichannel Temperature Data Logger, Wang Liangwei, Liao Quanrong and Zhang Yaonan

An Overview of Large-Scale Effects of Seasonal Snow Cover, Li Peiji

Development of Glaciological and Geocryological Research in China—from "A Bibliography of the Glaciology and Geocryology in China and Its Adjacent Districts," Liu Jingren and Ma Shimin

PERMAFROST AND PERIGLACIAL PROCESSES

Volume 4, Issue No. 4. (October–December 1993)

Devensian Thermal Contraction Networks and Cracks at Somersham, Cambridgeshire, U.K., R.G. West

A Low-Angle Slushflow in the Kirgiz Range, Kirgizstan, K. Elder and R. Kattelmann

Caractéristiques de la Cinétrique de Congélation de Sols Salins, A.D. Frolov and M.-K. Seguin

Notes on Open-System Pingo Ice, Adventdalen, Spitsbergen, K. Yoshikawa.

Short Communication

Origin of Permafrost Lake Deposits in the Central Andes, A.P. Gorbunov

Volume 5, Issue No. 1 (January–March 1994)

Present and Past Geocryogenic Processes in Mexico, K. Heine

Gravimetrical Investigation of Ice-Rich Permafrost Within the Rock Glacier Murtèl-Corvatsch (Upper Engadin, Swiss Alps), D.S. Vonder Mühll and E.E. Kingelé

Permafrost Distribution and Rock Glaciers in the Livigno Area (Northern Italy), M. Gugliebnin, A. Lozej and C. Tellini

Rheological Models of Active Rock Glaciers: Evaluation, Crituque and a Possible Test, W.B. Whalley and F. Azizi

Fabric Analysis of Rock Glacier Debris Mantles, La Sal Mountains, Utah, J.W. Nicholas

Short Communication

Quantitative Estimation of Cryogenic Weathering Energy, A.A. Vasiliyev

Volume 5, Issue No. 2 (April–June 1994)

Streamflow Processes in an Alpine Permafrost Catchment, Tianshan, China, M-K Woo, Z. Yang, Z. Xia and D. Yang

Climate Controls and High-Altitude Permafrost, Qinghai-Xizang (Tibet) Plateau, China, B. Wang and H.M. French

Thufur in the Mohlesi Valley, Lesotho, Southern Africa, S.W. Grab

Current Changes of Climate and Permafrost in the Arctic and Subarctic of Russia, A.V. Pavlov

Some Observations Regarding Sorted Stripes, Livingstone Island, South Shetland, K. Hall

Book Review

Les Versants du Spitzberg, M.-F. André

FORTHCOMING MEETINGS

1994

Bipolar Information Initiatives: The Needs of Polar Research—15th Polar Libraries Colloquy
3–8 July 1994, Cambridge, United Kingdom
Contact: William Mills, Scott Polar Research Institute, Cambridge CB2 1ER, United Kingdom
Tel: 0223-336557; Fax: 0223-336549
E-mail: wjm13@uk.ac.cam.phx

15th International World Soils Congress
10–16 July 1994, Acapulco, Mexico
Contact: Secretary General ISSS, Universitaet fuer Bodenkultur, Gregor Mendel-Strasse 33, A1180 Wien, Austria
Tel: 43 1 3106026; Fax: 43 1 3106027

Working Group on Geo-Indicators (IUGS-COGEOENVIRONMENT)
11–18 July 1994, Corner Brook, Newfoundland, Canada
Contact: A.R. Berger, 528 Paradise St., Victoria, British Columbia V9A 5E2, Canada
Tel/Fax: (604) 480-0840

4th International Conference on the Bearing Capacity of Roads and Airfields
17–21 July 1994, Minneapolis, Minnesota
Contact: Lori Graven, BCRA '94, Professional Development and Conference Services, 216 Nolte Center, University of Minnesota, 315 Pillsbury Drive SE, Minneapolis, Minnesota 55455-0139
Tel: (612) 625-9023; Fax: (612) 626-1632
E-mail: igraven@pdcs.cee.umn.edu

