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Direction de la physique du globe

CANADIAN GEOPHYSICAL BULLETIN

BULLETIN CANADIEN DE GÉOPHYSIQUE

Volume 36

Published by the Canadian National Committee for the
International Union of Geodesy and Geophysics of the
National Research Council of Canada

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Internationale de Géodésie et de Géophysique du Conseil
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**December/décembre 1983
Ottawa, Canada**

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INTRODUCTION

The Canadian Geophysical Bulletin is an annual report of geophysical research, development and services in industry, government and universities in Canada. Its main purpose is to provide a record, continuous from year to year, of active researchers and their projects and of the current year's publications. Brief mention is made of research results, but the latter are not recorded to any extent since they may be found from the extensive bibliographies. Since 1974 the Bulletin has been published under the authority of the Canadian National Committee for the International Union of Geodesy and Geophysics (CNC/IUGG).

The editor wishes to thank all of his colleagues who have cooperated as chapter compilers or as researchers responding to the requests for information issued by the compilers. During 1981 a sub-committee of the CNC/IUGG prepared a set of guidelines to aid compilers and individual contributors in preparing their reports. The compilers are to be thanked for their efforts in applying the guidelines and in the difficult task of reducing copy so that the Bulletin could be confined to 200 pages, a limit set by financial restraint. It is also a pleasure to acknowledge the assistance of Mr. E.B. Manchee, Ms. Joanne Wagner, Mrs. Debbie Adler, Mrs. Micheline Whissell, Miss Maxine Brunke and Mrs. Christina Lacasse of the Earth Physics Branch, Energy, Mines and Resources, Canada.

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R.A. Gibb
Editor

INTRODUCTION

Le Bulletin canadien de géophysique est un rapport annuel des recherches, des développements et des services géophysiques dans l'industrie, les gouvernements et les universités au Canada. Le but principal est d'établir un dossier permanent des chercheurs actifs, de leurs travaux et des publications de l'année. On y présente un bref aperçu des résultats de recherche. Cependant ces résultats ne sont pas donnés en détail, puisqu'on peut se renseigner à leur sujet en consultant la liste des ouvrages de référence. Ce bulletin, depuis 1974, est publié sous la direction du Comité national du Canada de l'Union géodésique et géophysique internationale (CNC/UGGI).

Le rédacteur en chef désire exprimer sa reconnaissance à tous ses collègues qui ont contribué à la publication du bulletin à titre de compilateurs, et à tous les chercheurs qui ont fourni des renseignements aux compilateurs. Au cours de 1981, un sous-comité du CNC/UGGI a préparé une série de lignes directrices destinées à aider les compilateurs et les autres participants à rédiger leurs rapports. Nous remercions les compilateurs d'avoir appliqué ces lignes directrices et d'avoir réussi la tâche ardue de raccourcir les textes de manière à ce que ce bulletin ne dépasse pas 200 pages, limite fixée par des contraintes financières. C'est avec non moins de reconnaissance que nous tenons à souligner l'aide apportée par: M. E.B. Manchee, Mlle Joanne Wagner, Mme Debbie Adler, Mme Micheline Whissell, Mlle Maxine Brunke et Mme Christina Lacasse de la Direction de la physique du globe, d'Énergie, Mines et Ressources Canada.

Ce bulletin est produit et distribué aux lecteurs du Canada et de l'étranger par la Direction de la physique du globe, d'Énergie, Mines et Ressources Canada, à la demande du CNC/UGGI du Conseil canadien des sciences de la Terre. Les demandes pour obtenir un exemplaire du numéro courant ou des numéros récents doivent être adressées à:

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R.A. Gibb
Rédacteur en chef

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I (A) GEODESY

Compiled by: R.B. Langley

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2. Geodetic Survey of Canada
3. Earth Physics Branch, Gravity, Geothermics and Geodynamics Division
4. National Research Council, Division of Physics
5. Canadian Hydrographic Service
6. Bedford Institute of Oceanography, Canadian Hydrographic Service
Atlantic Region
7. Memorial University of Newfoundland, Department of Earth Sciences
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12. University of Manitoba, Department of Earth Sciences
13. University of Calgary, Surveying Engineering Division
14. Nortech Surveys (Canada) Inc.
15. Bibliography

1. Summary

Geodesy continues to be a very active area of research in Canada with much activity centred on the development of new technologies. Progress is reported in the application of the Global Positioning System (GPS) to geodetic problems both on land and at sea. A number of tests have been performed using currently available American equipment with excellent results, despite the fact that the satellite component of the system is only partially deployed. Already routine surveying tasks using GPS are being performed by at least one Canadian commercial firm. Canadian-designed GPS receivers are also being developed. Progress is reported on the development of inertial technology both as a stand-alone surveying technique and as a component of an integrated inertial-GPS system for precise offshore navigation. A great deal of activity is also indicated in the geodetic and geophysical applications of long baseline interferometry (LBI). A new Canadian LBI system is being developed and plans are well underway for the visits of NASA transportable LBI systems to Canadian sites in 1984. Research efforts also continued in the areas of satellite Doppler positioning, LORAN-C navigation, local deformation studies, levelling, data base development, gravity field approximation, the rotation of the earth, and the readjustment of North American networks. Much of the university component of this activity is supported by the Natural Sciences and Engineering Research Council and departments of the federal government.

2. Geodetic Survey of Canada

Satellite Doppler observations were made at 6 existing stations in Quebec to improve their integration into the primary horizontal framework. Also in Quebec, 7 new first-order horizontal stations were established on a traverse between Lac Mistassini and Manicouagan.

Special purpose survey projects undertaken in 1983 included a 14-station high precision trilateration network spanning the St. Lawrence River at La Malbaie, to continue monitoring crustal movement in this seismologically active area; a 19-station trilateration network at the Mactaquac, N.B., generating station to monitor possible structural movement; high precision trilateration networks at Whitehorse, Y.T., and at Yellowknife, N.W.T., to monitor possible local movements at proposed LBI sites.

Calibration baselines for electronic distances were measured at 5 locations: Toronto, Belleville, London, Moncton and Montreal. The Belleville baseline is a new one, established this year.

Twenty-eight astronomical observations for latitude and longitude were made for geoid determination, 10 in Newfoundland, 11 in Quebec, 4 in Alberta, and 3 in Ontario. One first-order and two second-order Laplace azimuths were measured to provide azimuth control for the Mistassini-Manicouagan traverse in Quebec.

Inertial surveying was used to establish control for mapping and network densification in the 4 western provinces and Quebec. To support a study undertaken to determine the feasibility of using inertial surveying to determine variations in the intensity of gravity, inertial control was established on 111 points, gravity observations were made at 42 and precise levelled elevations were determined for 16 points. Gravity was also observed on 9 stations in the Ottawa Inertial Surveying Systems (ISS) Test Base. Satellite Doppler and other forms of mapping control were established in the Arctic.

About 5000 km of precise levelling was undertaken to extend and strengthen the primary vertical network. This included a joint Canada-U.S.A. relevening of 1200 km along the St. Lawrence River for recomputation of the International Great Lakes Datum (IGLD). Special order work (110 km) for earth crustal monitoring was completed west of Rivière-du-Loup, and at the Yellowknife and Whitehorse LBI sites. Automated recording of observed data was used on all 1983 levelling projects. A motorized levelling system was employed for 350 km of the IGLD work.

Water level transfers were made across Great Bear Lake between Fort Franklin and Hornby Bay, and across Great Slave Lake between Yellowknife and Hay River. Direct comparison will be made between the water level transfer across Great Slave Lake and bench marks already established at Yellowknife and Hay River.

Preparations for participation in the readjustment of North American horizontal networks continued. All primary data have been evaluated and filed. The final test adjustment, including both terrestrial and Doppler data has been completed. Observed data exchange with the United States National Geodetic Survey (USNGS) is complete and formats for the exchange of reduced normal equations and other continental adjustment data were finalized. The Helmert block adjustment software (program GHOST) was tested by comparison with the USNGS software. GHOST will be used for adjusting the Canadian blocks of the continental adjustment and for the integration of blocks of secondary data.

Area readjustments were computed for some 850 horizontal control stations. In addition, data for about 2200 stations were re-evaluated as part of the NAD83 project. About 500 vertical control stations were adjusted. A re-evaluation of vertical control totalling some 4800 stations in the Yukon, on Baffin Island and in northern Alberta was completed. About 1400 ISS and 130 Doppler stations were processed.

Progress continued on the automation, evaluation, and analysis of the geodetic vertical control data to be used in the North American Vertical Datum adjustment. Data automation was completed for a test net in Nova Scotia. The test net is being used in the development of analysis procedures and a portion of it was relevened one-way in the fall of 1983. Studies are being conducted on the effects of refraction and other factors which may influence the observed data. Computer files have been created of rod calibration data, instrument tests, equipment historical records, and bench mark records. Preliminary analysis has identified several areas where additional field work will be needed to support the redefinition of the network. About 40% of the existing precise levelling data has been compiled for transmittal to computer files and 25% of the total has been entered, corrected and stored in preparation for analysis.

The positional component of the National Geodetic Data Base is operational. The data base component for observed data is now being developed.

Three-dimensional network mathematical models were investigated for application in connecting LBI antennas to geodetic networks. Methods for optimally integrating geodetic networks and the corresponding statistical analysis were developed and tested.

An efficient computer program for the inversion of large, sparse, symmetric, positive definite matrices was developed to aid present efforts to readjust North American geodetic networks. Work also began to develop the application of two- and three-dimensional strain

analysis to geodetic networks.

Two types of commercially available GPS receiving equipment were tested in cooperation with the Earth Physics Branch (EPB), industry, and the University of New Brunswick (UNB). UNB completed development of GPS software under contract.

3. Earth Physics Branch, Gravity, Geothermics and Geodynamics Division

Optical astronomical (PZT) and satellite Doppler (TRANET I) monitoring of the earth's rotation continues from observatories near Ottawa and Calgary. Results are communicated daily to the DMAHTC Satellite Polar Monitoring Service in Washington, D.C., and weekly to the Bureau International de l'Heure in Paris and the International Polar Motion Service in Mizusawa, Japan, via the GE Mark III computer network. Since 19 September 1983, the observations have also been contributed to the MERIT campaign.

New software has been developed and installed on the HP 1000 mini-computer system to facilitate high precision reduction of astrometric data in compliance with Project MERIT standards. All 1983 PZT observations have been re-reduced using the new reference system in preparation for the mandatory adoption of the new system from 1 January 1984.

Satellite tracking instrumentation and software is being upgraded to produce TRANET II compatible data and facilitate positive offset tracking. The 1982 Doppler data set has been reduced using improved GERDOP software and precise satellite ephemerides supplied by DMAHTC.

Research and development of astronomical and satellite-based interferometry systems continued in cooperation with York University, University of Toronto, and Boojum Research Ltd. Geophysical LBI recording, playback and correlator hardware is being assembled and software for control and data processing is being developed for operational tests in 1984. Hardware assembly of a prototype GPS pseudorange measurement system is expected to be completed in spring 1984.

Continuous satellite Doppler tracking and precise dynamic positioning was provided for Operation CESAR. Additional data on meteorological parameters, local ice deformation and accuracy of the OMEGA and DECCA navigation systems in the high arctic have also been collected.

Preparation continued in 1983 for the arrival of NASA mobile LBI equipment at Whitehorse, Yellowknife, Penticton and the Algonquin Radio Observatory (ARO) in 1984. Precise geodetic networks have been established by the Geodetic Survey of Canada (GSC) at the three western sites for the monitoring of local crustal stability. This LBI experiment is a joint effort by EPB, GSC, Pacific Geoscience Centre, York University, and UNB.

4. National Research Council, Division Of Physics

The mathematical theory completed in 1982 for the calculation of pure astronomical refraction is being extended to applications in satellite geodesy.

Since 1 January 1972, national time services have been operated on atomic time with no frequency offset. The time disseminated, UTC, differs from atomic time, TAI, by an integral number of seconds, and is stepped by leap seconds to remain with 0.9 second of the astronomical time UT1. The value of DUT1, which is the difference between UT1 and UTC, is included in code in the broadcast of the NRC Canadian Time Service on CHU. A series of bulletins (TF-B) announce relevant changes, such as DUTI and leap seconds, several weeks in advance. Three new primary cesium standards, CsVI A, B, and C, have been built, and improve further the reliability and stability of the NRC time scale. Two satellite ground stations with 3 m antennas and 1 W power have been set up at the NRC laboratory for time transfers with low power CW tones, using the commercial satellites of Telesat Canada. Sub-nanosecond precision was achieved. The objective is to design an economical system for time transfer using commercial satellites.

5. Canadian Hydrographic Service

A network of water level gauging stations is operated along the shores of Canada's coastal and inland navigable waters by the Tides, Currents and Water Levels Sections of the various regions of CHS. The accumulation of long and continuous time series of water level data at these stations contributes to studies of sea level variations and vertical coastal movements, as well as to the establishment and control of vertical datums for levelling networks. Of particular interest at the present time is water level gauging for use in the re-evaluation of the IGLD.

Water level gauging of a more temporary nature is also carried out to provide mean sea level estimates for specific applications such as the GSC level lines which terminate along the arctic coastline. Temporary gauges are presently being operated at four sites in the arctic islands to determine mean sea level variations. This information will in turn be used to estimate variations in water mass transport through the islands.

Offshore tidal information is being gathered by moored deep-sea pressure gauges. The CHS continues to operate the International Hydrographic Organization Tidal Constituent Bank through the facilities of the Marine Environmental Data Service.

Continuation of the horizontal control adjustment program from NAD83 and the computation of LORAN-C lattice parameters particularly for the reconfiguration of the LORAN-C system in Newfoundland and Labrador waters and in the Gulf of St. Lawrence were the major activities in 1983.

Chartlets of observed Additional Secondary Factor were published in Radio Aids to Marine Navigation.

6. Bedford Institute of Oceanography, Canadian Hydrographic Service Atlantic Region

Sea tests of GPS made by Nortech Surveys (Canada) Inc. on BIO ships in 1982, using the slow-cycling STI 5010 receiver, showed agreement with Mini-Ranger positioning to about ± 25 m. In November 1983 the fast-cycling TI 4100 GPS receiver was tested against both Mini-Ranger and Syledis. Limited preliminary analysis shows that, given good satellite geometry, GPS just about matches the 10 m accuracy of Mini-Ranger and Syledis. Differential measurements were also made during this test.

Since the tests on UHF Syledis reported in 1982, CHS Central Region have used Syledis for positioning in the survey of the Belcher Is., Hudson Bay, with great success. Tests have shown that, given careful calibration and clear sites, the system produced range accuracy of better than ± 5 m.

The new Fox Harbour, Labrador, LORAN-C transmitter was commissioned on 31 December 1983, extending continuous Atlantic coast coverage to Hamilton Bank, Labrador. Its lattices will be calibrated in 1984.

A large data base of computed LORAN-C overland phase lags is currently being adjusted to calibration observations.

7. Memorial University of Newfoundland, Department of Earth Sciences

Tidal terms in Universal Time (UTI) have been shown to be influenced by ocean tides and the fluidity of the core and the modelling of these effects has now reached the level of accuracy (Merriam, 1983) where UTI observations can be used to constrain models of the possible frequency dependence of the mantle's Q. Observations of LAGEOS node residuals are currently being used to supply similar information at 1/2 year and 18.6 year periods.

Earth tide gravity observations from a world wide network have been used to test an earth tide theory based on a rotating ellipsoidal earth (Merriam, 1983). While the observations fit the theory quite well, it was determined that little confidence could be placed on that result.

The response of the mantle to tangential stresses is currently being studied. It is anticipated that this work will permit the separation of wind effects from earth strain signals, aid in understanding the processes which result in angular momentum exchange between the atmosphere and the earth and improve the modelling of strain fields due to ocean tide loading.

8. University of New Brunswick, Department of Surveying Engineering

Data collection of tilt and gravity variations at the UNB earth tide station has continued. In 1983 the station was upgraded by improving the instrumentation and recording system. Data presently being gathered are of much better quality than those previously obtainable. Recordings of temperature and pressure are also gathered for further investigations of the response of tilt and gravity to atmospheric variations. Further studies of the local behaviour of the lithosphere to ocean loading (Pagiatakis, 1982) will be carried out using the collected data.

A new combined solution for the geoid in Canada based on the usage of spheroidal Stoke's integration kernels yielded an accuracy of 50 cm (one sigma) in those parts of Canada where gravity data coverage is adequate. This accuracy deteriorates to about 140 cm in areas of poor gravity coverage, the average for Canada being about 70 cm.

Results of a study on complex crustal strain approximation have been published (Schneider, 1982).

Studies continued into applications of GPS to marine positioning (Wells et al., 1983; Grant and Wells, 1983; Mertikas, 1983) and to geodetic positioning (Chrzanowski et al., 1983; Delikaraoglou et al., 1983).

LORAN-C propagation model development continued (Wells and Davidson, 1983; Wells et al., 1983; 1983; Kolls and Wells, 1983).

A multidimensional cubic spline smoothing procedure was developed and successfully applied to the sequence of Transit positions from LOREX (Quek, 1983; 1983). Software for the microcomputer interfaced Transit receiving and processing system has been refined (Quek, 1983).

Work has been completed on the evaluation of mathematical models for gyrocompass behaviour (Christou, 1983). An evaluation of tidal water level transfer techniques for water boundary determination has been completed (Aboh, 1983).

Studies continued in the use of LBI in geodesy and geodynamics and in the measurement of the rotation of the earth (Langley et al., 1982; Robertson et al., 1983).

The least-squares spectral response technique was applied to SEASAT altimetry data in the eastern Mediterranean (Delikaraoglou, 1983). Work continues on the refinement of local variations of sea surface topography in the Maritimes.

Promising results have been obtained with a new navigation algorithm based on statistical-mechanical concepts. The development of this algorithm is continuing.

Work on deformation analysis continues, both in the interpretation of measurements in a microgeodetic network (Kavouras, 1982; Mbega, 1983; Tobin, 1983) and in the area of mining subsidence (Chrzanowski and Hart, 1983). In the latter area, surveying and photogrammetric measurements (Armenakis, 1983; Faig and Armenakis, 1983) are being combined with tilt measurements. A generalized approach (Chen, 1983; Chrzanowski et al., 1983) is being investigated as is the use of the finite element method (Chrzanowski et al., 1983). Work on subsidence prediction has started. Also underway is research on a modified form of trigonometric levelling. Tests of the technique indicate that first-order accuracy is achievable with a considerable saving in time (Chrzanowski, 1983).

9. Université Laval, Département de Géodésie et de Cartographie

Le programme de mesure de nivellement de précision s'est poursuivi à St. Hilarion, à l'observatoire géophysique de la Direction de la physique du globe. L'analyse des données recueillies depuis 1977 se poursuit. Un ensemble de 8 nouveaux repères répartis à moins d'un kilomètre autour du mini-réseau actuel situé sur un cercle de 40 mètres fera également l'objet de mesures périodiques (six mois).

Des travaux de métrologie reliés au nivellement géométrique ont été effectués à notre laboratoire de métrologie, sous la direction de J. Jobin. Un système interférométrique de calibrage de mire a été développé et est actuellement adapté à la technologie de pointe afin d'automatiser les pointes, ce qui permettra le calibrage de chacune des divisions des mires. Un système automatisé de calibration des semelles de mires pour en définir l'inclinaison et la déformation a également été développé. Un projet d'automatisation de la cueillette et de la réduction des données de nivellement de deuxième et troisième ordre (méthode à trois fils) est amorcé. Le projet sur le développement d'un inclinomètre pour l'étude de la stabilité des repères a été complété (Tachallait, 1983). Une étude sur les repères géodésiques de troisième et quatrième ordre a été complétée (Jalal, 1983).

Une étude sur les problèmes de contrôle d'orientation astronomique a été complétée (Sanchez et Santerre, 1983). Un projet sur l'utilisation de toutes les quantités observables pour la détermination de la latitude, de la longitude et de l'azimut astronomique est effectué par R.M. Sanchez qui conduit une étude sur l'extension de la formule de Schols.

Des travaux reliés au positionnement Doppler se sont poursuivis. Une étude des variations des résiduelles Doppler dans l'espace et dans le temps a été complétée (Gélinas, 1983). Un projet est en cours sur l'analyse et la généralisation du programme de traitement de données développé à l'Observatoire Royal de Belgique.

J.G. Leclerc a poursuivi ses travaux sur l'évaluation de la réfraction et ses effets sur le nivellement géométrique. Un projet a été amorcé sur la théorie géostatique de Matheron en vue d'étudier son application pour l'estimation des différentes variables de la géodésie physique. L'étude des méthodes interférométriques appliquées à la géodésie se continue.