International Conference on Climate Change
27–28 July 1994, Washington, D.C.
Contact: Jan McCusker, P.O. Box 236, Frederick, Maryland 21701
Tel: (301) 695-3762; Fax: (301) 695-0175

International Symposium on the Role of the Cryosphere in Global Change
7–12 August 1994, Columbus, Ohio
Contact: Secretary General, International Glaciological Society, Lensfield Road, Cambridge CB2 1ER, United Kingdom
Tel: 223 355974; Fax: 223 336543

International Conference on the Arctic and North Pacific: Bridges of Science Between North America and the Russian Far East
25 August–2 September 1994, Anchorage, Alaska and Vladivostok, Russia

Contact: Dr. Gunter Weller, Geophysical Institute, University of Alaska, Fairbanks, Alaska 99775-0800
Fax: (907) 474-7290
E-mail: gunter@dino.gi.alaska.edu

10th International Symposium and Workshop Northern Research Basins
28 August–3 September 1994, Svalbard, Norway
Contact: Knut Sand, SINTEF, Norwegian Hydrotechnical Laboratory, N-7034, Trondheim, Norway
Tel: 47 7 592300; Fax: 47 7 592376

International Conference on Arctic Margins (ICAM)
5–9 September 1994, Magadan, Russia
Contact: Dennis Thurston, Minerals Management Service, 949 E 36th Avenue, Anchorage, Alaska 99508-4302
Tel: (907) 271-6545; Fax: (907) 271-6565
E-mail: ahdt1@acad2.alaska.edu

Symposium on Periglacial Slope Processes and Deposits, Past and Present
4–9 September 1994, France
Contact: Jean-Pierre Lautridou, Centre de Géomorphologie du CNRS, 24 rue des Tilleuls, 14000 Caen, France
Tel: 31 45 5718; Fax: 31 45 5757
E-mail: lautridou@geomorpho.unicaen.fr

Symposium and Workshop on Time Domain Reflectometry
8–9 September 1994, Evanston, Illinois
Contact: Charles Dowding, Department of Civil Engineering, Northwestern University, Evanston, Illinois 60708
Tel: (708) 491-4338; Fax: (708) 491-4011

INQUA/GLOCOPH International Meeting
10–17 September 1994, Southampton, United Kingdom
Contact: J. Branson, GeoData Institute, University of Southampton, Southampton S09 5NH, United Kingdom

ATE '94—Arctic Town and Environment
11–16 September 1994, Vorkuta, Russia
Contact: A. Tashaev, Institute of Biology, Konii Scientific Centre, 167610 Syktyvkar, Russia
Tel: 7 821 22 25213; Fax: 7 821 22 20163

47th Canadian Geotechnical Conference
21–23 September 1994, Nova Scotia, Canada
Contact: L.D. Baike, Department of Civil Engineering, Technical University of Nova Scotia, Halifax, Nova Scotia B3J 2X4, Canada

7th International Symposium on Ground Freezing
24–28 October 1994, Nancy, France
Contact: ISGF '94, LCPC,CNRS/UMR 1113, Cité Descartes, 2 allée Képler, 77420 Champs sur Marme, France
Tel: 33 1 40 43 54 40; Fax: 33 1 43 54 50

Second International Exhibition and Symposium: Mineral Resources of Russia-94
25–29 October 1994, St. Petersburg, Russia
Contact: Organizing Committte, P.O. Box 215, "Minerals," 192004 St. Petersburg, Russia
Tel: 7 812 355 7952 or 218 9224; Fax: 7 812 213 5926
E-mail:vsg@sovamsu.sovusa.com

Third International Symposium on Glacier Caves and Cryokarst in Polar and High Mountain Regions
1–6 November 1994, Chamonix, France

Conference on the Dynamics of the Arctic Climate System (WMO/ICSU/IOC) World Climate Research Programme (WCRP)
7–10 November 1994, Gøteborg, Sweden
Contact: Leif Anderson, Chalmers University, S-41296 Gøteborg, Sweden
Tel: 46-31-772-2774; Fax: 46-31-772-2785