10. York University, Department of Earth and Atmospheric Science

The geophysics group at York University continues to be active in the field of geophysical and geodetic applications of LBI. The focus of this activity is presently centered on the development of a new made-in-Canada LBI system for geodesy and geophysics. Work (with P. Camilleri and C. Parkinson) has begun on the development of a three baseline LBI correlator and data processor to be used with the LBI data acquisition and recording system being developed at the University of Toronto.

S. Wild is developing new software for LBI data reduction for geodesy and geodynamics using the new IAU J2000 earth motion model.

Work on the use of a satellite phase link for applications to geophysical LBI has recently been completed (Petrachenko, 1982; Knowles et al., 1982; Cannon et al., 1983). This work made use of the 12/14 GHz transponders on ANIK-B and involved co-workers from the U.S. Naval Research Labs, University of Toronto and Herzberg Institute of Astrophysics, NRC.

W.H. Cannon continues to serve along with other radio astronomers and geodesists/geophysicists on the Planning Committee of the Canadian Long Baseline Array (Cannon, 1983) and York University recently hosted a meeting of representatives from 12 Canadian universities, NRC, NSERC, EPB, and GSC to discuss the future management of the array as a consortium-operated national facility for astronomy and geophysics.

Workers at York University are participating in the NASA Crustal Dynamics Program under which LBI measurements will be made in Canada and the U.S. in 1984 using both mobile

and fixed radio observatories.

11. University of Toronto/Erindale College, Department of Survey Science

An investigation of the effect of misalignment of the reference ellipsoid on deflection components and geodetic azimuth was completed. Research in levelling was pursued along four lines: use of autocorrelation functions as a diagnostic tool in levelling; analysis of the levelling refraction experiment in southern California; study of the systematic effects in the Canadian levelling network; and development of the concept of height on a deforming earth. The software for the determination of azimuth from observations of the sun and Polaris was further refined. Work has been initiated on geodetic problems in developing countries (Wassef, 1983).

12. University of Manitoba, Department of Earth Sciences

The theoretical study of ocean and solid earth tidal coupling is being continued (Moon, 1983; 1983). The application of satellite altimeter data, originally tested over the Hudson Bay area, is now being extended to include the East China Sea and Persian Gulf region (Moon and Tang, 1983).

13. University of Calgary, Surveying Engineering Division

Research on the use of inertial technology in geodesy and surveying proceeded. A study of the assumptions underlying inertial adjustment models (Schwarz, 1983) and a unified approach to the treatment of filtered and unfiltered inertial data and a comparison of different empirical models (Schwarz, 1983) have been published. The use of precise azimuth data to control heading sensitivity in traverses has been analysed (Schwarz and Arden, 1983). A first study on optimal field procedures shows that current methods can be improved (Arden and Schwarz, 1983). The development of an integrated GPS-INS for precise offshore navigation has been done in conjunction with Nortech Surveys (Canada) Inc. (Wong and Schwarz, 1983; Schwarz et al., 1983). A tutorial introduction to Kalman filtering and optimal smoothing (Schwarz, 1983) and an appraisal of the impact of new high technology developments in surveying and geodesy (Schwarz, 1983) have been published.

Recent developments in gravity field approximation techniques have been reviewed (Schwarz, 1983) and a detailed report on results achieved in the White Sands Test Area by a number of international research groups has been published (Schwarz, 1983).

A software package (CANDSN) for the design, adjustment and analysis of surveying networks using interactive computer graphics is complete (Mephram, 1983).

Work has been completed also on the development of a methodology for three-dimensional monitoring networks using free network constraints, data snooping, variance component analysis, S-transformations, and scaled distances. A high-precision photogrammetric deformation monitoring system has also been developed and implemented for the detection of subcentimetre rock movements on the crown of the Frank slide, Turtle Mountain, Alberta (Fraser, 1983). Phase two of the experimental EDM monitoring of fractures on Turtle Mountain has commenced using a new distance differencing approach which does not rely on a conventional geodetic network. Results of the theoretical study conducted in phase one indicate that an optimum sensitivity, at the 95% confidence level, of 6.5 mm can be achieved with monitoring stations approximately 4 km from the fracture zone. Work has continued on the experimental determination of systematic effects in precise levelling: E.G. Anderson reports vertical movements of levelling rods with an exponential displacement/time function which can amount to 0.1 mm displacement over durations extending to as much as 10 minutes.

During the summer of 1983, the Kananaskis Test Network area was covered with aerial photography taken with a Wild RC-10 camera at an approximate flying height of 10,000 m. The CCRS aircraft also carried a Litton LTN-051 INS system, a laser profiler and a Multi-Spectral Scanner. The photogrammetric measurements and other sensor data are currently being processed. The extension of SPACE-M to accept auxiliary airborne sensor data from statorscope, INS, GPS and other sensors has been completed in its first phase.

The formulation in SPACE-M has also been extended to accept auxiliary terrestrial data from local survey nets with unknown translation and/or orientation and/or scale biases with respect to the geodetic datum. A new SPACE-M User's Guide has been published to document these options with auxiliary data (Blais and Chapman, 1983).

The investigation of Givens transformations for the solution of least-squares estimation problems has been continued (Blais, 1983). The survey network applications are discussed by Teskey (1983). Kriging and related estimation methods using generalized covariance functions have also been further studied from different theoretical and practical viewpoints (Blais, 1982; Blais and Vanicek, 1983). Research work has also been done on the duality relationships in linear least-squares estimation (Blais, 1983).

Research in various areas of geodynamics and tectonophysics is also being continued from work done at the Australian National University (Nakiboglu, 1982; 1982; Nakiboglu et al., 1982; 1983; Nakiboglu and Isikara, 1982; Nakiboglu and Lambeck, 1982; Nakiboglu and Torenberg, 1982; Lambeck and Nakiboglu, 1983).

14. Nortech Surveys (Canada) Inc.

Research and development related to the use of GPS for land, marine and air positioning was pursued using Texas Instruments 4100 multiplexing GPS receivers delivered to Nortech in mid-1983. Routine offshore rig positioning and navigation for seismic purposes were carried out with these instruments. An airborne differential GPS navigation test was carried out for CHS in October 1983 to evaluate accuracy obtainable for the positioning of the CHS airborne LIDAR bathymetric system. Marine differential GPS navigation was tested off Nova Scotia in November 1983 in cooperation with BIO and UNB. Also tested during the same period in cooperation with BIO and the University of Calgary was the integration of the TI 4100 GPS receiver with Nortech's FILS inertial system in order to increase the relative accuracy and extend the useful period of unaided GPS navigation.

Analysis of marine tests carried out during 1982 with Nortech's STI 5010 slow-switching sequential GPS receiver and FILS inertial system was completed.

15. Bibliography

- Aboh, E.A. 1983. Evaluation of tidal water level transfer techniques for land surveying. M.Sc.E. thesis. Department of Surveying Engineering, University of New Brunswick, Fredericton.
- Arden, D.A.G. and Schwarz, K.P. 1983. Optimizing field procedures for inertial networks. Proceedings of the IAG Symposia at the 18th General Assembly, Hamburg, August.
- Armenakis, C. 1983. Subsidence determination by aerial photogrammetry. M.Sc.E. thesis. Department of Surveying Engineering Technical Report No. 93, University of New Brunswick, Fredericton.
- Blais, J.A.R. 1982. Synthesis of Kriging estimation methods. Manuscripta Geodaetica, 7(4), 325-352.
- Blais, J.A.R. 1983. Quality considerations in linear least-squares estimation. Manuscripta Geodaetica, 8(4), 199-213.
- Blais, J.A.R. and Chapman, M.A. 1983. User's guide: Program SPACE-M (CDC version). Division of Surveying Engineering Publication No. 50006, University of Calgary, Calgary.
- Blais, J.A.R. and Vanicek, P. 1983. Overview of advanced estimation methods in surveying. Papers for the Canadian Institute of Surveying Adjustment and Analysis Seminars, Ed. E.J. Krakiwsky, CIS, Ottawa, 308-350.

- Cannon, W.H. 1983. The Canadian Long Baseline Array: CLBA. International Coordination of Space Techniques for Geodesy and Geodynamics, 5, 160-166.
- Chen, Y.Q. 1983. Analysis of deformation surveys--a generalized method. Ph.D. dissertation. Department of Surveying Engineering Technical Report No. 94, University of New Brunswick, Fredericton.
- Christou, N.T. 1983. Evaluation of mathematical models for gyrocompass behavior: error modelling and applications. M.Sc.E. thesis. Department of Surveying Engineering Technical Report No. 100, University of New Brunswick, Fredericton.
- Chrzanowski, A. 1983. Economization of vertical control surveys in hilly areas by using modified trigonometric levelling. Technical Papers of the 43rd Annual Meeting of the American Congress on Surveying and Mapping, Washington, D.C., March, 635-644.
- Chrzanowski, A. and Hart, F. 1983. Role of the surveyor in North America in studies of ground movements in mining areas. Technical Papers of the 43rd Annual Meeting of the American Congress on Surveying and Mapping, Washington, D.C., March, 262-271.
- Chrzanowski, A., Chen, Y.Q. and Secord, J. 1983. On the strain analysis of tectonic movements using fault crossing geodetic surveys. *Tectonophysics*, 97, 297-315.
- Chrzanowski, A., Chen, Y.Q. and Szostak-Chrzanowski, A. 1983. Use of the finite element method in the design and analysis of deformation measurements. Proceedings of the Fédération Internationale des Géomètres Congress XVII, Sofia, Bulgaria, June, Paper No. 611.1.
- Chrzanowski, A., Langley, R.B., Wells, D.E. and McLaughlin, J.D. 1983. A forecast of the impact of GPS on surveying. Technical Papers of the 43rd Annual Meeting of the American Congress on Surveying and Mapping, Washington, D.C., March, 625-634.
- Costain, C.C., Daams, H., Boulanger, J.-S. and Douglas, R.J. 1983. Time dissemination from the National Research Council of Canada. Proceedings of the 37th Annual Symposium on Frequency Control.
- Delikaraoglou, D. 1983. Adjustment and filtering of SEASAT altimetry data with the least squares response technique. Proceedings of the IUGG Symposium on Geodetic Features of the Ocean Surface and their Implications, Hamburg, August.
- Faig, W. and Armenakis, C. 1983. Photogrammetric subsidence monitoring in mountainous terrain. Proceedings of Fédération Internationale des Géomètres Congress XVII, Sofia, Bulgaria, June, Paper No. 612.4.
- Fraser, C.S. 1983. Photogrammetric monitoring of Turtle Mountain: a feasibility study. *Photogrammetric Engineering and Remote Sensing*, 49(11), 1551-1559.
- Gagnon, P.A. et Jobin, J. 1983. Un cas particulier de perçage de tunnel. *Le Géomètre Canadien*, 37(2), 61-69.
- Gélinas, D. 1983. Étude des résiduelles Doppler dans l'espace et dans le temps. Thèse de maîtrise. Département de Géodésie et de Cartographie, Université Laval, Québec.
- Grant, S.T. and Ruxton, M.A. 1983. An integrated inshore and offshore navigation system. Proceedings of Fédération Internationale des Géomètres Congress XVII, Sofia, Bulgaria, June, Paper No. 407.1.
- Gray, D.H. 1983. Chart latticing - past, present and future. Proceedings Centennial Conference Canadian Hydrographic Service, Ottawa, April, 62-68.

- Jalal, A. 1983. Matérialisation du réseau géodésique du quatrième ordre. Thèse de maîtrise. Département de Géodésie et de Cartographie, Université Laval, Québec.
- Kavouras, M. 1982. Error detection and reliability in geodetic networks. M.Sc.E. thesis. Department of Surveying Engineering, University of New Brunswick, Fredericton.
- Knowles, S.H., Waltman, W.B., Yen, J.L., Galt, J., Fort, D.N., Cannon, W.H., Davidson, D., Petrachenko, W.T. and Popelar, J. 1982. A phase coherent link via synchronous satellite developed for very long baseline interferometry. Radio Science, 17, 1661-1670.
- Kolls, F. and Wells, D.E. 1983. The use of LORAN-C in the Canadian fishing fleet. Proceedings Centennial Conference Canadian Hydrographic Service, Ottawa, April, 196-203.
- Kouba, J. 1983. An efficient short arc orbit computation. Bulletin Géodésique, 57, 138-145.
- Kouba, J. 1983. A review of geodetic and geodynamic satellite Doppler positioning. Rev. Geophys. Space Phys., 21(1), 27-40.
- Ku, L.F. 1983. The computation of tides from GEOS-3 altimeter data. Ph.D. dissertation. Dalhousie University, Halifax.
- Lambeck, K. and Nakiboglu, S.M. 1983. Long-period love numbers and their frequency dependence due to dispersion effects. Geophys. Res. Lett., 10, 857-860.
- Langley, R.B., King, R.W., Morgan, P.J. and Shapiro, I.I. 1982. Earth rotation by lunar distances: MIT report. Project MERIT: Report of the Short Campaign and Grasse Workshop with observations on earth-rotation during 1980 August-October. G.A. Wilkins and M. Feissel (Editors). Royal Greenwich Observatory, Herstmonceux, 104-105.
- Mbega, A.R. 1983. A comparison of methods of crustal strain computations from repeated geodetic measurements in an active fault zone. M.Sc.E. thesis. Department of Surveying Engineering, University of New Brunswick, Fredericton.
- Mephram, M.P.S. 1983. Computer aided survey network design. M.Sc. thesis. Division of Surveying Engineering, University of Calgary, Calgary.
- Merriam, J.B. 1983. Variations in the Earth rotation. Sci. Prog., 68, 387-401.
- Merriam, J.B. 1983. Inertial and ellipsoidal Earth effects on gravity tide observations. Proceedings of the Ninth International Symposium on Earth Tides. E. Schweizerbart'sche Verlagsbuchhandlung, Stuttgart, 137-144.
- Merry, C.L. and Vanicek, P. 1983. Investigation of local variation of sea surface topography. Marine Geodesy, 7(1-4), 101-126.
- Mertikas, S.P. 1983. Differential Global Positioning System navigation: a geometrical analysis. M.Sc.E. thesis. Department of Surveying Engineering, University of New Brunswick, Fredericton.
- Moon, W. 1983. Evolution of variational type finite element method in whole earth geodynamics. Congressus Numerantium, 38, 183-201.
- Moon, W. 1983. Solution of the whole earth geodynamic equation in a slightly elliptical coordinate system. Computer Physics Comm., 28, 219-227.
- Moon, W. and Tang, R. 1983. Transient sea surface height variation and the SEASAT altimeter data application. Proceedings of the IUGG Interdisciplinary Symposium, Hamburg, 161.

- Mungall, A.G. and Costain, C.C. 1983. Performance of the four NRC long-beam primary cesium clocks, CsV, CsVIA, CsVIB, and CsVIC. IEEE Trans. on Instr. and Meas., IM-32(1), 224-227.
- Nakiboglu, S.M. 1982. Contemporary changes in sea level and gravity around Australia. Aust. J. Geod. Photo. Surv., 36, 15-26.
- Nakiboglu, S.M. 1982. Hydrostatic theory of the Earth and its mechanical implications. Phys. Earth Planet. Inter., 28, 302-311.
- Nakiboglu, S.M. and Isikara, A.M. 1982. Analysis of stress and strain around a transform fault. Multidisciplinary Approach to Earthquake Prediction, A.M. Isikara and A. Vogel (Editors). Friedr. Vieweg & Sohn, Wiesbaden, 523-538.
- Nakiboglu, S.M. and Lambeck, K. 1982. A study of the Earth's response to surface loading with application to Lake Bonneville. Geophys. J. R. astr. Soc., 70, 577-620.
- Nakiboglu, S.M. and Torenberg, M. 1982. Secular changes in the Earth's gravity due to surface loads. Aust. J. Geod. Photo. Surv., 36, 1-13.
- Nakiboglu, S.M., Clerici, E. and Isikara, A.M. 1982. Detection of crustal motion by repeated geometrical observations. Multidisciplinary Approach to Earthquake Prediction, A.M. Isikara and A. Vogel (Editors), Friedr. Vieweg & Sohn, Wiesbaden, 307-314.
- Nakiboglu, S.M., Lambeck, K. and Aharon, P. 1983. Sea level changes in the Pacific: Implications with respect to deglaciation history and local tectonics. Tectonophysics, 91, 335-358.
- Pagiatakis, S.D. 1982. Ocean tide loading, body tide and polar motion effects on very long baseline interferometry. Department of Surveying Engineering Technical Report No. 92, University of New Brunswick, Fredericton.
- Petrachenko, W.T. 1982. Evaluation of a satellite phase link for use in long baseline radio interferometry. Ph.D. dissertation. York University, Toronto.
- Popelar, J. and Kouba, J. 1983. Satellite Doppler determination of differential sea ice motion in the vicinity of the North Pole. Marine Geodesy, 7(1-4), 171-198.
- Quek, S.H. 1983. Spline smoothing of two-dimensional data series with precision estimation, applied to satellite navigation. M.Sc.E. thesis. Department of Surveying Engineering Technical Report No. 101, University of New Brunswick, Fredericton.
- Quek, S.H. 1983. LOREX-79 ice station positions and velocities using two-dimensional cubic spline approximation. Department of Surveying Engineering Technical Report No. 97, University of New Brunswick, Fredericton.
- Quek, S.H. 1983. Programs SATNAV and LINK, descriptions and user's guide. Department of Surveying Engineering Technical Report No. 98, University of New Brunswick, Fredericton.
- Robertson, D.S., Carter, W.E., Eanes, R.J., Schutz, B.E., Tapley, B.D., King, R.W., Langley, R.B., Morgan, P.J. and Shapiro, I.I. 1983. Comparison of Earth rotation as inferred from radio interferometric, laser ranging and astrometric observations. Nature, 302, 509-511.
- Saastamoinen, J. 1983. Contributions to the theory of atmospheric refraction II. No. 1, July, NRCC 22431.
- Sanchez, R.N. et Santerre, R. 1983. Analyse de certaines déterminations astronomiques appliquées au contrôle d'orientation. Le Géomètre Canadien, 37(2), 71-78.

- Schneider, D. 1982. Complex crustal strain approximation. Department of Surveying Engineering Technical Report No. 91, University of New Brunswick, Fredericton.
- Schwarz, K.P. 1983. Inertial adjustment models - A study of some underlying assumptions. Geodesy in Transition, K.P. Schwarz and G. Lachapelle (Editors), Division of Surveying Engineering Publication No. 60002, University of Calgary, Calgary, 327-345.
- Schwarz, K.P. 1983. A unified approach to post mission processing of inertial data. Proceedings of the IAG Symposia at the 18th General Assembly, Hamburg, August.
- Schwarz, K.P. 1983. Kalman filtering and optimal smoothing. Papers for the Canadian Institute of Surveying Adjustment and Analysis Seminars, E.J. Krakiwsky (Editor), CIS, Ottawa, 230-264.
- Schwarz, K.P. 1983. New instruments, new methods - Future prospects. Proceedings of Fédération Internationale des Géomètres Congress XVII, Sofia, Bulgaria, June, Paper No. 501.3.
- Schwarz, K.P. 1983. Report of the Special Study Group No. 4.70 of the IAG. Comptes Rendues of the 18th General Assembly of the IUGG/IAG, Hamburg, August.
- Schwarz, K.P. (Editor) 1983. Techniques to predict gravity anomalies and deflections of the vertical in mountainous areas. Division of Surveying Engineering Publication No. 30004, University of Calgary, Calgary.
- Schwarz, K.P. and Arden, D.A.G. 1983. The use of precise azimuth data in inertial surveying. Proceedings of Fédération Internationale des Géomètres Congress XVII, Sofia, Bulgaria, June, Paper No. 606.3.
- Schwarz, K.P., Lachapelle, G. and Mainville, A. 1983. Gravity and deflection estimation using different data types. In: Techniques to Predict Gravity Anomalies and Deflections of the Vertical in Mountainous Areas, K.P. Schwarz (Editor), Division of Surveying Engineering Publication No. 30004, University of Calgary, Calgary.
- Tachallait, T. 1983. Conception et construction d'un inclinomètre et développement d'une méthodologie pour l'étude de la stabilité des structures et des repères géodésiques de quatrième ordre. Thèse de maîtrise. Département de Géodésie et de Cartographie, Université Laval, Québec.
- Teskey, T. 1983. Least-squares survey computations using Givens transformation. M.Sc. thesis. Division of Surveying Engineering, University of Calgary, Calgary.
- Tobin, P. 1983. Examination of deformation measurements using invariant functions of displacements. M.Sc.E. thesis. Department of Surveying Engineering, University of New Brunswick, Fredericton.
- Vanicek, P. 1983. Transit satellite positioning. Lecture notes for UNDP Graduate Course in Geodesy for East Africa, Regional Centre for Services in Surveying, Mapping and Remote Sensing, Nairobi, July.
- Wassef, A.M. 1983. Who's making the dream come true? Proceedings of the IAG Symposium on Strategies for Solving Geodetic Problems in Developing Countries, Hamburg, FRG, August.
- Wells, D. and Davidson, D.A. 1983. LORAN-C phaselag investigation. Department of Surveying Engineering Technical Report No. 96, University of New Brunswick, Fredericton.
- Wells, D.E., Lachapelle, G., Eaton, R.M. and Mertikas, S. 1983. The impact of GPS on hydrography. Proceedings Centennial Conference Canadian Hydrographic Service, Ottawa, April, 69-77.

Wells, D.E., Nickerson, B.G. and Rennie, J.C. 1983. Differential LORAN-C for buoy position checking. Proceedings of the Wild Goose Association Technical Symposium, Washington, October.

Wells, D.E. Nickerson, B.G. and Davidson, D. 1983. Differential LORAN-C for buoy position checking. Department of Surveying Engineering Technical Report No. 99, University of New Brunswick, Fredericton.

Wong, R.V.C. and Schwarz, K.P. 1983. Dynamic positioning with an integrated GPS-INS: Formulae and baseline tests. Division of Surveying Engineering Technical Report No. 30003, University of Calgary, Calgary.

I (B) GRAVITY

Compiled by: M.D. Thomas

1. Summary
2. Earth Physics Branch
3. Atlantic Geoscience Centre
4. Carleton University
5. Ecole Polytechnique
6. Memorial University of Newfoundland
7. New Brunswick Department of Natural Resources
and University of New Brunswick
8. Nova Scotia Research Foundation Corporation
9. Ontario Ministry of Natural Resources
10. Université Laval
11. University of British Columbia
12. University of Calgary
13. University of Western Ontario
14. Bibliography

1. Summary

The main effort in the National Gravity Mapping Program in 1983 took place in offshore areas. Earth Physics Branch carried out major surveys in the Pacific Ocean southwest of Vancouver Island, over the continental shelf off Ellesmere Island and over the eastern half of the Alpha Ridge. Atlantic Geoscience Centre conducted surveys in Jones Sound and over the west Scotian shelf/margin.

There was also considerable activity in the form of surveys directed at investigating specific geological targets. These ranged in scale from crustal sections (Quebec Appalachians, Central Metasedimentary Belt, Avalon Peninsula and offshore) down to salt structures (New Brunswick) and local ground ice (Calgary Frost Heave Site). Granitic intrusions were a common target for investigation (Ackley Batholith, Araisné Lake Granite, Croll Lake Stock, Weslemkoon Granite). Sedimentary basins (St. George's Basin, Sydney Coal Basin) were also investigated. Interpretations of the data acquired by these surveys are in progress or are planned.

Gravity interpretation of data obtained in previous surveys has been completed for a variety of geological structures: a graben in Richmond Gulf; mafic bodies in the Grenville Province; greenstones and granites of the Abitibi Belt; Deer Lake Carboniferous basin; regional structure of the Avalon Peninsula and offshore areas. Gravity modelling has been applied to studies of thermomechanical events related to continental margin rifting. Interpretations are in progress of anomalies along the Kapuskasing structure and in the Sudbury district.

Microgravimeter surveys continued to be used to monitor crustal movements in the Charlevoix region and Vancouver Island. In the field of absolute gravimetry, studies are being carried out to determine temporal variations of gravity of environmental origin.

In the area of mathematical-oriented research, new developments have been made in processing marine potential field data, the production of contoured and coloured maps, and the calculation of terrain corrections. A method to compute the gravity effect of bodies with circular symmetry at points off the axis of symmetry has been developed and improved formulae for the computation of theoretical gravity are being investigated.

Research on instrumentation has been directed at further testing of the KSS-30 sea gravimeter and evaluating satellite positioning systems.

2. Earth Physics Branch (EPB)

(a) Gravity Standards (R.K. McConnell)

A gravimeter calibration line was established in British Columbia to facilitate the calibration of marine gravimeters. The line extends from Manning Park in the south to Hudson's Hope in the north and has a range of 896 mGal. The Canadian long-range calibration line (Calgary, Alberta to Inuvik, N.W.T.) was re-observed in July.

(b) Gravity Data Base (D.B. Hearty)

The Gravity Data Centre processed 185 external requests involving open file maps, manuscript maps, digital gravity data, software packages and earth tide values. An open file digital terrain file for a large sector of the Cordillera has also been released. It contains spot elevations and water depths distributed an average distance of 1 km apart. Data may be requested by quadrangle (15' latitude by 30' longitude, containing approximately 1,000 points).

(c) Gravity Map Production (L.A. Warren, J.F. Halpenny, D. Nagy)

Three open file gravity maps were published: Avalon Peninsula, British Columbia Coast, and Alpha Ridge and Ellesmere Shelf. A polar gravity map (north of 64° N latitude), scale 1:6,000,000, is being compiled from 60 larger scale maps (1:1,000,000). Software development has been directed at the production of contoured maps. In addition an assessment has been made of the APPLICON plotter for producing contoured potential field data and images of the data for 3-D viewing.

(d) Absolute Gravimetry (L.M.A. Jeudy)

In the field of absolute determination of gravity from free fall measurements an improved data analysis method using statistical tests is being developed to eliminate the systematic effect due to low frequency vibrations such as microseisms. One order of magnitude better in precision is expected and the accuracy should also be improved. In addition, published absolute determinations of gravity at Sèvres (Bureau International des Poids et Mesures) are being analyzed and correlated with atmospheric pressure, latitude variations due to polar motion, variations in water level of the River Seine and changes in the length of the day. The objective is to determine temporal variations of gravity of environmental origin. In addition to the well-known local atmospheric pressure correlation, a significant dependence of gravity on length of day appears in the semi-annual frequency band; this phenomenon is being investigated.

(e) Gravity Surveys (J.B. Boyd)

(i) Pacific Ocean (R.P. Riddihough, R.V. Cooper, D. Seeman)

A total of 13,500 line kilometres of gravity data was observed on board CSS PARIZEAU during multiparameter surveys in an area southwest of Vancouver Island. Line spacing, controlled by Loran-C navigation, varied from 5 to 10 km. A LaCoste and Romberg straight line meter (SL-1) was used to acquire the data. The survey area is contained by latitudes 48° and 50° N and extends westward from approximately 90 km west of the entrance to Juan de Fuca Strait out to the limit of the Economic Zone, 370 km from the coast.

Two co-operative SEABEAM bathymetry cruises on U.S. Survey Ship SURVEYOR were carried out with National Ocean Surveys over the Juan de Fuca Ridge. Areas covered include the northern part of the ridge (north of 48°N), the Sovanco Fracture Zone, the Explorer Ridge and Tuzo Wilson Knolls. A series of 1:50,000 maps showing bathymetric contours at 10 m intervals is in preparation and will be issued jointly with NOS in 1984.

SeaMARC II surveys (broad swath digital side scan) over the Tuzo Wilson and Dellwood knolls and the northern part of the Juan de Fuca Ridge were carried out, under contract, by the University of Hawaii. These surveys clearly show the complex nature of the seafloor and will be made available in conjunction with the SEABEAM surveys.

(ii) Cordillera (D. Seeman, P.J. Winter)

EPB in cooperation with the Surveys and Mapping Branch, completed the recovery of gravity station positions previously occupied and observed new gravity readings as needed in the Rocky Mountains between latitudes 52° and 54° N and longitudes 118° and 121° W. An inertial navigation system was used and about 250 stations were occupied.

The project to establish gravity observations at Geodetic Bench Marks continued during the year. About 580 measurements along logging and main roads in the eastern interior of British Columbia were observed by contractor personnel. The station spacing averaged 3 km.

A regional gravity survey, under contract, was carried out in northern British Columbia in a zone (latitude 58° to latitude 60° N) immediately south of the B.C./Yukon border that stretched from longitude 120° W westward to longitude 132° W. Approximately 825 stations, spaced about 12 km apart, were observed.

A small regional gravity survey was carried out by EPB personnel in Willmore Wilderness Park north of Jasper, Alberta to complete a survey initiated in 1982. Forty-five stations were observed using helicopter transport.

(iii) Grenville Province, Ontario (M.D. Thomas)

Gravity surveys along profiles crossing the western boundary and margin of the Central Metasedimentary Belt, Grenville Province, Ontario realized a total of 223 stations; station spacing ranged generally from 2 to 4 km. Structural interpretations of the boundary region and of the Weslemkoon Granite are planned.

(iv) Appalachians, Quebec (M.D. Thomas, M.R.L Laverdure)

In the Quebec Appalachians 205 gravity observations were made in conjunction with a COCORP Extended Research Project involving a VIBROSEIS seismic reflection profile that extends some 25 km into Quebec from northwestern Maine. Stations were spaced approximately 2 km apart along the Quebec part of the profile and along an earlier Ministry of Energy and Resources, Quebec, VIBROSEIS line that extends from near the U.S. border northwestward to the St. Lawrence River. Many stations were positioned to better define the negative gravity anomaly associated with the Araignées Lake Granite that straddles the border near the new seismic line.

(v) Calgary Frost Heave Site (J.A. Pilon, M.D. Thomas)

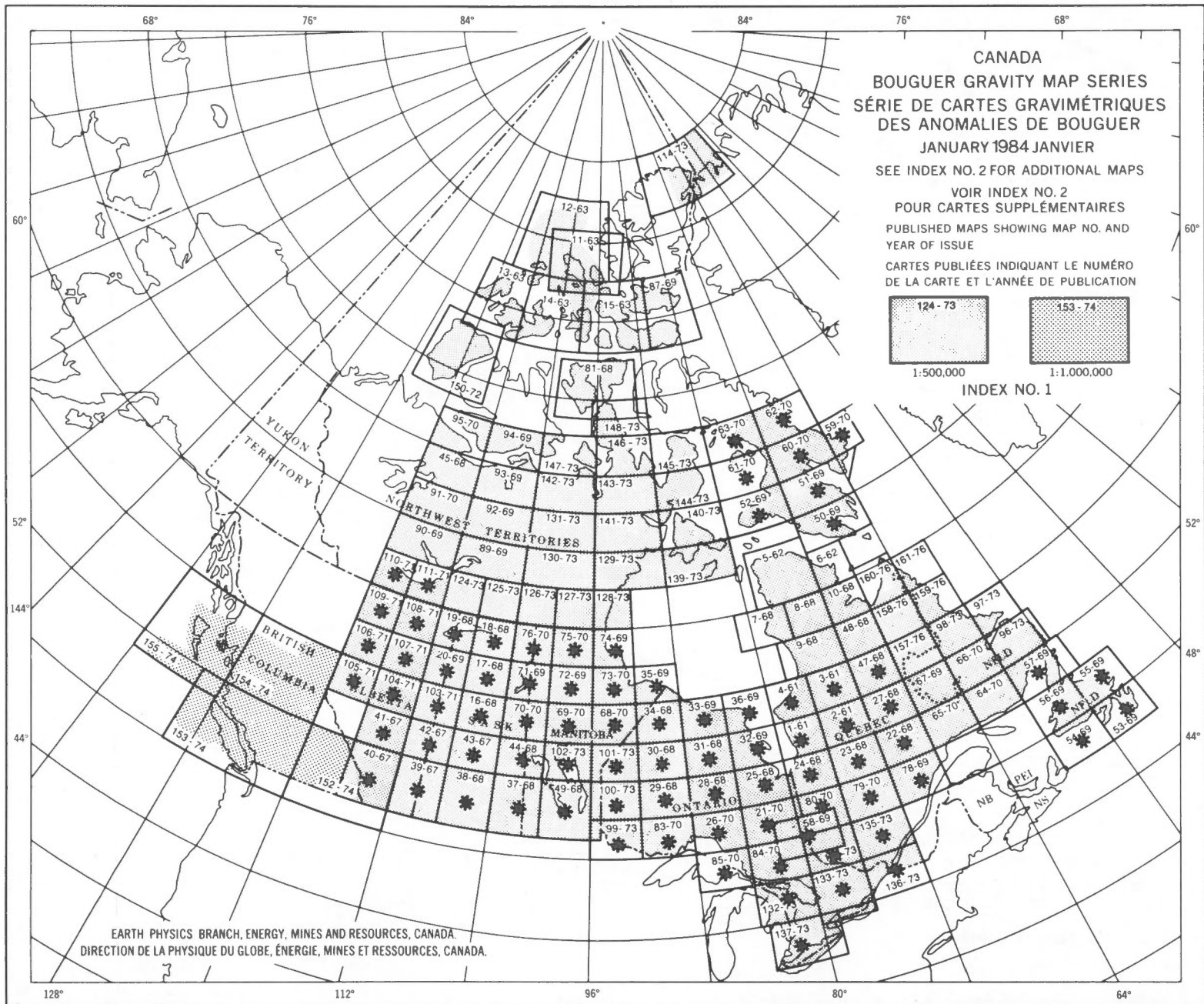
Standard detailed gravity surveys (LaCoste and Romberg G meter) and microgravity surveys (D meter) were conducted at the Calgary Frost Heave Site (operated by Foothills Pipe Lines (Yukon) Ltd.). The microgravity surveys involved vertical gradient measurements using a specially constructed tripod. About 430 readings were made with station spacing along profiles being 0.5 or 1 m. The results of the surveys will be applied to the problem of detecting ground ice.

(vi) Arctic Ocean (J.R. Weber, J.B. Boyd, D.W. Halliday)

During the Canadian Experiment to Study the Alpha Ridge (CESAR), EPB in cooperation with the Canadian Hydrographic Service established 1,307 bathymetric and gravity stations: 861 stations over the Ellesmere Island continental shelf from the coastline to the 1,000 m isobath at a 6 km grid interval, and 446 stations over the Alpha Ridge from the 1,000 m isobath seawards at a grid interval varying from 10 to 20 km. In addition 303 stations were established along the drift track of Ice Station CESAR.

(f) Microgravimetry (H. Dragert, A. Lambert, J.O. Liard)

Semi-annual resurveys of precise gravity networks in the seismically active areas of Charlevoix, Quebec and Vancouver Island, British Columbia continued. The surveys at Charlevoix were extended to include several stations southeast of the St. Lawrence River.

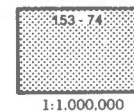
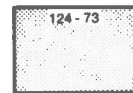


CANADA
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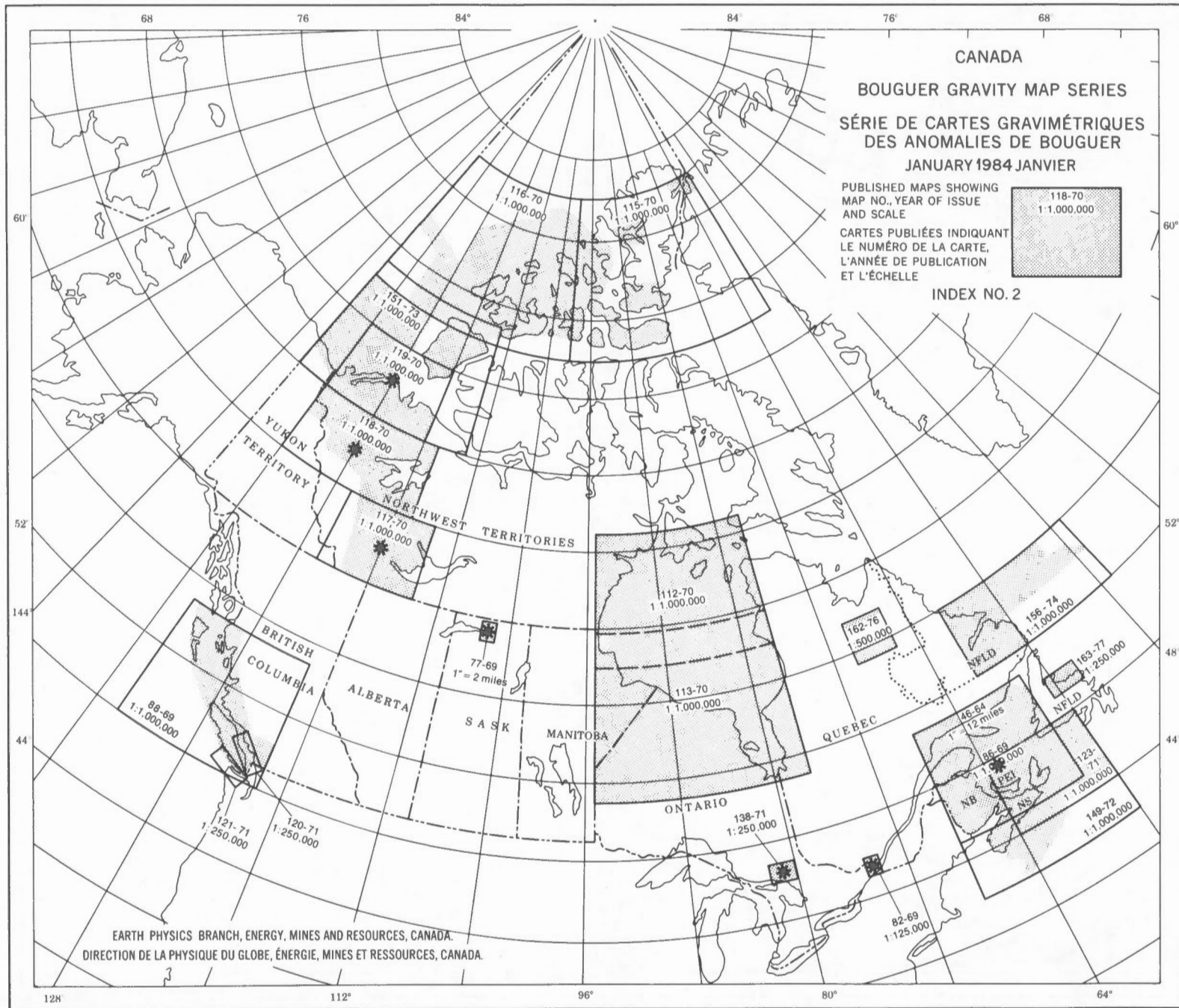


INDEX NO. 1

EARTH PHYSICS BRANCH, ENERGY, MINES AND RESOURCES, CANADA.
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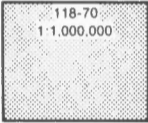
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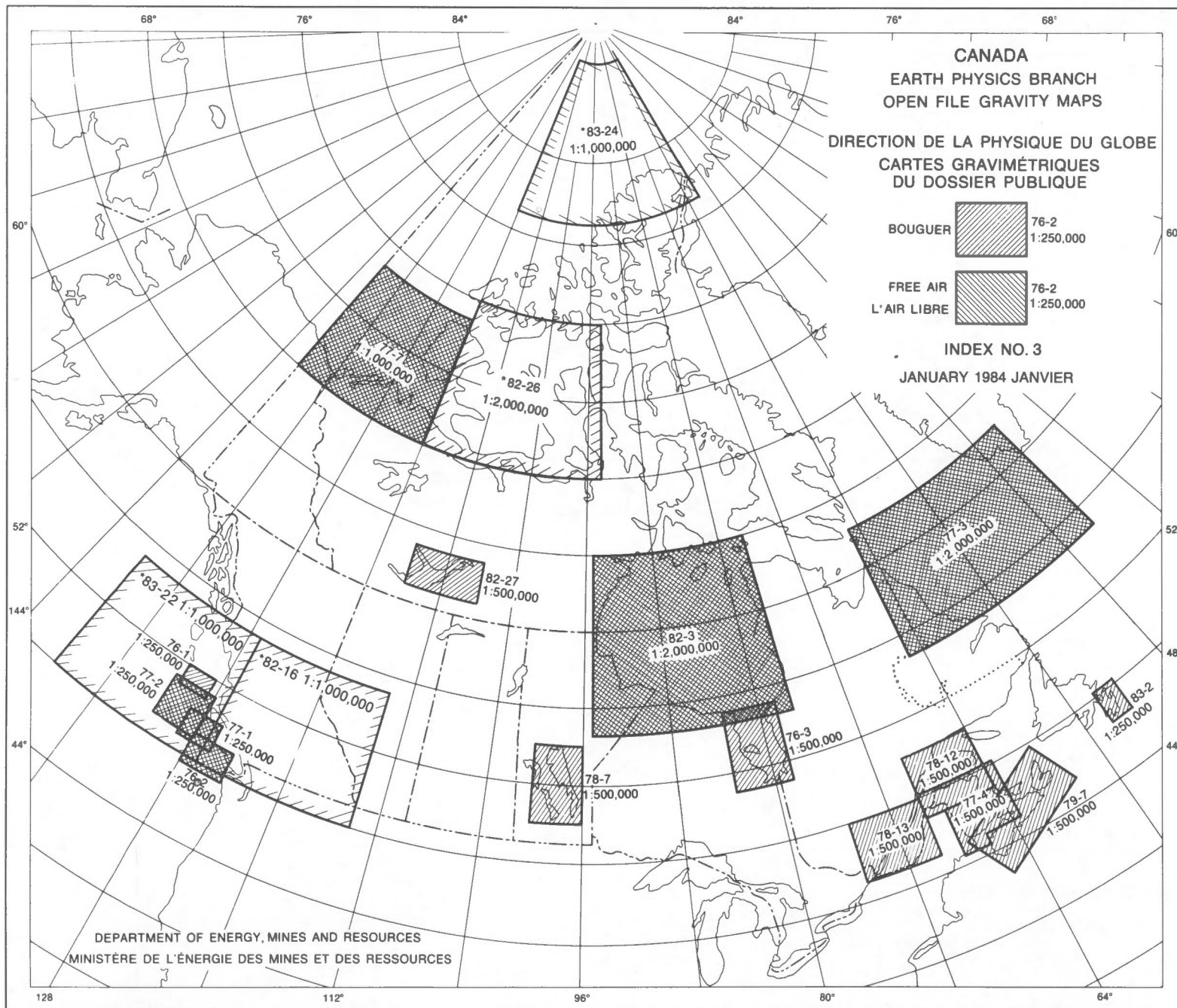