Symposium on Permafrost-Affected Soils
Soil Science Society of America Annual Meeting
13–18 November 1994, Seattle, Washington
Contact: J.G. Bockheim, Department of Soil Science, University of Wisconsin, Madison, Wisconsin 53706-1299
Tel: (608) 263-5403; Fax: (608) 265-2595

Permafrost and the Changing Climate (proposed)
American Geophysical Union Fall Meeting
5–9 December 1994, San Francisco, California
Contact: Bernard Hallet, Quaternary Research Center, AK-60, University of Washington, Seattle, Washington 98195
Tel: (206) 685-2409; Fax: (206) 543-3836
E-mail: hallet@u.washington.edu

1995

74th Annual Meeting, Transportation Research Board
Frost Action Committee
21–26 January 1995, Washington, D.C.
Contact: TRB, National Research Council, 2101 Constitution Avenue NW, Washington, D.C. 20418

Second International Conference on Mechanics of Jointed and Faulted Rocks (MJFR-2)
10–14 April 1995, Vienna, Austria
Contact: H.P. Rossmanith, Institute of Mechanics, Technical University Vienna, Wiedner Hauptstrasse 8-10/135, A-1040 Vienna, Austria
Tel: 43 1 58 801 5514 / 43 1 58 75863

ISOPE-95: Fifth International Offshore and Polar Engineering Conference
11–16 June 1995, The Hague, The Netherlands
Contact: P.O. Box 1107, Golden, Colorado 80402-1107
Fax: (303) 420-3760

Southeast Asia Conference on Geomorphology
18–23 June 1995, Singapore
Contact: K. Chuan, Division of Geography, Nanyang Technological University, 469 Bukit Timah Road, Singapore 1025
Fax: 65 469 8433

XIV International Union for Quaternary Research (INQUA)
3–10 August 1995, Berlin, Germany
Contact: Congress Partner GMBH, Emmastr. 220, 28213 Bremen, Germany
Tel: 49 421 21 9073; Fax: 49 421 21 6419

International Symposium on Glacial Erosion and Sedimentation
20–25 August 1995, Reykjavik, Iceland

19th International Congress of International Institute of Refrigeration (IIR) and Institut International Froid (IIF)
20–26 August 1995, The Hague, The Netherlands
Contact: PR Group 19th Congress IIR/IIF 1995, c/o Den Daas/CM, P.O. Box 747, 3700 AS Zeist, The Netherlands

Monitoring of Permafrost and Frozen Soils: Implications for Studies of Periglacial Processes Under a Changing Climate (proposed)
American Geophysical Union Fall Meeting
11–15 December 1995, San Francisco, California
Contact: Bernard Hallet, Quaternary Research Center, AK-60, University of Washington, Seattle, Washington 98195
Tel: (206) 685-2409; Fax: (206) 543-3836
E-mail: hallet@u.washington.edu

1996

75th Annual Meeting, Transportation Research Board
Frost Action Committee
6–11 January 1995, Washington, D.C.
Contact: TRB, National Research Council, 2101 Constitution Avenue NW, Washington, D.C. 20418

8th International Cold Regions Engineering Conference
1 August 1976, Fairbanks, Alaska

30th International Geological Congress
4–14 August 1996, Beijing, China
Contact: Professor Zhao Xun, 30th International Geological Congress, P.O. Box 823, Beijing 100037, China
Tel: 86 1 8327772; Fax: 86 1 8328928

1997

IV International Geomorphology Conference
28 August–3 September 1997, Bologna, Italy
Contact: M. Panizza, Universita Degli Studi di Moden, 59-41100 Modena, Italy
Tel: 059 23 0394; Fax: 059 21 8326

1998

Seventh International Conference on Permafrost
27–31 July 1998, Yellowknife, Canada
Contact: J.A. Heginbottom, Geological Survey of Canada, 601 Booth Street, Ottawa, Ontario K1A 0E8, Canada
Tel: (613) 992-7813; Fax: (613) 992-2468
E-mail: heginbottom@gsc.emr.ca

International Permafrost Association

June 1994

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