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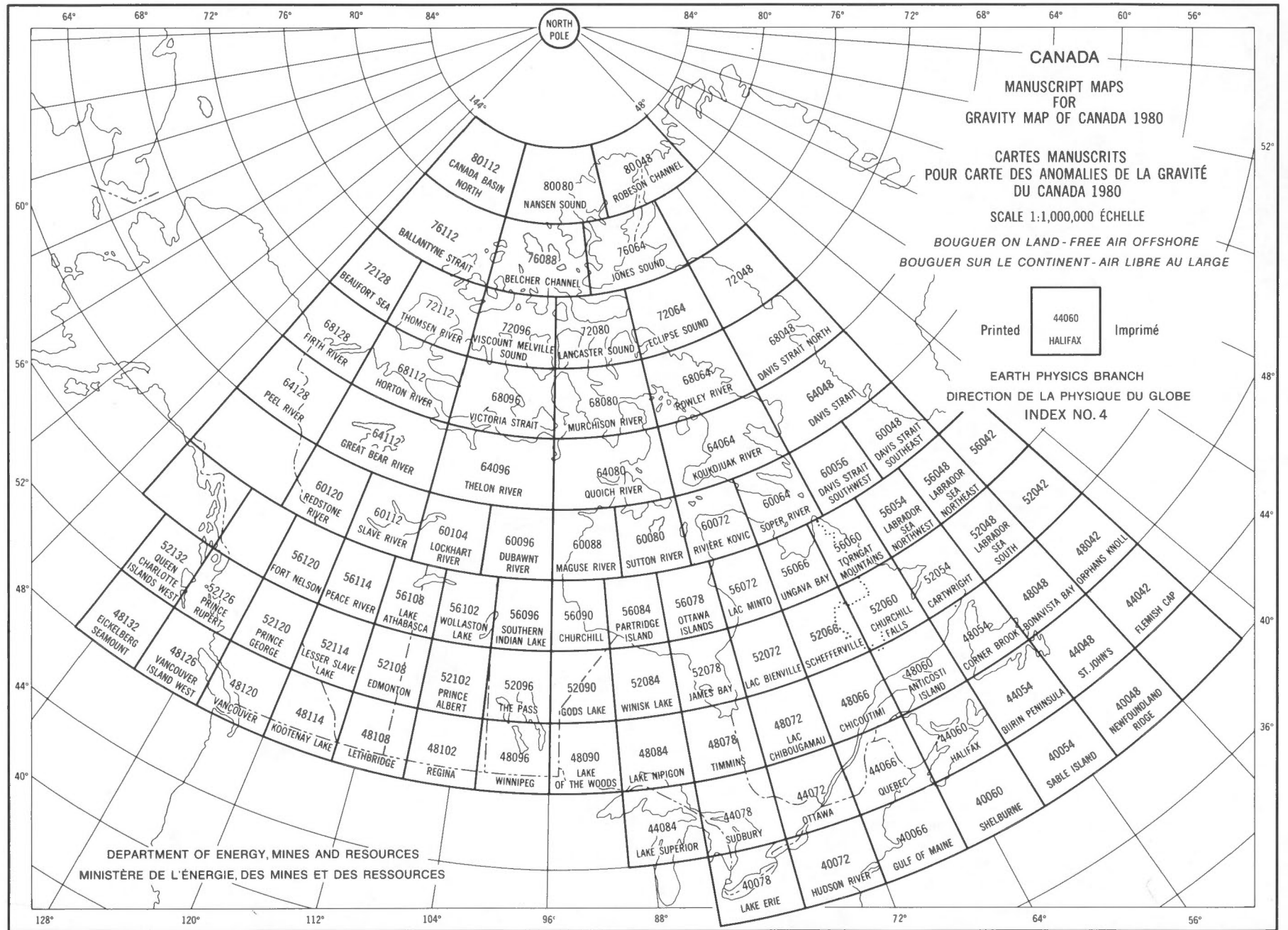
EARTH PHYSICS BRANCH, ENERGY, MINES AND RESOURCES, CANADA.
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BOUGUER ON LAND — FREE AIR OFFSHORE
 BOUGUER SUR LE CONTINENT — AIR LIBRE AU LARGE



EPB participated in an international calibration experiment in West Germany in which thirteen LaCoste and Romberg model D gravimeters were intercompared. The results are being analyzed by EPB and by the Institut für Physikalische Geodäsie. One of the purposes of the experiment is to evaluate the suitability of these gravimeters for crustal deformation studies.

The monitoring of contemporary crustal deformation on central Vancouver Island is being continued. In conjunction with the semi-annual precise (LaCoste and Romberg D meter) gravity surveys, lake-level monitors have been installed on Buttle Lake to provide frequent gravity corrections during the course of the surveys. In the Campbell River area preliminary releveling results from 1976 and 1982 indicate an apparent relative uplift of about 3 cm.

(g) Gravity Interpretation

(i) Arctic Islands and Ocean (L.W. Sobczak)

A project to prepare two posters for the Canadian Arctic Transect (Corridor G) as part of the North American Continent-Ocean Transects Program of the Decade of North American Geology (DNAG) remains in progress as new data are incorporated. The posters illustrate, at a scale of 1:500,000, 100 km wide strip maps of geology, bathymetry, topography, Bouguer and Free-air anomalies, seismicity and aeromagnetic anomalies, and structural sections to a depth of 48 km; these extend from Somerset Island to the Arctic Ocean. A pamphlet to accompany the posters has been prepared.

(ii) Richmond Gulf (R.A. Gibb, S.L. Fogarasi)

In cooperation with F.W. Chandler, Geological Survey of Canada, a study of a positive gravity anomaly associated with the Richmond Gulf graben indicates the presence of a mafic igneous body at depth that could be a large axial dyke. This interpretation supports geological arguments that the graben is a failed rift.

(iii) AECL Research Area 2, Chalk River, Ontario (M.D. Thomas, D.K. Thomsons)

An interpretation of a small positive Bouguer anomaly ascribed to metagabbroic rocks and associated with folded Grenvillian gneisses has been completed. Constrained by surface geological mapping and borehole information it supports a geological interpretation that the gneisses are folded into an asymmetrical synform.

(iv) Alpha Ridge (J.R. Weber)

New gravity data obtained during CESAR and by helicopter-supported ice-surface surveys over the Ellesmere Island continental shelf and eastern Alpha Ridge are being used to investigate the nature of the ridge-shelf junction and structures of the ridge and Makarov Basin.

(v) Numerical Methods (M.K. Paul)

A numerical method has been developed to compute the gravity effect of bodies with circular symmetry at any point off the vertical axis of symmetry using an algorithm that uses gravity values computed for a number of points on the axis.

(vi) Theoretical Gravity (D. Nagy)

A critical review of the formulae for computing some geometric (b , e^2 , E , f , R_1 , R_2 , R_3 ...) and physical (m , γ_e , γ_p , f^* , k) constants for an ellipsoidal reference system was carried out. A set of subroutines has been developed which allows the calculation of these constants for any reference system defined by its fundamental parameters: a , GM , J_2 and ω . Procedures to obtain optimal low-degree piece-wise polynomial approximations to the theoretical gravity formula for an ellipsoidal reference surface have also been investigated.

(h) Instrumentation (H.D. Valliant)

EPB, in cooperation with the Surveys and Mapping Branch of EMR and the University of New Brunswick, ran a series of field trials during the summer of 1983 to evaluate the MACROMETER positioning system. MACROMETER is a trade name for a global satellite positioning system which can be used to measure the position of one station relative to another without requiring a direct line-of-sight between the two stations. Despite some technical difficulties with one of the MACROMETER receivers, baselines in the Ottawa area ranging in length from a few tens of metres to a few tens of kilometres were measured to a relative accuracy of a few parts per million. The MACROMETER system may be of potential use in geodetic and crustal dynamic studies.

3. Atlantic Geoscience Centre (AGC) (R. Macnab et al.)

(a) Gravity Surveys

In a continuation of the offshore multiparameter surveys program undertaken in collaboration with the Canadian Hydrographic Service, mapping operations aboard CSS BAFFIN were carried out in Jones Sound and over the shelf/margin off western Nova Scotia (Macnab, Miller and others).

(i) Jones Sound

In Jones Sound, severe ice, fog and weather conditions combined to restrict mapping operations for the most part to Lady Ann Strait at the sound's eastern entrance (MacLean, Woodside, and Girouard). Gravity data were collected along a total of 2,079 km of ship's track. Ship's positions were derived through a combination of satellite navigation, Hifix, and Miniranger. In conjunction with this survey, additional data were collected on long regional profiles through the Labrador Sea as the vessel traversed to and from Jones Sound. These profiles will serve as check lines for tying together and adjusting numerous overlapping and contiguous surveys that have been undertaken in the Labrador Sea since 1972.

(ii) West Scotian Shelf/Margin

On the west Scotian shelf/margin, the survey pattern was designed to interline the tracks of an earlier survey, and to execute a number of check lines for purposes of assembling data sets from adjacent and overlapping surveys. Data were collected along a total of 7,000 km of ship's track; positions were derived through a combination of satellite navigation and rho-rho Loran-C.

(b) Data Handling

Procedures for handling and processing marine potential field data have undergone further refinement and improvement. A new minicomputer-based package for the shipboard processing of multiparameter survey data has been put into service (Macnab). A joint development effort is underway, involving EPB and the Geological Survey of Canada, to integrate AGC marine gravity data into the national gravity data base. It is likely that both AGC and PGC marine magnetic data will be included in the same data base (Macnab, Woodside, and Loncarevic).

Further trials and investigations have been undertaken of techniques for the satisfactory computer contouring of marine potential field data. Efforts have been concentrated mainly on the selection of suitable algorithms for pre-gridding data sets prior to input to commercially-supplied contour packages (Shih and Macnab). Additional procedures have been implemented that involve the use of high-speed colour plotters for the rapid production of camera-ready contour plots.

(c) Data Interpretation

Vogt, Kovacs, Berners and Srivastava have reviewed and suggested possible causes of the asymmetry of geophysical signatures in the Greenland-Norwegian and southern Labrador seas, and the Eurasian Basin. Beaumont, Boutilier and Keen applied gravity modelling

techniques in their studies of the thermomechanical events that occur during the evolution of rifted continental margins.

(d) Instrumentation

Atlantic Geoscience Centre's KSS-30 sea gravimeter has undergone further trials and development (Loncarevic). The system was used for a total of over four months at sea during 1983. The first cruise was on CSS MAXWELL, Bedford Institute of Oceanography's smallest ship (35 m length, 275 T displacement) for a test cruise in Mahone Bay in April. A superior navigational control was provided by a specially installed SYLEDIS system (3 beacons) with a positional accuracy of 1 to 2 m. With such navigational control, it is possible to achieve an accuracy of better than 1 mGal in protected inshore water utilizing a small ship.

On the second cruise on CSS HUDSON, two KSS-30 sea gravimeters were operated side-by-side for a period of four weeks. The readings of the two instruments were remarkably consistent with a mean difference of only a few hundredths of a milligal (after applying a correction for differential drift and another correction to the calibration factor of one of the instruments). Serious difficulties were encountered with the BIONAV navigational system and it was concluded that LORAN based systems are not capable of providing sufficiently accurate navigation to realize the full potential of the KSS-30 gravimeter.

The third and fourth cruises were regular hydrographic, multi-disciplinary cruises. The August-September cruise encountered severe ice problems in Jones Sound and the survey results were meagre. The November cruise was more productive and completed the Nova Scotian continental margin survey off Georges Bank.

Also in November, the Navigation Development Group of the Atlantic Region of the Canadian Hydrographic Service carried out an evaluation of the GPS satellite and its integration with a Ferranti inertial navigation system (INS). Further evaluation of the system is required and may be carried out in 1984. The last step in the evaluation of KSS-30 sea gravimeter is a comparison with a LaCoste-Romberg instrument which may be carried out in 1984.

4. Carleton University (F.M. Lindia)

A gravity interpretation of the Bouguer gravity field in the region of the Parry Sound domain, southwestern Grenville Province formed the subject matter for a B.Sc. thesis. The main conclusions of the study were that Parry Sound domain is a bowl-shaped structure with a maximum thickness of 13 km and that Parry Sound rocks extend and thin southeastward beneath adjacent Seguin and Moon River subdomains.

5. École Polytechnique (M.R.L. Laverdure)

A gravity study of the Abitibi greenstone belt was undertaken for a M.Sc. thesis. Gravity modelling indicates that granitic batholiths and greenstone belts vary in thickness from about 4 to 10 km. A negative regional field removed prior to modelling was selected on the basis of a simple graphical technique and matched closely a regional field obtained by upward continuation. Three-dimensional modelling of this regional anomaly suggests a thickening of the lower crust ranging from about 0.4 to 5 km.

6. Memorial University of Newfoundland (H.G. Miller)

The 1983 gravity program consisted of two major and two minor projects. One of the major projects is the Avalon project which is a joint EPB and Memorial University endeavour with onshore and offshore components. Onshore 77 stations were occupied in the southern Avalon Peninsula and offshore, 193 underwater stations were occupied on a 6 km grid in the Cape Race-St. Mary's Bay region. The second major project was the Bay St. George project on the west coast of Newfoundland. Here, approximately 150 gravity stations were established as part of a multiparameter geophysical study of the Carboniferous basin.

The minor projects consisted of the collection of gravity data at 37 stations in the eastern portion of the Gander Zone in association with a Newfoundland Mines Branch geochemistry survey, and a gravity survey across the Ackley Batholith (straddling the boundary between the Avalon and Gander zones) done in conjunction with geological and geochemical studies. The latter survey consisted of 52 stations along a 65 km long profile and two shorter profiles.

Interpretations have been completed of gravity anomalies associated with the Deer Lake Carboniferous basin and of anomalies located in the region of the Avalon Peninsula, both onshore and offshore.

7. New Brunswick Department of Natural Resources and University of New Brunswick
(J.J.Chandra, K.B.S Burke)

In the summers of 1982 and 1983, a total of 1,674 new gravity stations were established in the Lake George-Magaguadavic Lake-Fredericton Junction-Fredericton area (N.T.S. Map Sheets 21 G/14, 21 G/15, 21 G/11 and 21 G/10). Surveys along roads and trails were done at a station spacing of 500 m. However, a few target areas defined by airborne magnetics and enhanced satellite imagery were covered at a station spacing of 100 m or less. The results of these surveys will be interpreted in the winter of 1983 and will include gravity modelling for salt structures and for small stocks of the type found near Lake George which hosts antimony deposits.

The gravity survey of the 1982 Miramichi Earthquake site has been completed. The results have been published in D.N.R. Open File Report 83-3. Ground geophysical surveys (EM, magnetics and radiometrics) were also undertaken at the earthquake site in 1983. Interpretation of the 1983 data is presently underway and results will be published in the spring of 1984.

8. Nova Scotia Research Foundation Corporation (K. Howells)

Approximately 300 land gravity stations were measured over the western margin of the Sydney Coal Basin. These new gravity stations will be compiled with older gravity surveys in the area to produce Bouguer gravity contour maps. Interpretation and computer modelling will commence after completion of terrain correction estimates for the new data. Rock densities and porosities have been measured using samples from five boreholes in the Sydney Coal Basin.

Terrain corrections have also been estimated for the Stellarton- Thorburn 1981/82 gravity surveys and this project will continue with terrain correction computations for older gravity surveys in the area.

Commercial gravity projects consisted of digitizing and data reduction of gravity surveys and the sale of maps and data to mineral exploration companies.

9. Ontario Ministry of Natural Resources (V.K. Gupta)

The grid at the Night Hawk Lake Geophysical Test Range in Thomas Township near Timmins, Ontario, has been extended to the east and south and a gravity survey was conducted to cover this extension.

A small gravity survey was conducted near Geraldton, Ontario, to determine the extension of a cigar-shaped granitic body (the Croll Lake Stock) beneath the mineralized zone at Geraldton. Geological data suggest that fluid has migrated westward from the granitic body and deposited gold within the supracrustals.

10. Université Laval (M.K. Séguin)

M.K. Séguin et quelques étudiants de génie physique ont procédé aux corrections topographiques de quelque 275 stations gravimétriques obtenues lors d'un levé gravimétrique effectué au cours de l'été 1982 dans la région de La Malbaie. Le but de ces corrections est d'améliorer la carte d'anomalie de Bouguer et de vérifier si la corrélation entre les forts gradients linéaires de gravité et les failles actives telles

celles localisées au sud de Grand Fonds ou encore les unités lithologiques cartographiées devient alors plus évidente.

Une présentation orale traitant de la corrélation entre divers modèles gravimétriques et la sismicité de la région de La Malbaie sera bientôt publiée dans les Annales de l'Association Canadienne Française des Sciences lors du Colloque de Géophysique Appliquée qui a eu lieu en mai 1983.

11. University of British Columbia (R.M. Clowes)

A free air gravity anomaly map (contour interval 5 mGal) for the entire Caribbean coast of Costa Rica extending to a distance of 150 km offshore has been compiled from data acquired during a 3,300 km multi-parameter survey carried out under the terms of a contract with Recope, the national oil company of Costa Rica. Acquisition and reduction of the data were carried out with the cooperation of R.L. Couch and staff at Oregon State University.

12. University of Calgary (J.A.R. Blais)

Further research and development has been carried out to optimize the accuracy and computation of gravimetric terrain corrections using test data from the Cordilleran digital terrain file. As a result corrections for the region can be calculated with an accuracy of 1 to 1.5 mGal, which was an initial objective of the study. All results of the study have been documented in a paper that is now in press. In a parallel study for a M.Sc. thesis, M. Sideris (under the supervision of K.P. Schwarz) has used a fast Fourier transform to compute terrain corrections using elevation data distributed on a regular grid.

13. University of Western Ontario (L. Mansinha, B. James and M. Grigotski)

B. James is interpreting gravity data for a region bounded by latitudes 47° and 53° N and longitudes 78° and 85° W and covering the Kapuskasing Structural Zone, northern Ontario. These were obtained from the National Gravity Data Base (EPB, Ottawa) and entered into the PDF 11/42 computer of the Physics Department. The original data set containing irregularly spaced data has been converted to a set having data distributed on a regular grid. Currently effort is directed towards choosing the starting density model for the final 2-D model fitting process.

M. Grigotski is undertaking an interpretation of the Shining Tree Lake gravity anomaly located at latitude 47° 40' N and longitude 81° 15' W sitting astride the Superior-Southern boundary in Ontario. The major part of the anomaly is in the Sudbury district, a region noted for metallic ore deposits and producing mines. A large gravity anomaly over Gowanda, east-northeast of the Shining Tree Lake Anomaly is also being investigated.

14. Bibliography

Becker, M., Dragert, H., Kanngieser, E., Lambert, A., Makinen, J., Richter, B. and Woodward, D. 1983. Report on High Precision Gravimetry, Volume II. IAG Special Study Group 3.37, E. Groten (Editor), Information relative to Cartography and Geodesy, Series II: Translations, No. 41, Institut fur Angewandte Geodasie, Frankfurt a.M.

Blais, J.A.R., Lodwick, G.D. and Ferland, R. 1983. Gravimetric terrain corrections in western Canada. Can. J. Earth Sci., 20, 259-265.

Burke, K.B.S. and Chandra, J.J. 1983. Gravity survey of the epicentral area of the main sequence of 1982 Miramichi earthquakes. Open File Report No. 83-3, Mineral Resources Branch, New Brunswick Department of Natural Resources.

Earth Physics Branch. 1982. Gravity Map of Victoria Island (scale 1:2,000,000). Open File 82-26.

- Earth Physics Branch. 1982. Gravity Map of Great Slave Lake (scale 1:500,000). Open File 82-27.
- Earth Physics Branch. 1983. Gravity Map of Avalon Peninsula (scale 1:250,000). Open File 83-2.
- Earth Physics Branch. 1983. Gravity Map of British Columbia Coast (scale 1:1,000,000). Open File 83-22.
- Earth Physics Branch. 1983. Gravity Map of Alpha Ridge and Ellesmere Shelf (scale 1:1,000,000). Open File 83-24.
- Earth Physics Branch. 1983. Digital Terrain File for Cordillera areas of Alberta, British Columbia, Northwest Territories, Yukon Territory and offshore areas of British Columbia. Open file 83-25.
- Feininger, T. and Séguin, M.K. 1983. Simple Bouguer gravity anomaly field and the inferred crustal structure of continental Ecuador. *Geology*, 11, 40-44.
- Gibb, R.A. 1983. Model for suturing of Superior and Churchill plates: an example of double indentation tectonics. *Geology*, 11, 413-417.
- Gibb, R.A., Chandler, F.W. and Fogarasi, S. 1983. The Richmond Gulf gravity anomaly, northern Quebec-Northwest Territories. In: Current Research, Part B, Geological Survey of Canada Paper 83-1B, 53-56.
- Gibb, R.A., Thomas, M.D., Lapointe, P.L. and Mukhopadhyay, M. 1983. Geophysics of proposed Proterozoic sutures in Canada. *Precambrian Research*, 19, 349-384.
- Haworth, R.T. and Miller, H.G. 1982. The structure of Paleozoic oceanic rocks beneath Notre Dame Bay, Newfoundland. In: Major structural zones and faults of the Northern Appalachians, P. St. Julien and J. Beland (Editors), Geological Association of Canada Special Paper 24, 149-176.
- Irving, E. and Sweeney, J.F. 1983. Origin of the Arctic Basin. *Trans. Roy. Soc. Canada, Series 4*, 20, 409-416.
- Lindia, F.M. 1983. An interpretation of the Bouguer anomaly field in the Parry Sound area, Ontario. Unpublished B.Sc. Thesis, Carleton University, Ottawa.
- Lindia, F.M., Thomas, M.D. and Davidson, A. 1983. Geological significance of Bouguer gravity anomalies in the region of Parry Sound Domain, Grenville Province, Ontario. In: Current Research, Part B, Geological Survey of Canada, Paper 83-1B, 261-266.
- Macnab, R., 1983. Multiparameter surveys in the offshore: broadening the dimensions of hydrography. In: Proceedings of Centennial Conference. Canadian Hydrographic Service, Ottawa, 149-156.
- Macnab, R.F. 1983. Multiparameter mapping off the east coast of Canada. In: Current Research, Part A, Geological Survey of Canada Paper 83-1A, 163-171.
- Macnab, R. 1983. SHIPAC: A software package for the shipboard processing of marine geophysical survey data. In: Current Research, Part B, Geological Survey of Canada Paper 83-1B, 327-330.
- Miller, H.G. 1983. A geophysical interpretation of the geology of Conception Bay, Newfoundland. *Can. J. Earth Sci.*, 20, 1421-1433.
- Miller, H.G. 1983. Geophysical constraints on the size and extent of the Wabana hematite deposit. *Economic Geology*, 78, 1017-1021.

- Miller, R.O., Macnab, R., Amos, C.L. and Fader, G.B. 1983. Canadian east coast multiparameter surveys, 1982. In: Current Research, Part B, Geological Survey of Canada Paper 83-1B, 331-334.
- Nagy, D. 1982. Direct gravity formulae for the Geodetic Reference System 1980. Bolletino di Geodesia e Scienze Affini, No. 4, Anno XL1, 409-420.
- Nagy, D. 1983. Computational formulae for the theoretical gravity (in Hungarian). In: Proceedings of a Symposium on Electronic Data Handling and Automation in Geodesy, Sopron 1983, 235-247.
- Paul, M.K. 1983. Recurrence relations for the truncation error coefficients for the extended Stokes function. Bulletin Géodésique, 57, 152-166.
- Riddihough, R.P. 1983. Recent plate motions: Juan de Fuca Plate Map JFP9. Earth Physics Branch Open File 83-6.
- Riddihough, R.P., Beck, M.E., Chase, R.L., Davis, E.E., Hyndman, R.D., Johnson, S.H. and Rogers, G.C. 1983. Geodynamics of the Juan de Fuca Plate. In: Geodynamics of the Eastern Pacific Region, Caribbean and Scotia Arcs, R. Cabre (Editor), AGU Geodynamics Series, 9, 5-21.
- Robertson, P.B. and Sweeney, J.F. 1983. Haughton impact structure: structural and morphological aspects. Can. J. Earth Sci., 20, 1134-1151.
- Séguin, M.K. 1983. Tectonic style of the Appalachian allochthonous zone of southern Quebec: seismic and gravimetric evidence. Tectonophysics, 96, 1-18.
- Séguin, M.K. 1983. Application géophysique de l'interprétation structurale de la région du lac Bécancour, Thetford Mines, Québec. Can. J. Earth Sci., 20, 1327-1339.
- Shih, K.G. and Macnab, R. 1983. A gravity map of the Canadian east coast offshore: a demonstration of computer techniques for the construction of regional contour maps from large data sets. In: Current Research, Part B, Geological Survey of Canada Paper 83-1B, 429-431.
- Shih, K.G. and Macnab, R. F. 1983. Computer contouring of marine survey data: choosing the best technique for gridding input data. In: Current Research, Part A, Geological Survey of Canada Paper 83-1A, 173-178.
- Sobczak, L.W. 1983. Gravity surveys in the NEA/IAEA Athabasca test area. In: Uranium exploration in Athabasca Basin, Saskatchewan, Canada, E.M. Cameron (Editor), Geological Survey of Canada Paper 82-11, 151-166.
- Sweeney, J.F. 1983. Evidence for the origin of the Canada Basin margin by rifting in Early Cretaceous time. In: The Origin of the Arctic Ocean, C.G. Mull and K.M. Reed (Editors), J. Alaska Geol. Soc., 2, 17-23.
- Sweeney, J.F. 1983. Arctic-Alaska, a two-stage displaced terrane. EOS Trans. Am. Geophys. Union, 64, 87.
- Thomas, M.D. 1983. Tectonic significance of paired gravity anomalies in the Southern and Central Appalachians. In: Contributions to Tectonophysics and Geophysics of Mountain Chains, R.D. Hatcher Jr., H. Williams and I. Zietz (Editors), Geol. Soc. America Memoir, 158, 113-124.
- Valliant, H.D. 1983. Field trials with the LaCoste and Romberg straight-line gravimeter. Geophysics, 48, 611-617.
- Weber, J.R. 1983. Maps of the Arctic Basin sea floor: a history of bathymetry and its interpretation. Arctic, 36, 121-142.

II. SEISMOLOGY AND PHYSICS OF THE EARTH'S INTERIOR

Compiled by: E.R. Kanasewich

1. Canadian Seismicity
2. Atlantic Geoscience Centre
3. Earth Physics Branch
4. Pacific Geoscience Centre
5. University of Alberta
6. University of British Columbia
7. University of Calgary
8. Dalhousie University
9. University of Manitoba
10. McGill University
11. Memorial University
12. University of Saskatchewan
13. University of Toronto
14. University of Western Ontario
15. Bibliography

1. Canadian Seismicity, Earth Physics Branch (Ottawa, and Pacific Geoscience Centre, Sidney, British Columbia)

Provisional data for approximately 600 earthquakes in or bordering Canada are available for 1983 (to mid-December, 1983). Additional information and events are being compiled and added daily to the Earth Physics Branch (EPB) epicentre file. To date there are 23 earthquakes with magnitude (M) 4.0 or greater, five with magnitude greater than 5.0 and one with magnitude greater than 6 (~M7). The magnitude, date and location of the larger earthquakes are as follows: M5.0 on 12 February in southern Baffin Bay; M5.4 on 30 March near Burwash Landing, Yukon; M5.2 on 06 April off northern tip of Queen Charlotte Islands; M5.2 on 07 October near Blue Mountain Lake in northern New York State (United States); and M6.9 on 28 October in Idaho (United States). In western and northern Canada, 310 earthquakes were located to the end of May and provisional epicentres are available for another 150 events to the end of November in southwestern British Columbia, in the area covered by the Western Canada Telemetered Network (WCTN).

The epicentral distribution remained similar to the previous year and some felt earthquakes generated appreciable public concern and much news media coverage in both southeastern and southwestern Canada. Sporadic seismic activity continued in the Miramichi, New Brunswick, area; the largest event, M4.1, occurred on 13 May and was widely felt in New Brunswick. Along the lower St. Lawrence Valley, an M4.1 on 17 January was felt in nearby communities. In western Quebec and southern Ontario, five earthquakes were felt during October and early November. Because these earthquakes occurred in a short time span (four weeks), in a relatively confined area (epicentres within 600 km of each other), and were felt in many communities, there was appreciable public concern and also much newspaper and television coverage. These felt earthquakes are as follows: M3.1 on 04 October in Burlington, Ontario; M5.2 on 07 October near Blue Mountain Lake, New York State; M4.2 on 11 October near Ottawa, Ontario; M3.1 on 16 October near Rockland, Ontario; and M3.5 on 01 November near Montreal, Quebec. The M5.2 Blue Mountain Lake earthquake was felt in many provinces and states and is the largest from the upper New York State-southern Ontario region since the M5.7 Cornwall earthquake of 1944. Fourteen earthquakes were reported felt in western and northern Canada and bordering regions. The most widely felt was the M6.9 Idaho earthquake of 28 October, with intensity IV throughout much of southeastern British Columbia and to a lesser extent in Alberta; isoseismals show a distinct northeast elongation, and extend as far northeast as Saskatoon, Saskatchewan. The M5.4 earthquake that occurred near Burwash Landing was widely felt over much of southwestern Yukon, with intensity IV to V. The M5.2 earthquake off the northern tip of Queen Charlotte Islands was felt on Vancouver Island and in parts of Alaska.

Two field aftershock surveys were carried out in eastern Canada in 1983. The Earth Physics Branch (R.J. Wetmiller, coordinator), with participation by the United States

Geological Survey (Menlo Park), deployed seismographs at strategic locations in the Miramichi, New Brunswick, epicentral area to record aftershocks and also two calibration shots to determine more accurate local crustal velocities. The data are now being analyzed to determine, more precisely, the shallow faults along which the aftershocks are occurring.

Intensity surveys through standard questionnaires and/or requests for letters were conducted by M. Cajka and A.E. Stevens following felt earthquakes on 17 January (near Matane, Quebec), 07 October (near Blue Mountain Lake, New York, but widely felt in Ontario and Quebec), and 11 October (south of Ottawa). Isoseismal maps are published in the relevant quarterly national summaries. A.E. Stevens and M. Cajka have completed analysis of intensity data from six 1982 New Brunswick earthquakes and have discovered a more rapid attenuation of intensity with distance than observed previously in other parts of eastern Canada.

R.J. Wetmiller and others have completed a study of aftershock sequences of the Miramichi, New Brunswick, earthquakes. Aftershock hypocentres, when projected onto a vertical E-W cross-section, outline a V-shaped configuration; furthermore, when the hypocentres are partitioned into quadrants, the corresponding composite P-nodal solutions are in close agreement with the slope of the corresponding segment of the V-shaped pattern. Analysis of the main (M5.7) shock indicates E-W compression. P.W. Basham and J. Adams have prepared a summary of the current understanding of the Miramichi earthquakes and made speculative interpretations of the various configurations of thrust fault on which they may have occurred. They have also compiled the various evidence from pop-ups and stress measurements in New Brunswick mines to confirm the high horizontal E-W stresses that have been inferred from the focal mechanism results. Adams has been involved with planning overcoring stress determinations in the epicentral region and future bedrock clean-off projects with Ontario Hydro, the Atomic Energy Control Board, Geological Survey of Canada (GSC), New Brunswick Power, and the New Brunswick Department of Natural Resources.

In the Charlevoix, Quebec, seismic region both seismicity and changes in seismic velocity are being monitored. The Charlevoix array was in continuous operation during 1983 and the data were used to locate, precisely, hypocentres in the more active zone. F. Anglin has observed that the hypocentres are randomly oriented amongst the previously located microearthquakes but do not migrate outside of the previously defined boundaries. As part of a continuing Earth Physics Branch program to detect changes in P-wave velocities in the seismically active region of La Malbaie, Quebec, under the supervision of G. Buchbinder four more calibration shots were fired in 1983, two in June and two in October. A maximum of 17 seismographs were deployed at 16 sites by EPB personnel. The P-wave travel times for the October shots are, on average, 6 ms less than those for the corresponding June shots that originated from the south shore shot point.

Induced seismicity has occurred in the recently filled La Grande 3 (LG3) reservoir of the James Bay hydroelectric complex. The largest event, M4, which appears to be related to a known fault that transects the LG3 reservoir, is one of a series of 29 events that occurred during a 5-day interval in April, 1983. R.B. Horner, in co-operation with D.J. Gendzwill of the University of Saskatchewan, conducted a 10-day microearthquake survey over the IMC potash mines near Esterhazy, Saskatchewan. An average of six events per day were recorded which is a higher rate than that observed over the Cory Mines near Saskatoon.

D.H. Weichert and staff, in co-operation with Dome Petroleum, continued the Beaufort Sea special seismicity study through part of the year. The five land-based station network is now in reasonable operating condition and should remain in place for another five years. Thoughts about ocean bottom seismometer (OBS) modifications to allow useful deployment near the seismic cluster are still entertained.

D.H. Weichert and T.S. Hamilton presented a paper that casts some doubt about the Anahim hotspot hypothesis on the basis of a correlation between recent volcanism and earthquake swarm activity in the 1940's in the western part of the Anahim volcanic belt. P.W. Basham, J. Adams and F. Anglin have assessed the implications of speculative earthquake source models of the eastern Canadian continental margin which assume that

large earthquakes are equally likely at any location along the margin. Four-fold differences in probabilistic ground motion can result in areas of current petroleum exploration and development. J. Adams is near completion of a study to relocate instrumental seismicity near the epicentre of the 1929 Grand Banks earthquake. Previously unanalysed seismograms from Memorial University have helped to show that most of the earthquakes are restricted to a 100 km x 30 km E-W box near the mouth of the Laurentian Channel.

P.W. Basham, D.H. Weichert, F.M. Anglin and M.J. Berry have compared the new seismic zoning maps with the ground motion calculations used for the 1970 zoning map to assess the factors that have changed the perceptions of seismic risk in Canada, and compared the new probabilistic ground motion results in the region of the Canada-U.S. border with similar calculations made in the U.S. Differences in earthquake source models, strong motion attenuation and methods contribute to significant differences in some regions of the border. G.M. Atkinson is examining the attenuation of strong ground motion in eastern Canada using theoretical predictions based on random vibration theory, modified for the observed characteristics of Lg attenuation. Preliminary indications are that this approach will provide results in good agreement with available data. D.H. Weichert and staff made a special study of seismic risk in the Queen Charlotte area. Although the point-source model used for the whole of Canada is not appropriate for this area, the necessary additional assumptions on the unknown statistical distributions of dynamical fault source parameters introduce considerable uncertainty.

J. Adams and I. Reid of Atlantic Geoscience Centre (AGC) coordinated a joint EPB/AGC two-month ocean-bottom seismometer deployment in June and July that saw eight AGC and four Pacific Geoscience Centre (PGC) OBS successfully deployed and recovered. M. Bone, D. Weichert and A. Whitford deployed the four PGC ocean bottom seismometers. Although the experiment achieved technical success, the level of microseismicity was extremely low. Experiences from the experiment were shared at an OBS design meeting at PGC in October. During the year J. Adams initiated three contracts related to eastern offshore seismicity: one to Memorial University to run three regional seismographs for four months during the OBS experiment, the second to run a regional seismograph for a 10-month period at Guysborough, Nova Scotia, and the third to Memorial University for a literature search of Newfoundland records to compile the historical seismicity of Newfoundland.

H.S. Hasegawa has summarized and correlated available data on the seismotectonics of eastern Canada, including the offshore regions, as part of a contribution to the forthcoming Decade of North American Geology (DNAG) volumes. J. Adams has assumed responsibility for coordination of Canadian contributions to the Geological Society of America DNAG Neotectonics project, and attended the first planning meeting in October. The project will involve the compilation of a stress, a seismicity, and a neotectonics map, as well as accompanying volume, due to be completed by 1987.

H.S. Hasegawa, J. Adams and K. Yamazaki have compiled stress data from surficial stress relief features, in-situ stress measurements and earthquake fault-plane solutions to present an integrated description of the stress field in eastern Canada. Finite-element calculations of a viscoelastic model of the crust-upper mantle of the Canadian Shield subjected to a horizontal tectonic stress field indicate how horizontal stresses can migrate from the upper mantle and lower crust to the upper crust, thereby confining earthquake activity to the upper crust. H.S. Hasegawa has completed two reports, one dealing with transient stress generation by seismic waves impinging upon an underground vault and the other with the induced stress field around an underground vault, for Atomic Energy of Canada Limited.

2. Atlantic Geoscience Centre, Bedford, N.S.

A micro earthquake survey has been carried out on the Grand Banks by I. Reid (AGC), D. Heffler and J. Adams (EPB, Ottawa) and by D. Weichert (PGC). To improve our knowledge of the seismotectonics of passive margins, particularly as related to seismic hazard to offshore development, a two-month seismicity survey, using a total of 12 ocean bottom seismometers from the Atlantic and Pacific Geoscience Centres, was carried out in the area of the 1929 Grand Banks earthquake. Preliminary analysis indicates low background seismicity consistent with extrapolation of the recurrence relation for larger earthquakes.

Seismic studies of the southern Newfoundland margin were carried out by C. Keen, I. Reid and B. Nichols. Seismic refraction and reflection work was undertaken along the continental margin south of Newfoundland. This was intended to investigate the effectiveness of an ocean bottom seismometer array in combination with powerful airgun sources and to be the first stage in a continuing structural study of this transform margin. Initial results show arrivals detectable out to 88 km, and the studies are to be extended in 1984.

CESAR (Canadian Experiment to Study the Alpha Ridge) was carried out by H. Weber, A. Judge, A. Green, A. Taylor and D. Forsyth of EPB and H.R. Jackson of AGC. On a drifting ice station in the Arctic Ocean located at approximately 85°50'N 110°W, seismic reflection and refraction data were collected to determine the crustal structure of the Alpha Ridge and adjacent ocean basin. The refraction experiment was a joint project with Earth Physics Branch. Atlantic Geoscience Centre contributed an ocean bottom seismometer. The initial corrections and data reduction have been done. For the seismic reflection a 40 cu. in. airgun was the sound source. The data display 0.2 to 0.5 s of generally flat lying sediments overlying a rugged-relief basement. Faults that involve sediments as well as basement are observed. A major graben 30 km across was identified.

3. Earth Physics Branch

R. Haddon has continued his attempt to develop efficient and practical methods for the computation of complete synthetic seismograms in layered media. A computer program combining Bouchon's method with the accurate layer transfer matrix method of Menke has been developed and work on modal theory is continuing. C. Wong has continued development of the SAM software package. The current version (SAM V2.3) provides interactive display and picking (onset times, amplitudes, periods, polarity, etc.) of digital time series files, interactive epicentre location, and storage and retrieval of derived parameter data from an earthquake database.

A. Green, Z. Hajnal and W. Weber have completed an interpretation of a multi-disciplinary data set across the Superior-Churchill boundary zone. C. Spencer and H. Huang (a visitor from the People's Republic of China) have begun an analysis of seismic refraction data collected in the Ottawa region as part of the 1982 COCRUST experiment.

P. Morel, C.B. Wright et D. Dufresne ont participé à l'expérience de sismique réfraction COCRUST-84 qui s'est déroulée du 3 au 13 août dans la région des îles de la Reine Charlotte (Colombie-Britannique). Un des buts de cette expérience est d'étudier la zone de failles de la Reine Charlotte. P. Morel, A. Green et R. Haddon continue l'interprétation des données de sismique réfraction enregistrées dans la zone frontière entre le Supérieur et le Churchill ainsi que sur le bassin du Williston lors des expériences COCRUST de 1977, 79 et 81. Les méthodes par rayons et par sismogrammes synthétiques sont appliquées au modelage.

D.A. Forsyth, A. Green, F. Andersen and C. Pile in cooperation with A. Overton and R. Jackson of the GSC and J. Ardai of Lamont-Doherty collected 600 km of reverse refraction data over the Alpha Ridge in the seismic portion of CESAR '83. Approximately 30% of the data has been reduced as of December 1, 1983. Preliminary interpretation shows (1) a crustal thickness of near 35 km beneath the Alpha Ridge, (2) the Alpha and Lomonosov Ridges have different crustal structures, and (3) the Alpha Ridge is wider than heretofore appreciated and the Makarov Basin much narrower in the region of the LOREX '79 and CESAR '83 surveys. C. Spencer, B. Poole (GSC), A. Green, R. Gagné (GSC) and P. Morel have supervised the acquisition of seismic reflection (vibroseis) data in southeastern Quebec and conducted ancillary seismic experiments designed to assist in the processing and interpretation of the data. "Brute stacks" of the reflection data have been produced and further processing steps organized.

The preliminary interpretation of the Saudi Arabian seismic deep-refraction profile has provided reasonable starting models for the Arabian Shield and Red Sea Shelf. To improve these models and obtain better understanding of crustal attenuation, it has been necessary to calculate synthetic seismograms for two-dimensional models. Two synthetic seismogram programs, both based on asymptotic ray theory, have been extensively examined for this purpose by I. Asudeh. Both provide approximate amplitude synthesis for laterally

varying models and are now ready for detailed studies of the Saudi Arabian data set.

R. Hayman, who directs the activities of the Instrument Section, participated in several workshops in the United States to keep abreast of recent developments in recording modes of World Wide Standard Seismograph Network (WWSSN) stations and in optimizing characteristics of near-field portable seismographs (IASPEI CCSS). W.E. Shannon has continued to be involved with digital data processing and Eastern Canada Telemetered Network (ECTN) operations. In response to recent developments, several changes were made to the configurations of both the ECTN and the WCTN. The ECTN station at the LG3 reservoir has been moved to LG4. The ECTN station planned for Eldee, Ontario, should be on-line early in 1984. F. Andersen is improving the performance of ECTN outstations and also backpacks by identifying and minimizing spurious noises. Modifications to backpacks used in the CESAR experiment resulted in high quality records despite the difficult recording conditions. M. Andrew has joined the Datalab group and has become involved in WCTN and SLTN development.

J.A. Lyons has continued to maintain and develop the ECTN and WCTN operating and application software systems. He has also undertaken the procurement, software installation, and system management of a new VAX 11-750 32-bit minicomputer system to be used for seismic data analysis and experiments in international data exchange. With the help of a contracted programmer/analyst, software for a state-of-the-art digital seismograph to be installed at the Sudbury Science Centre is nearing completion. Called the Sudbury Local Telemetered Network (SLTN), this system incorporates a modified 4-channel version of ECTN and a full-featured version of SAM (Seismic Analysis Monitor). Work is beginning on establishing a dial-up 9600 baud synchronous communications link for remote access of SLTN event files for the Datalab VAX. A. Vesa continues to look after hardware maintenance for all Datalab systems.

The Earth Physics Branch geothermal group has produced, sometimes in collaboration with others, a series of regional measurements and interpretations of heat flow. During 1983, A.M. Jessop, J.G. Souther (GSC, Vancouver), T.J. Lewis and A.S. Judge have completed a study of the intermontane region of northern British Columbia and the southern Yukon Territory. The site in the Stikine Volcanic Belt, although not having the highest heat flow, shows a probable component of enhanced heat flow or the presence of a young intrusion below the site.

In the Atlantic region a diamond-drill hole has been completed on the campus of the University of Prince Edward Island, in order to test temperature gradient for possible geothermal energy extraction. Preliminary measurements show a low gradient, possibly related to temperature field distortion by large salt features.

A method for the direct measurement of thermal diffusivity of rocks, using the same discs on the divided bar, has been developed and reported by M.J. Drury, V.S. Allen and A.M. Jessop. Diffusivity controls the transient thermal field and is of importance in studies of thermal effects of intrusions or disposal of heat-producing or heat-absorbing wastes. F.W. Jones and his geothermal team at University of Alberta, under contract to EPB, have been analyzing the temperature and net-rock data of Alberta in terms of temperature gradient and heat flow above and below the Palaeozoic erosional surface. Strong vertical contrasts in both quantities show the effects of lateral transfer of heat by water flow.

In the spring of 1983, A.S. Judge, A.E. Taylor and V.S. Allen participated in the CESAR experiment on the Arctic Alpha Ridge. Some 12 new heat flow determinations reveal a wide range of values with a mean higher than the previously reported values for the region, although evidence is present in the results for unstable bottom water temperatures.

As part of the continued collection of northern data, a contracted study by W. Bawden of Geotechnical Resources in Calgary assembled all industry-acquired thermal data from the Arctic Islands and the Beaufort Sea, producing a series of contoured maps of temperature and temperature gradient. Whereas strong contrasts in temperature and temperature gradient are apparent in the Arctic Islands, the Beaufort area is more uniform. In a parallel contracted study by I. Norquay of the D&S Group in Calgary, all existing

well-logs were examined to produce a map of the distribution and thickness of permafrost in the Mackenzie Delta/Beaufort Sea region. Noteworthy is the very thick wedge of permafrost in the central Mackenzie Delta, reaching thicknesses in excess of 700 m and extending to the shelf edge. The presence of gas hydrates was observed in about 20% of the 175 wells examined for the study.

A.E. Taylor, A.S. Judge and D. Desrochers examined the variation of heat flow and the distribution of permafrost at an emerging Arctic shoreline in northeastern Melville Island. Previous studies have been largely theoretical in nature and based on a single well. A group of wells from close to the shoreline to 10 km distant show good agreement with the best shoreline histories currently available.

J. Pilon, M. Burgess and A.S. Judge have continued investigations of freezing and thawing processes through joint operation of the Calgary Test Facility with J. Ellwood and T. Ersoy of Foothills Pipelines Ltd., through the joint Canada-France simulations at Caen in northern France involving Carleton University, and through a proposal to conduct long term field investigations at a number of sites along the Norman Wells to Zama Lake pipeline right-of-way.

4. Pacific Geoscience Centre

G.C. Rogers has been analyzing the deeper earthquakes within the subducted plate under Georgia Strait. Deep events have been detected as far north as Texada Island and have down-dip tension focal mechanisms that are similar to those under Puget Sound. No deep earthquakes have yet been detected beneath central Georgia Strait. G.C. Rogers also participated with the University of British Columbia in a microearthquake survey of the Queen Charlotte Islands.

A detector was replaced in the gamma-ray spectrometer system, and the heat generation was determined for samples from the Tye Well in Queen Charlotte Basin, from two areas in the Devonian Intrusives of Nova Scotia, from the Thompson Plateau and from a borehole at PGC. Heat generation measured for the two areas in Nova Scotia was very high. T. Lewis and W. Bentkowski have prepared an open file report of all heat generation data from this lab.

Shallow holes were drilled near the Anahim Volcanic Belt east and west of Wells Gray Park as well as four extra holes along the Elaho River near Squamish. T. Lewis and W. Bentkowski report that the results from this and last year's drilling demonstrate widespread ground water flow in rugged topography. Preliminary analysis of excellent data from shallow holes in subduced topography west of Wells Gray Park indicate normal heat flow densities.

E. Davis has analyzed heat flow in a series of shallow holes across the southern Intermontane and Omineca belts of British Columbia where the heat flow is moderately high and uniform. The best explanation of the level of heat flow is that it is associated with a back-arc convective heat transfer process in the upper mantle. E. Davis is continuing his work on establishing the level and variability of heat flow in old ocean basins; results up to now demonstrate that heat flow through old ocean lithosphere is considerably higher than expected from the predictions of plate or boundary layer cooling models, and that there must be a considerable difference between the thermal structure of the upper mantle beneath old oceans and that of the upper mantle beneath continental cratons. More data will be collected from the Jurassic west Pacific in January.

E. Davis has collected new data from the northern Juan de Fuca ridge system in order to characterize more realistically the tectonic processes, and to allow a detailed bathymetric and geologic map to be constructed. Data comprise SEABEAM bathymetry collected swath by swath and compiled into continuous crestal coverage, SeaMARC II acoustic backscatter and bathymetric imaging, seismic reflection, 3.5 kHz acoustic profiling, gravity, and bottom photography. The data afford a new detailed look at a spreading ridge.

M. Bone and A. Whitford have commissioned two new WCTN stations, one at Port Renfrew and the other at Vedder Mountain, British Columbia; a temporary site has been deployed on top of Mount Grey.

5. University of Alberta

Research on inversion of the 1981 Saskatchewan refraction project is continuing by E.R. Kanasewich, C. Macrides and S. Chiu. A unique arrangement of sources and receivers was set up by COCRUST in 1981 to obtain three-dimensional structures over a 300 km equilateral triangle. A low velocity zone has been detected on the profiles in the area. The Moho in the area appears to be broken up into at least three blocks by normal faulting. The inversion scheme shows lateral velocity variation in the mantle and a horst structure between Regina and Swift Current with depths varying from 38 to 47 km. M. Shahriar is carrying out interpretation of the NS and EW refraction lines from 1977 and 1981 in the provinces of Saskatchewan and Manitoba.

Theoretical seismogram studies are being carried out by P. Daley, F. Hron, B. Mikhailenko, R. Chen, L. Pascoe and Bao-shan Zheng. Drs. Daley and Hron have concentrated on non-geometrical arrivals generated by concentrated sources close to the boundary separating two elastic media. They also have a program based on the ray-reflectivity method with results valid in the super-critical region. Dr. Mikhailenko has developed software for the computation of synthetic seismograms for three-dimensional models with lateral inhomogeneities. The method uses a combination of a finite Fourier transform (horizontal distance) and a finite difference method for two other coordinates (vertical and time).

The relationship between lithospheric strain and seismicity in Mexico is being studied by E. Nyland and A.C. Uribe. Both E. Nyland and E.R. Kanasewich and their students are examining oilfield microseismicity. D.I. Gough, J.S. Bell and C.K. Fordjor have made a determination of the azimuths of breakouts in wells over the North American plate. They find a NE-SW orientation of the greater horizontal principal stress throughout the craton. Earth tides are being studied with Stacey-type mercury tiltmeters by F.W. Jones, J.S. Rogers, P. Rouleau and P. Burns. They have constructed a new biaxial mercury level borehole tiltmeter.

Regional variations in heat flow are being investigated by F.W. Jones, J. Majorowicz, H.L. Lam, M. Rahman, C. Kushigbor and A.M. Jessop. They are also examining the geothermal resources in Western Canada.

6. University of British Columbia

Analysis of data obtained during the 1980 Vancouver Island Seismic Project (VISP) carried out by COCRUST is almost complete. W.R.H. White (Centennial College, Toronto), working with R.M. Clowes, has interpreted crustal structure of the oceanic Juan de Fuca plate from explosion data recorded on 3 ocean bottom seismographs deployed in the deep ocean. G.D. Spence, with R.M. Ellis and R.M. Clowes, has completed interpretation of data recorded across Vancouver Island and the mainland from a series of offshore shots. The result is a complex structural representation of the oceanic Juan de Fuca plate subducting beneath the America plate; including a sliver of high-velocity material above the downgoing crust, possibly representing a remnant of subducting lithosphere.

G.D. Spence, K.P. Whittall and R.M. Clowes have developed a fast, efficient algorithm based on asymptotic ray theory for the calculation of synthetic seismograms through two-dimensional media. It represents a practical tool for the interpretation of seismic refraction data. M. Lane and T.J. Ulrych have completed an investigation of various approaches to the problem of phase unwrapping and wavelet estimation in homomorphic deconvolution. In particular they have examined the applicability of the K-L transformation in the homomorphic approach. J. Cabrera and S. Levy have developed algorithms to compute the plane-wave decomposition of the vertical displacement component of the spherical-wave field corresponding to a compressional point source. The forward and reverse transformations (into and out of the plane-wave domain) are formulated as inverse problems and the smallest and flattest Backus-Gilbert models are generated. Applications to mode separation and trace interpolation are already advanced, but the

techniques will be extended so that further processing can be carried out in the plane-wave domain.

E. Gens-Lenartowicz and R.M. Clowes are nearing completion of the interpretation of an extensive set of airgun/sonobuoy refraction data recorded in Queen Charlotte Sound, an area of renewed interest for petroleum exploration. D.J. White and R.M. Clowes have completed interpretation of a 1982 airgun/sonobuoy refraction survey in Georgia Strait between Vancouver Island and the mainland of B.C. The study shows no evidence for a major fault along Georgia Strait, as required in some tectonic models.

R.D. Meldrum and J. Bennest completed construction of 6 ocean bottom seismographs, following the basic design provided by the Atlantic Geoscience Centre, and incorporating a few minor modifications. The OBSs were used for the first time in August 1983, with 7 successful deployments and recoveries. R.M. Clowes, R.M. Ellis and D. Mackie with the collaborative efforts of personnel from the Pacific Geoscience Centre and the Earth Physics Branch (Ottawa) carried out a major onshore-offshore seismic refraction program using the 6 OBSs and 11 land-based seismographs in the Queen Charlotte Islands region. A principal objective is to test tectonic models which indicate a component of underthrusting beneath the Queen Charlotte Islands and Hecate Strait to the east.

E. Gens-Lenartowicz and R.M. Clowes have completed a preliminary interpretation of the southern part of the Fennolora (Scandinavia) profile, a 550 km segment extending from the East German sedimentary basin to the southern part of the Swedish Precambrian Shield. R.M. Clowes as Principal Investigator and A. von Breyman as Project Manager are continuing their work on a geophysical reconnaissance study of the Caribbean continental margin of Costa Rica for the purpose of petroleum exploration under the terms of a contract with Recope, the national oil company of Costa Rica. Gravity, magnetic and bathymetric maps have been completed. Analysis of airgun/sonobuoy refraction data and seismic reflection data is currently in progress. R.M. Ellis and D. Denham of the Bureau of Mineral Resources (BMR) in Canberra, Australia, are using surface wave data for the 1966 and 1982 Mt. Hotham earthquakes to determine the focal parameters and develop improved structural models for the crust and upper mantle of S.E. Australia. In a second study, surface waves are being processed to determine an adequate seismic model for the Yilgarn Craton.

T. Bostwick and R.M. Ellis are examining the data set of the 1949 Queen Charlotte Islands earthquake ($M=8.1$) for which only the magnitude and P-nodal mechanisms are well-constrained. Epicenters of 49 aftershocks have been determined. Surface wave analyses are underway to determine the moment and focal depth. Some researchers have used dendrochronology and the observation of anomalous growth patterns in the rings of trees located on a fault zone to show during which years earthquakes have occurred. This procedure is being attempted for the Beaufort-Cruickshank fault by E. Bendesso (Forestry Department, UBC) in cooperation with W.F. Slawson.

M. Lisowski has reduced the data obtained from the precise trilateration network established near Gold River, B.C., in 1982. Adjustment of the net suggests, from the internal consistencies, a precision of 0.3 ppm. True precision can only be obtained by comparing subsequent surveys of the same network.

J. Berube, R.M. Ellis and G.C. Rogers of the Pacific Geoscience Centre carried out a 9-week seismicity monitoring program in the Queen Charlotte Islands-Hecate Strait region. In this area, where there is renewed interest in hydrocarbon exploration, 15 portable stations were deployed to supplement the 4 regional seismographs. During the experiment, 270 earthquakes were recorded with the larger two having magnitudes near 4. R.M. Ellis and R.D. Meldrum continue operating the UBC 6-station digital seismic array. The research array complements the Earth Physics Branch stations and is designed to provide accurate hypocenters and high quality digital seismograms to aid understanding of current geodynamic processes of the Georgia Strait region.

R.M. Ellis and S.P. Mathur of BMR are analysing deep crustal and Moho reflections in Australian data by using the Karhunen-Loeve transformation to determine properties of the crust and reflectors. S. Levy, I.F. Jones, T.J. Ulrych and D.W. Oldenburg have developed a new approach to the processing of seismic reflection records. This approach uses the

Karhunen-Loeve (K-L) transformation, which is an optimal one from the point of view of extracting correlated information from a multi-trace input. The K-L transformation may be applied either to scalar data or to data which are presented in the form of the analytic signal. Various applications of this transformation include wavelet estimation, velocity analysis, stacking common mid-point gathers, dispersion correction and bad-trace identification.

Work has continued on the inversion of reflection seismic data to recover the acoustic impedance. D.W. Oldenburg, S. Levy, and K.J. Stinson have developed robust algorithms to invert stacking velocities and then show how such information can be included in the acoustic impedance inversion. T.J. Ulrych and C. Walker have created an improved autoregressive (AR) algorithm which can also incorporate this information from stacking velocities. The linear programming and AR solutions to the acoustic impedance can now incorporate all geological and geophysical information available for the seismic interpretation.

W.F. Slawson and W.H. Mathews (Geological Sciences, UBC) are attempting to determine whether the Beaufort-Cruickshank Fault (30 km west of Courtenay, B.C.) is currently active and whether breakage occurred along this fault at the time of the 1946 ($M_s 7.3$) earthquake. Ground reconnaissance has confirmed that several anomalous areas identified from aerial photographs are, in fact, features caused by Holocene faulting. Approximately nine weeks of data collection, using arrays of 4 seismographs, was not successful in locating any activity along the fault. A single instrument is now in place at Mt. Washington about 5 km from the epicenter of the 1946 event.

W.F. Slawson and H. Dragert (Pacific Geoscience Centre) continued the Gold River net survey program by adding six more ties of precise net to the 1947 triangulation survey. M. Lisowski has now computed the apparent changes in the positions of the stations over the last 35 years. The axis of maximum compression (N39°E) is close to that presumed for the direction of convergence between the Juan de Fuca and North American plates. A magnitude 6.0 earthquake occurred near Gold River in 1957. A shallow earthquake of this magnitude would distort the surface near its epicenter. It was considered that the shear strain observed between 1947 and 1982 might be due to the 1957 earthquake. An analysis of the Gold River network as independent northern and southern polygons does not show significant difference in the deformation in the two zones. This strongly suggests that the 1957 earthquake actually occurred outside of the surveyed area, an interpretation in accord with a reanalysis of the seismic data by G.C. Rogers (Pacific Geoscience Centre).

7. University of Calgary

F.A. Cook has carried out seismic reflection profiling in the Purcell anticlinorium of southern British Columbia using a land airgun source which has revealed reflections from depths of at least 15-20 km. These reflections are probably from autochthonous North American basement rocks, and are overlain by structurally complex layering. A large homoclinal structure may be the east limb of an anticlinorial structure which cores the Purcell anticlinorium. The data demonstrate the capability of land airguns for deep crustal reflection work.

E.S. Krebes continued his theoretical study of the reflection and transmission of viscoelastic waves. A special case was found in which the reflection and transmission coefficients are identical to the elastic ones, even for highly anelastic solids. D.J. Hearn, K. Coflin and E.S. Krebes are investigating in detail the effects of physical dispersion on viscoelastic waves.

R.J. Brown has found that a new equidistant latitude reduces the ellipticity errors, which accompany geocentral latitudes, by 3 orders of magnitude to insignificant levels. These have one ready application in two-station surface-wave velocity determinations. Another application, to near-source travel-time investigations, is under continuing study. R.J. Brown has also carried out research in Induced Polarization. Simple, physically reasonable, models of EM coupling in multifrequency IP are being sought. A 'model I', derived to represent a uniform conductive halfspace, improves on the empirically employed Cole-Cole model which is a degenerate case of model I. Improvements to the physical model and extension to layered halfspaces are current goals.

D.C. Lawton has carried out testing of a seisgun seismic source. The objective of this research was to test the effectiveness of a 'BETSY SEISGUN' energy source for seismic data acquisition in Alberta. The gun is a threshold energy source, and in good data areas, high resolution data were obtained up to one second two-way time. However, poor surface conditions and wind noise reduced data quality. Best sections were obtained using high subsurface coverage rather than multiple shots per station. D.C. Lawton and D. Poley have undertaken a quantitative assessment of various seismic recording systems and acquisition geometry used in the Beaufort Sea for detailed site surveys and delineation of engineering hazards. In particular, a comparison between different sources and source arrays is being made, for both single and multi-channel systems.

A seismic modelling tank is being developed by D.C. Lawton and S. Cheadle for physical modelling of various geological features, particularly permafrost (Beaufort Sea) and overthrust structures (Rocky Mountain foothills). The tank measures 4mx3mx1.5m. Source and receiver are ITC transducers which have a flat response from 100 KHz to 35 KHz. Data are acquired on an IBM-XT microcomputer and are processed on the Department's P.E. computer facility.

8. Dalhousie University

Seismic studies of transform faults are being undertaken by K.E. Loudon, R.S. White and D.W. Forsyth. To investigate the manner by which transform faults alter the formation and subsequent tectonism of ocean crust and lithosphere, we have performed seismic refraction and earthquake location experiments at the western intersection of the mid-Atlantic ridge and Vema fracture zone. Earthquakes are located by a 6-station array at depths of 2-5 km sub-seafloor and with normal faulting composite mechanisms with a tensional axis oblique to that of the ridge crest.

To measure heat flow through old ocean crust, K.E. Loudon has taken 28 measurements in the Sohm's abyssal plain of the Nova Scotian margin using a new, digital heat flow and in-situ conductivity probe. Our preliminary results give values of $52 \pm 4 \text{ mW-m}^{-2}$ at an age of approximately 165 Ma. This is 20-30% higher than predictions of either plate or halfspace thermal models. Additional measurements will be taken in 1984.

9. University of Manitoba

W. Moon, D. Messfin and E. Berrer are carrying out seismic modelling of the Sudbury basin. Based on the seismic velocity data (eleven lithologic units around Sudbury basin, Ontario), applicability study of seismic methods in the Precambrian shield environment is completed. Synthetic seismic modelling is done using ART. The Red Lake seismic project is being carried out by D.H. Hall, B. Maxwell, T. Miller and W. Moon. Seismic data collected during the field seasons 80, 81 and 82 are being interpreted with synthetic seismogram and ray tracing techniques. The complicated patterns are also being modelled with W. Moon.

W. Moon, J. Owusu and J. Wenham are using vertical seismic profiling (VSP) techniques at the URL site, Pinawa, to map fracture patterns in the host rock. Presently the computer program for VSP synthetic seismogram is completed and can generate up- and down-going waves as well as multiples. This technique can also be applied to the deep crustal drilling and VSP seismic experiments. Field test is planned for the summer of 1984. A. Carswell and W. Moon are studying slant-stack and cross-stack wave field transformation with the modified Herglotz type inversion method. Tests indicate that this method can produce preliminary velocity structure with great accuracy and speed.

Dynamic parameters of early earth are being studied by W. Moon, I. Yeung and L.D. Ayers with thermal history (parameterized convection) models. Some of the preliminary results are being correlated with the characteristic features of the Canadian shield. The ocean and solid earth tide coupling is being examined by W. Moon and R. Tang. Hydrodynamic modelling algorithm is completed for various air-sea interaction and ocean bottom friction laws. The result has been successfully tested with SEASAT satellite data over the Hudson Bay region of Canada. Currently a similar test is being carried out for the East China sea and Persian Gulf area for global information.

10. McGill University

Considerable progress has been made in the interpretation of the 1982 COCRUST refraction experiment in the Abitibi greenstone belt of western Quebec. The experiment ran a profile from Val d'Or in the south to a point 50 km north of Matagami in the north with shot points at Val d'Or, Matagami, Mastachewan (300 km west of Val d'Or) and Chibougamau (300 km east of Matagami). The inline profile data has shown (a) that the Moho dips gently south towards the Grenville front with a depth of 30 km under Matagami to 40 km under Val d'Or and (b) that there is a low velocity channel identified in the central portion of the profile at a depth of about 12 km which also dips at about the same angle as the Moho. Use of the fan shot data, analysing the arrival times of both Pn and wide angle reflections, enables a crude 3D model of the Moho under the belt to be determined. In this model, a Moho high of 35 km appears in the southern Abitibi NE of Val d'Or and a pronounced low of about 50 km is apparent midway between the Val d'Or/Matagami profile and Chibougamau. These results were found using a primitive form of delay time analysis and a linearised least squares procedure is now being programmed to improve the objectivity of the results. This work is being done by C. Parker and D. Crossley.

J. Todoeschuck and D. Crossley are continuing with the formulation and programming of seismic attenuation theory concerned with non-linear amplitude dependent attenuation in the Earth's mantle. Assuming as a working hypothesis that the velocity attenuation is described by a power law, as evidenced by laboratory experiments, we are attempting to compute the Q and frequency shift of the Earth's free oscillations and of travelling waves in this model. The 1D case has been solved for waves in a box and we are now applying the formalism to the free-oscillation equations.

D. Crossley has recently completed a semi-qualitative assessment of the possibility of detecting long period hydrodynamic waves in the Earth's core, with the prediction that the long period gravity spectrum will require a very long continuous record of several years before a definite conclusion can be drawn. Nevertheless, the practical problem is being solved with the new superconducting gravimeter of Slichter and there is some hope that the question can be settled within the next few years.

A. Vafidis and O. Jensen have completed a study of the application of linear theory to the deconvolution of seismograms with minimization of higher-order moments such as the skew and kurtosis of the convolutional noise as criteria. In simple cases where the noise has significant kurtosis, the new method can be proved to be required for accurate calculations. In real data situations, the advantages are less evident but still potentially useful.

11. Memorial University

H.G. Miller, J.A. Wright, F.K. Ahmed and B.K. Pal are continuing the study of Carboniferous basins in western Newfoundland. Refraction and multichannel reflection data from the Deer Lake basin have been processed and interpreted in conjunction with the gravity and magnetic data (Ahmed, M.Sc.). The results show two reflecting horizons within the basin. The depth section interpreted from the reflection data is consistent with the results from the refraction data. Work is continuing on a system using the Betsy seismic source for high resolution studies in the Bay St. George basin. The objective is to evaluate the fossil fuel potential of the basin. H.G. Miller and P.R. Mohanty are investigating the effect of different migration techniques for seismic data (provided by Mobil Canada) from the Adolphus structure, offshore Newfoundland.

J.A. Wright and C.-L. Fang are continuing a marine geothermal program. Design and construction of a microprocessor-based heat flow probe has been completed. Sea trials were conducted in the Saguenay fjord in October and off the Newfoundland south coast in December. The probe performed well with the exception of the acoustic telemetry link. Production collection of data will take place in 1984. G. Quinlan has initiated a program of studies with C. Beaumont of Dalhousie in the Paleozoic Appalachian foreland basin of the eastern U.S.A. The stratigraphy of this region is explicable in terms of loading and flexure of a temperature-dependent visco-elastic lithosphere by overthrust loads of the Appalachian Mountains. The causal relationship between overthrusts and stratigraphy means that the stratigraphic record can provide valuable insight into the accretionary history

of the Appalachian orogen. A significant result of this work has been the realization that interbasinal arches are flexural effects and that unconformities on these arches are the result of viscoelastic relaxation of the lithosphere. Preliminary data are being gathered for application of the model to Canadian foreland basins.

12. University of Saskatchewan

High resolution seismic models have been developed by Z. Hajnal and M. Lomas over the Lloydminster heavy oil deposits. Detailed core and well log analysis from the Celtic Field area showed significant heterogeneities in the producing Cretaceous Mannville sands. Synthetic seismograms, computed from borehole compensated sonic logs, indicate that carefully designed high resolution seismic surveys can map most heterogeneities in the sandstone of interest.

A. Congram and Z. Hajnal are analyzing 1981 COCRUST data. Four 300 km long crustal refraction profiles are interpreted, implementing different modelling techniques. Models obtained by Chapman's WJBH approximation method indicate a complex crust, with zones of velocity reversal. Two-dimensional ray tracing techniques necessitated introduction of graben-like faulting in a segment of the crust.

A. Hajnal and B.L. Reilcoff have developed a processing method which will improve the signal to noise ratio of crustal reflection data. It is hoped that these improved CDP data sets will provide a coherent, reliable velocity-depth function for the crust. Preliminary results reveal encouraging stacking velocity information.

D. Gendzwill, A. Prugger and B. Horner are involved in seismicity studies in Saskatchewan. Only one seismic event was located in Saskatchewan in 1983, an induced earthquake at the Cory mine of magnitude 2.7, January 6. The microseismic monitoring system at the Cory mine detected numerous microearthquakes. The system is a digital event recognition system with six geophones on the surface over the mine. A one week seismic recording experiment by the Earth Physics Branch and University of Saskatchewan at the IMC mine near Esterhazy detected numerous microearthquakes.

13. University of Toronto

G. West is coordinating seismic refraction studies in the Kapuskasing area for the 1984 LITHOPROBE study.

14. University of Western Ontario

During the past year the operation of the small seismic network over the Gobles oilfield of southwestern Ontario was continued by R.F. Mereu and students. To date over 400 small induced seismic events have been detected and located along at least two active faults. A detailed seismicity study of the Charlevoix region of Quebec is also being carried out by LaMontagne.

A detailed study of the resolution of sedimentary structures of economic importance in southwestern Ontario was begun by R.F. Mereu and students. Data for this work were obtained from the Cangeo seismic exploration company.

During the past year R.F. Mereu completed the compilation of the data and the summary report for the 1982 COCRUST long range seismic experiment across the Ottawa-Bonnechere graben and the Grenville Front. As an aid to the interpretation of the seismic results, Mereu also wrote a computer program which generates synthetic seismograms over laterally varying structures. The program is based on the method of dividing the medium up into triangular blocks. The analysis of the 82 COCRUST results which is being carried out by Wang, Kuhn, Baerg and Mereu shows that the characteristics of the record sections are dominated by lateral near-surface velocity variations (up to 0.4 km/s). The data also indicate that there is a thinning of the crust under the Ottawa graben. This supports the theory that this graben may owe its origin to an ancient rift zone.

The determination of surface temperature history from borehole temperature gradient profiles by A.E. Beck and P.Y. Shen is formulated as a least squares minimization

problem. By using a series of intervals of constant temperature to approximate the surface temperature history, the best solution is obtained by systematically adjusting the number, duration and temperature of these intervals so as to minimize the least squares measure between the measured and calculated gradient profiles. The results indicate that under realistic conditions, only about 4 intervals of constant temperature can be used to approximate the surface temperature history. The major implications are:

- (a) Time span and resolution are mutually exclusive. For example, with a resolution of 100 years, the maximum time span would be about 400 years. If, however, a resolution of 50 years is desired, the maximum time span would be only 200 years.
- (b) In order to have a reasonable solution, the epochs at which surface temperature changes took place must be known from independent information because it is impossible to approximate adequately the surface temperature history with 4 arbitrarily chosen time intervals of constant temperature.
- (c) Any surface temperature changes which take place outside the time span of interest must be known and their effects removed from the gradient data. Otherwise, interference from these temperature changes will lead to distorted surface temperature history.

High Pressure research was carried out by H.H. Schoessin, R. Govindarajan and G. Thompson. These included the measurement of the electrical conductivity of magnetite between 90 and 900°K. The generation of very high pressures by contact stresses was examined theoretically and experimentally. Laboratory experiments were conducted on electrification and luminescence of minerals, the superposition of spontaneous strains at the ferro/paraelectric transition, lattice thermal conductivity with p and T of glasses, and the thermal, optical and dielectric properties of olivine. Theoretical research has been done by H.H. Schloessin on the phasor relations between the magnetic field and fluid core motions.

15. Bibliography

- Asudeh, I. 1983. I.S.C. mislocation of earthquakes in Iran and geometrical residuals. *Tectonophysics*, 95, 61-74.
- Basham, P.W. 1983. New seismic zoning maps for Canada. *GEOS*, 12, 10-12.
- Basham, P.W. and Adams, J. 1983. Earthquakes on the continental margin of eastern Canada - need future large events be confined to the locations of large historical events? In: *The 1886 Charleston earthquake and its implications for today* W.W. Hays (Editor), U.S. Geol. Survey Open File Rep. 83-843, 16 pp.
- Basham, P.W. and Berry, M.J. 1983. New seismic zoning maps of Canada. In: *Proceedings of the Fourth Canadian Conference on Earthquake Engineering*, Vancouver, K15-K17.
- Basham, P.W., Adams, J. and Anglin, F.M. 1983. Earthquake source models for estimating seismic risk on the eastern Canadian continental margin. In: *Proceedings of the Fourth Canadian Conference on Earthquake Engineering*, Vancouver, 495-508.
- Clowes, R.M., Ellis, R.M., Hajnal, Z. and Jones, I.F. 1983. Seismic reflections from subducting lithosphere? *Nature*, 303, 668-670.
- Daley, P.F. and Hron, F. 1983. High frequency approximation to the non-geometrical S* arrival. *Bull. Seism. Soc. Am.*, 73, 109-123.
- de la Cruz and Spanos, T.J.T. 1983. Mobilization of oil ganglia. *A.I.Ch.E. Journ.*, 29, 854-858.
- Drury, M.J. and Jessop, A.M. 1982. The effect of a fluid-filled fracture on the temperature profile in a borehole. *Geothermics*, 11, 145-152.

- Drury, M.J. and Jessop, A.M. 1983. The estimation of rock thermal conductivity from mineral content - an assessment of techniques. *Zbl. Geol. Palaeontol.*, 1, 35-48.
- Drury, M.J. and Lewis, T.J. 1983. Water movement within Lac DuBonnet Batholith as revealed by detailed thermal studies of three closely-spaced boreholes. *Tectonophysics*, 95, 337-351.
- Ellis, R.M., Spence, G.D., Clowes, R.M., Waldron, D.A., Jones, I.F., Green, A.G., Forsyth, D.A., Mair, J.A., Berry, M.J., Mereu, R.F., Kanasewish, E.R., Cumming, G.L., Hajnal, Z., Hyndman, R.D., McMechan, G.A. and Loncarevic, B.D. 1983. The Vancouver Island Seismic Project: a COCRUST onshore-offshore study of a convergent margin. *Can. J. Earth Sci.*, 20, 719-741.
- Fordjor, C.K., Bell, J.S. and Gough, D.I. 1983. Breakouts in Alberta and stress in the North American Plate. *Can. J. Earth Sci.*, 20, 1445-1455.
- Forsyth, D., Morel, P., Hasegawa, H.S., Wetmiller, R., Adams, J., Goodacre, A., Nagy, D., Coles, R., Harris, J., and Basham, P. 1983. Comparative study of the geophysical and geological information in the Timiskaming- Kapuskasing area. Atomic Energy of Canada Technical Report No. 238, December, 71 pp.
- Green, A.G. and Clowes, R.M. 1983. Deep geology from seismic reflection studies in Canada. *First Break*, 1, 24-33.
- Green, A.G. and Mair, A.G. 1983. Subhorizontal fractures in a granitic pluton: their detection and implications for radioactive waste disposal. *Geophysics*, 48, 1428-1449.
- Green, A.G. and Soonawala, N. 1983. Detection of fracture zones in granites by geophysical logging and seismic reflexion surveys. In: *Geophysical Investigations in connection with Geological Disposal of Radioactive Waste; proceedings of a workshop, Ottawa, September, 1982, Nuclear Energy Agency, Organization for Economic Co-operation and Development (OECD)*, 21-36, Atomic Energy of Canada Ltd.
- Hasegawa, H.S. 1983. Lg spectra of local earthquakes recorded by the Eastern Canada Telemetered Network and spectral scaling. *Bull. Seism. Soc. Am.*, 73, 1041-1061.
- Heidebrecht, A.C., Basham, P.W., Rainer, J.H. and Berry, M.J. 1983. Engineering applications of new probabilistic seismic ground motion maps of Canada. *Can. J. Civil Eng.*, 10, 670-680.
- Horner, R.B. 1983. Seismicity in the St. Elias region of northwestern Canada and southeastern Alaska. *Bull. Seism. Soc. Am.*, 73, 1117-1137.
- Horner, R.B. 1983. Earthquakes in Saskatchewan: a potential hazard to the potash industry. In: *Proceedings of the First International Potash Technology Conference, October 3-5, 1983 in Saskatoon, Saskatchewan*, 185-190.
- Hron, F. and Covey, J.D. 1983. Wavefront divergence, multiples and converted waves in synthetic seismograms. *Geophys. Prosp.*, 31, 436-456.
- Hyndman, R.D. and Weichert, D.H. 1983. Seismicity and rates of relative motion on the plate boundaries of western North America. *Geophys. J.R. astr. Soc.*, 72, 59-82.
- Jeffreys, H. and Haddon, R.A.W. 1983. Travel times for Pacific earthquakes. *Geophys. J.R. astr. Soc.*, 72, 273-291.
- Jessop, A.M. 1983. The essential ingredients of a continental heat flow determination. *Zbl. Geol. Palaeontol.*, 1, 70-79.
- Kanasewish, E.W., Kelamis, P.G. and Abramovici, F. 1983. Exact seismograms for a point force using generalized ray theory. *Geophysics*, 48, 1421-1427.

- Kelamis, P.G., Kanasewich, E.R. and Abramovici, F. 1983. Synthetic seismograms for simple "Alberta" models. *J. Can. Soc. Explor. Geophys.*, 18, 43-48.
- Kelamis, P.G., Kanasewich, E.R. and Abramovici, F. 1983. Attenuation for seismograms obtained by the Cagniard-Pekeris method. *Geophysics*, 48, 1204-1211.
- Krebes, E.S. 1983. The viscoelastic reflection/transmission problem: two special cases. *Bull. Seism. Soc. Am.*, 73, 1673-1683.
- Lewis, T. 1983. Bottom water temperature variations as observed, and as recorded in the bottom sediments, Alice Arm and Douglas Channel, British Columbia. In: Proceedings of a Workshop on the Kitimat Marine Environment, R.W. Macdonald (Editor), Can. Tech. Report, Dept. of Hydrography and Ocean Sciences, 18, 138-161.
- McMechan, G.A. and Spence, G.D. 1983. P-wave velocity structure of the earth's crust beneath Vancouver Island. *Can. J. Earth Sci.*, 20, 742-752.
- Mereu, R.F. 1983. A microseismic survey of the Gobles oil field area of southwestern Ontario. Geoscience Research Program, E.G. Pye (Editor), Ontario Geological Survey Miscellaneous Paper 113.
- Mereu, R.F., Mykkeltveit, S. and Husebye, E. 1983. FENNOLORA recordings at NORSAR. *J. Geophys.*, 52, 119-130.
- Messfin, D. and Moon, W. 1983. Seismic approaches for structural studies of the Sudbury Basin. 1982 Annual Report, Centre for Precambrian Studies, University of Manitoba, 69-79.
- Moon, W. 1983. Solution of the whole earth geodynamic equation in a slightly elliptical coordinate system. *Computer Physics Comm.*, 28, 219-227.
- Moon, W. 1983. Evolution of variational type finite element method in whole earth geodynamics. *Congressus Numerantium*, 38, 183-201.
- Moon, W. and Tang, R. 1983. Transient sea surface height variation and the SEASAT altimeter data application. Proceedings IUGG Inter-disciplinary symposium, Hamburg, Germany.
- Ojo, S.B. and Mereu, R.F. 1983. Regional differences in upper mantle heterogeneity from coherency measurements on array data. *Geophys. J.*, 82, 173-192.
- Oldenburg, D.W. 1983. Funnel functions in linear and nonlinear appraisal. *J. Geophys. Res.*, 88, 7387-7398.
- Oldenburg, D.W., Scheuer, T. and Levy, S. 1983. Recovery of the acoustic impedance from reflection seismograms. *Geophysics*, 48, 1318-1337.
- Riddihough, R.P., Beck, M.E., Chase, R.L., Davis, E.E., Hyndman, R.D., Johnson, S.H. and Rogers, G.C. 1983. Geodynamics of the Juan de Fuca Plate. In: Geodynamics of the Eastern Pacific Region, Caribbean and Scotia Arcs, R. Cabre (Editor), Geodynamics Series Amer. Geophys. Un., Washington, D.C., 9, 5-21.
- Rogers, G.C. 1983. Some comments on the seismicity of the northern Puget Sound-southern Vancouver Island region. In: Earthquake hazards of the Puget Sound region, Washington State, J.C. Yount and R.S. Crosson (Editors), U.S.G.S. Open File Report 1983-19, Menlo Park, California, 19-39.
- Rogers, G.C. and Souther, J.G. 1983. Hotspots trace plate movements. *GEOS*, 12, 10-13.
- Shannon, W.E., Munro, P.S., Schieman, D.R.J. and Halliday, R.J. 1983. Canadian Seismograph Operations - 1982. *Seism. Ser. Earth Phys. Br.*, 89, 111 pp.

- Shen, P.Y. 1983. On oscillations of the earth's fluid core. *Geophys. J.R. astr. Soc.*, 75, 737-757.
- Shen, P.Y. and Beck, A.E. 1983. Determination of surface temperature history from borehole temperature gradients. *J. Geophys. Res.*, 88, 7485-7493.
- Shen, P.Y. and Mansinha, L. 1983. On the principle of maximum entropy and the earthquake frequency-magnitude relation. *Geophys. J.*, 74, 777-785.
- Slawson, W.F. and Savage, J.C. 1983. Deformation near the junction of the creeping and locked segments of the San Andreas Fault, Cholame Valley, California (1970-1980). *Bull. Seism. Soc. Am.*, 73, 1407-1414.
- Sprenke, F. and Kanasewich, E.R. 1983. Gravity modelling and isostasy in Western Canada. *J. Can. Soc. Explor. Geophys.*, 18, 49-57.
- Stevens, A.E. (Editor) 1983. Miramichi, New Brunswick, Canada: Earthquake Sequence of 1982 - A Preliminary Report. Earthquake Engineering Research Institute, Berkeley, Calif., 99 pp.
- Turner, G.M. and Gough, D.I. 1983. Magnetic fabric, strain and paleostress in the Canadian Rocky Mountains. *Tectonophysics*, 96, 311-330.
- Van Wagoner, N., Moon, W., Ayres, L.D., Tang, R. and Carswell, A. 1983. Rheological modelling of a Proterozoic volcano and earth. 1982 Annual Report, Centre for Precambrian Studies, University of Manitoba, 128-150.
- Walker, C. and Ulrych, T.J. 1983. Autoregressive recovery of the acoustic impedance. *Geophysics*, 48, 1338-1350.
- Weichert, D.H., Rogers, G.C., Hyndman, R.D. and Horner, R.B. 1983. Seismic risk of the Queen Charlotte Islands and adjacent area. In: Proceedings of the Fourth Canadian Conference on Earthquake Engineering, Vancouver, 529-538.
- Wetmiller, R.J., Horner, R.B., Stevens, A.E. and Rogers, G.C. 1983. Canadian Earthquakes - 1980/Tremblements de terre canadiens - 1980. *Seism. Ser. Earth Phys. Br.*, 87, 60 pp.

III (A) GEOMAGNETISM

Compiled by P.J.C. Ryall

1. Summary
2. Geomagnetic Surveys and Interpretations
 - (a) Atlantic Geoscience Centre
 - (b) Earth Physics Branch
 - (c) Geological Survey of Canada
3. Magnetic Observatories and Instruments
 - (a) Earth Physics Branch
4. Electromagnetic Induction in the Earth
 - (a) Earth Physics Branch
 - (b) Pacific Geoscience Centre
 - (c) University of Alberta
 - (d) Memorial University of Newfoundland
 - (e) Queen's University
 - (f) University of Victoria
5. Palaeomagnetism and Rock Magnetism
 - (a) Earth Physics Branch
 - (b) Pacific Geoscience Centre
 - (c) University of Alberta
 - (d) Dalhousie University
 - (e) Université Laval
 - (f) Memorial University of Newfoundland
 - (g) University of Toronto
 - (h) University of Western Ontario
 - (i) University of Windsor
6. Bibliography

1. Summary

Magnetic surveying has continued through the year, much of the effort being concentrated in northern areas with additional shipborne (AGC) and airborne magnetics (GSC) in the Labrador Sea and adjoining areas.

Electromagnetic induction studies are being actively pursued by many groups. Geographically they cover the country from Queen Charlotte Sound in the West (PGC) to the Gander-Avalon Zone in the East (MUN), with studies as far north as the Alpha Ridge (EPB) and as far away as China (U. of A.). The main thrust of the U. of A. work, however, is devoted to an investigation of conductive structures in Western Canada and their tectonic significance. Major numerical modelling programmes are being developed at Victoria. Other induction studies are related to seismically active areas such as La Malbaie, P.Q. and Miramichi, N.B. (EPB). An especially interesting project is the use of a controlled source from a ship to determine the conductivity and thickness of sediments overlying basement (U. of T. and PGC).

The extraordinary range of activities of palaeomagnetists makes it difficult to summarize them. Canadian workers are studying rocks which cover three-quarters of the geologic time scale ranging from archaeomagnetic work (U. of A.) to 2.2 Ga intrusives in the Slave Province (EPB) and 2.6 Ga in the Superior Province (U. of T.) and the 3.5 Ga Komati Formation in South Africa. Canadian palaeomagnetists are busy around the world, often in collaboration with foreign scientists, in France (U. of A.), Cyprus - a 2.5 km drillhole (Dalhousie U.), the Baltic Shield, Ecuador and Peru (Laval), Iceland (MUN) and South Africa (U. of T.). Despite this diversity, the bulk of work is concentrated in Canada with major activity concentrated in the Appalachians (EPB, Laval, MUN, PGC) and the Cordillera (PGC, U. of A., U. Windsor) with continuing activity in the centre of the country (EPB, Laval, U. of T., UWO, U. Windsor). Work on sediments is restricted to studies of lake cores (UWO), glacial sediments (U. Windsor) and cores from the Alpha Ridge (Dalhousie U.). Rock magnetic studies continue (MUN) to study magnetostrictive control and on oolitic iron ores to examine the effects of different iron minerals during

heating. Fundamental studies into the relationship between CRM and TRM during the oxidation of magnetite, the inversion of titanomaghemite, and the low temperature oxidation of submarine basalts are underway (U. of T.) along with domain state calculations for domain transitions in magnetite cubes.

In brief, geomagnetic research appears to be in a healthy state with some activity in almost every area.

2. Geomagnetic Surveys and Interpretations

(a) Atlantic Geoscience Centre (R. Macnab)

(i) Magnetic Surveys. In a continuation of the offshore multiparameter surveys program undertaken in collaboration with the Canadian Hydrographic Service, (R. Macnab; Miller et al.) mapping operations were carried out in two regions: Jones Sound and the shelf/margin off western Nova Scotia. In Jones Sound, (B. MacLean, J. Woodside, and J. Girouard) magnetic data were collected along a total of 382 km of ship's track. In conjunction with this survey, additional data were collected on long regional profiles through the Labrador Sea as the vessel transited to and from Jones Sound. These profiles will serve as check lines for tying together and adjusting numerous overlapping and contiguous surveys that have been undertaken in the Labrador Sea since 1972. On the west Nova Scotia shelf/margin, the survey pattern was designed to interline the tracks of an earlier survey in the same region, and to execute a number of check lines for purposes of assembling data sets from adjacent and overlapping surveys. Data were collected along a total of 7788 km of ship's track.

(ii) Data Handling. Procedures for handling and processing marine potential field data have undergone further refinement and improvement. A new minicomputer-based package for the shipboard processing of multiparameter survey data has been put into service (R. Macnab). A joint development effort is underway involving EPB and GSC, with the objective of establishing a consolidated data base management system. This should reduce or eliminate many of the problems that have arisen in the past from fragmented, incompatible, and geographically-dispersed data bases (R. Macnab, J. Woodside, and B. Loncarevic).

Investigations have confirmed the validity of the new International Geomagnetic Reference Field models for processing marine magnetometer data. Techniques have been devised to accelerate the computer evaluation of these formulae when applying them to large data sets. (K.G. Shih, F. Doherty, R. Macnab, and S.P. Srivastava).

Further trials and investigations have been undertaken in techniques for the satisfactory computer contouring of marine potential field data. Efforts have been concentrated mainly on the selection of suitable algorithms for pre-gridding data sets prior to input to commercially-supplied contour packages (K.G. Shih and R. Macnab). Additional procedures have been implemented that involve the use of high-speed colour plotters for the rapid production of camera-ready contour plots.

(iii) Data Interpretation. H.R. Jackson and I. Reid have investigated the variation of oceanic magnetic anomalies with seafloor spreading, and have suggested several mechanisms that could cause an overall increase in intensity. P.R. Vogt, L.C. Kovacs, C. Bernero and S.P. Srivastava have reviewed and suggested possible causes of the asymmetry of geophysical signatures in the Greenland-Norwegian and southern Labrador Seas, and the Eurasian Basin. H.R. Jackson has studied plate motions around the Eurasian Basin of the Arctic Ocean between magnetic anomalies 0 and 24, and has calculated the theoretical rotation of Greenland relative to North America.

(b) Earth Physics Branch (L.R. Newitt, G.V. Haines, R.L. Coles)

(i) Geomagnetic Surveys, Charts and Compilations. As part of a continuing study of geomagnetic secular variation, 13 repeat stations were occupied in eastern Canada. Six of these were occupied by contract. The routine occupation and observation is similar to that outlined in CGB Vol. 32, p. 60.

The solution of Laplace's Equation has been developed, in spherical coordinates, from the boundary value problem appropriate to fitting the geomagnetic field over a spherical cap. The solution involves associated Legendre functions of integral order but non-integral degree. The rate of convergence of the (uniformly convergent) series for the field components is rapid, and truncation errors as low as 1 nT can be obtained with a reasonable number of coefficients. Upward continuation is quite accurate at low continuation altitudes; at 600 km the upward continuation error is about five times the truncation error.

(ii) Interpretation of Magnetic Surveys. An analysis of the geomagnetic observations made at Canadian International Polar Year sites has led to a better understanding of the secular variation in Arctic Canada. In particular, the decrease in total intensity during the past century at Ft. Conger and Clearwater Fiord is only one-third to one-half that observed in central and southern North America.

A revised selection of Magsat data at northern high latitudes has been made and a new map of scalar magnetic anomalies prepared. Maps of dawn and dusk data subsets are in generally good agreement, except for parts of eastern Canada and Siberia.

(c) Geological Survey of Canada (P.J. Hood)

During 1983, 136 aeromagnetic maps were published by the Geological Survey of Canada. Of these 91 were 1:50,000 and 27 were 1:250,000 scale total field aeromagnetic maps and 9 were 1:1,000,000 coloured magnetic anomaly maps. In addition 9 coloured 1:50,000 vertical gradient maps for the Flin Flon area of Manitoba and the first 1:1,000,000 shaded relief map of the Lockhart River sheet (NP-12/13) were issued. An index map showing aeromagnetic and shipborne magnetometer contour map coverage of Canada to December 31, 1983 is included at the end of the chapter.

High resolution aeromagnetic gradiometer surveys were flown by the GSC Queenair aircraft in the Guysborough County area of Nova Scotia (5364 line km), the Buchans area of Newfoundland (8071 line km) and the Barrington Lake area of Manitoba (5716 line km). Two open files of aeromagnetic gradiometer data were released in June 1983; the areas surveyed were Lynn Lake (OF 936) and McClarty Lake (OF 937), Manitoba.

An aeromagnetic survey of a southern portion of the Greenland Ice Cap was carried out by the Convair 580 aircraft of the National Aeronautical Establishment at the request of the Greenland Geological Survey. The survey was completed in two phases, namely April/May and September 1983 using Sondrestrom as the base of operations. Tie lines were also flown along the length of the Labrador Sea and Baffin Bay, and from Davis Strait to Iceland in support of the compilation of the Magnetic Anomaly Map of North America.

During 1983, the Geological Survey of Canada with the co-operation of the Ontario Geological Survey completed a transfer technology process which permitted Kenting Earth Sciences Ltd. of Ottawa to offer aeromagnetic (vertical) gradiometer surveys on a commercial basis.

3. Magnetic Observatories and Instruments

(a) Earth Physics Branch (R.L. Coles, G. Jansen van Beek, G. Brown, R. Libbey, F. Plet, D.F. Trigg, F. Kollar, J. Hruska, M. Gervais)

The Geomagnetic Observatory Unit of the Division of Seismology and Geomagnetism continued its management of the Canadian Magnetic Observatory Network (CMON) consisting of the following 10 digital magnetic observatories: Resolute, Cambridge Bay, Baker Lake, and Yellowknife in the Northwest Territories; Fort Churchill, Manitoba; Great Whale River, Quebec; Meanook, Alberta; St. John's, Newfoundland; Ottawa, Ontario; and Victoria, British Columbia. The observatories at Alert and Mould Bay continued to use photographic recording on their primary magnetometers. Glenlea, Manitoba was operated in cooperation with the University of Manitoba in Winnipeg. The standard digital recording interval for CMON is one minute except at the variation station in Igloolik, N.W.T. where 10 second data are available. Full descriptions of the network are contained in the various annual reports for magnetic observatories. The latest published annual report is for 1981.

The final 1982 digital magnetic observatory data including 1 minute values and hourly means and ranges were deposited in the World Data Centre in Boulder, Colorado in November, 1983. Copies of magnetograms and edited digital data are available at cost plus 100% handling charge from: Division of Seismology and Geomagnetism, Earth Physics Branch, Department of Energy, Mines and Resources, Ottawa, Ontario, K1A 0Y3. Details of other services are listed in the Catalogue of Services for the Geomagnetic Service of Canada.

The program to replace the aging incremental reel-type tape decks at the 10 digital Canadian magnetic observatories was completed in 1983. These observatories have all been equipped with the new Columbia 300D cartridge drives. Reconstituted magnetograms from 10-second AMOS digital data have replaced analogue records as the principal data source for the measurement of Meanook and Ottawa K-indices.

High-sensitivity ocean-bottom magnetometers built at the Geomagnetic Laboratory were provided with increased memory for data storage and with a faster measurement capability. This work was done for a cooperative project with the University of Toronto in which controlled source magnetometric methods are used to establish the electrical properties of the sea floor.

The staff of the Geomagnetic Laboratory have participated in the MARIA project of the CANOPUS program. Work has included assistance in definition of magnetometer specifications, evaluation of industrial proposals and provision of facilities for magnetometer tests and evaluation.

The Geomagnetic Service issues 27 day forecasts of geomagnetic activity every three weeks. These are available on request. Short term forecasts (72 hours) are also available (Tel. 613-992-1299). Research into improved forecasts for high latitude regions is in progress.

4. Electromagnetic Induction in the Earth

(a) Earth Physics Branch (E.R. Niblett, R.D. Kurtz, P.A. Camfield, J.C. Gupta, J.A. Ostrowski, C.C.M. Michaud, D.H. Krentz)

Magnetotelluric data continue to be recorded at four stations in the seismically active area near La Malbaie, Quebec, as part of the Earth Physics Branch's on-going program to detect changes in earth resistivities. Large changes in apparent resistivity are still occurring at the Charlevoix station. Reference values for magnetotelluric parameters are being accumulated at the new station at St. Siméon.

The magnetotelluric study of the gabbro-anorthosite intrusion at East Bull Lake, Ontario, continued in 1983 with additional scalar audio magnetotelluric measurements in two orientations at 112 sites. Some of these were oriented along the strike of the Folsom Lake Fault Zone. Interpretation is in progress. Five tensor soundings were obtained along the new access road. Inversion of the data, performed in the field, indicates a good conductor at a depth of approximately 800 m in the central part of the intrusion. As well there is evidence for a conducting zone at the base of the crust.

A magnetotelluric survey was conducted in the Miramichi, N.B., earthquake zone in July. Tensor soundings were made at 11 locations in the frequency range from .00055 to 384 Hz. In addition, scalar soundings were taken at each of these sites in the major and minor axes of anisotropy to extend the apparent resistivity data to 5000 Hz. Inversion of the data, performed in the field, indicates a conducting zone at the base of the crust or in the upper mantle. Scalar audiomagnetotelluric measurements were made at 76 locations along an east-west profile in two orientations. Several interesting anomalies were observed and interpretation is in progress.

A magnetotelluric station was established at the CESAR base camp in April to study deep structure beneath the Alpha Ridge. Telluric signals were derived from silver-silver chloride electrodes suspended beneath the sea ice. Good quality data were recorded at 1-min intervals for a 30 day period. The impedance tensor is anisotropic at periods above 10,000 s suggesting structural inhomogeneities in the oceanic lithosphere beneath the Ridge. Analysis and interpretation of the data are in progress.

An audio-MT survey was completed in September on the Eye-Dashwa Lakes Pluton near Atikokan, Ontario by the Mineral Exploration Research Institute (Ecole Polytechnique de Montréal) under contract to Atomic Energy of Canada Ltd. Observations were made at frequencies between 8 Hz and 5000 Hz at about 130 stations in the test area known as the intrablock region. The objective was to identify and locate conducting faults and fractures along surveyed cut lines within the region and to estimate variations in electrical conductivity with depth in the upper crust.

Geomagnetic data collected during the International Magnetospheric Study (IMS) were used to investigate the electrical conductivity structure of northeastern Manitoba and part of the Northwest Territories. The computed transfer functions resolved a major east-west trending conductor between the communities of Gillam and Back in Manitoba. Regional trends in the surface geology suggested that this conductor might be linked with the North American Central Plains electrical conductor. Two-dimensional modelling of the data indicated that the conductor dips to the north from a shallow depth beneath Gillam and may extend to the lowermost crust.

Forward modelling techniques were applied to audiomagnetotelluric data from the Wopmay Orogen near Great Bear Lake to assist in the interpretation of the subsurface orientation of the fault zone. A conductivity model of the fault zone consistent with the known geology was developed which produced synthetic sounding profiles closely matching the observed profiles. Analysis of this model in conjunction with the field data has led to the conclusion that the Wopmay Fault Zone, at the survey location, has a width of $4 \pm 1/2$ km, is sub-vertical and has a considerable vertical extent.

A magnetotelluric survey in the Magdalen Sedimentary Basin (P.E.I.) was done in August to identify regional variations in basin structure and possible anomalous conducting zones which might be associated with elevated temperatures. MT and AMT measurements were made at a total of 10 locations reasonably well distributed over the Island. High quality data were obtained; analysis and interpretation are now in progress. This is a cooperative project with participation by the Physics Department, University of Toronto and Earth Physics Branch.

(b) Pacific Geoscience Centre (L.K. Law, J.M. DeLaurier, D.R. Auld)

Ocean Bottom Magnetometers were deployed in 1982 at sites on the shelf and on the Pacific Plate, spanning the transform fault west of Queen Charlotte Sound. Induction arrows for the shelf site are perpendicular to the shelf-slope break, which is consistent with the usual "coast-effect" of electric currents flowing along the boundary of the deep ocean. In contrast, the induction arrows at the site near the base of the slope (2 km water depth) are large (0.5 - 1.8), are subparallel to the strike of the fault and the continental shelf, and are directed toward electric currents most likely associated with the recently initiated Tuzo Wilson spreading segment.

A controlled source magnetometric survey in Jervis Inlet, using seafloor magnetic field receivers and a vertical electric dipole from the ship, determined the electrical conductivity and thickness of the sediments overlying the resistive basement. The results from this first survey prove the feasibility of the method for seafloor conductivity studies. The project is a co-operative program involving the University of Toronto, the Geomagnetic Laboratory, Ottawa, and the Pacific Geoscience Centre.

(c) University of Alberta

(i) Magnetometer Array and Magnetotelluric Studies (D. I. Gough, V.R.S. Hutton, G. Dawes, W.D. Parkinson, D.K. Bingham, M.R. Ingham, Chen Guangming, Wang Xishuo, K. Wilson, G.S. Hoye, M. Connors, S. Kapotas, E. Kapotas). The various studies noted below form parts of a general investigation of conductive structures in western Canada, and their tectonic and geothermal significance.

The 1980 Magnetometer Array Studies - Gough et al. 1982, Ingham et al. 1983. The large initial array 1980A located two structures subsequently studied by means of two arrays operated in 1981. Z response functions at nine stations of the 1980A array, near a

line joining Squamish to Edmonton, are being used in model studies of the major conductive structure under British Columbia.

The 1981A Magnetometer Array Study. This array was placed with Tête Jaune Cache near its centre and the Rocky Mountain Trench bisecting it. The array included about 200 km of the Rockies and the Trench, about 100 km of the Cariboo and the northwestern end of the Monashee Mountains. Our Fourier transform (FT) maps show a positive anomaly in both horizontal components along the southwestern part of the Main Ranges and the adjoining Rocky Mountain Trench, with a number of closed maxima of which the largest is centred near Tête Jaune Cache (TJC). Using the artificial event analysis method initiated by Bailey et al. (1974) we have applied unit horizontal field, linearly polarized along N50°E, at right angles to the Rocky Mountains and Trench, to these transfer functions to obtain the vertical component of the field of currents which would be induced by such a field. In this way the source-fields of individual events should be largely averaged out. In addition to the attenuation of Z to the southeast, the very large change, from the Z maxima along the Icefields Parkway to very small Z 60 km to the southwest in the Trench, indicates induced currents under the mountains between.

The 1981B Magnetometer Array Study. This array was located to study a conductive structure, identified by the 1980A array, which runs from the Idaho-B.C. border northeastward across the southern Rocky Mountains and across Alberta. As far as a point a few kilometres east of Calgary, the conductive structure coincides with the rift structure in the lower crust proposed by Kanasewich, Clowes and others from seismic, gravity and magnetic anomalies. From that point Kanasewich traces the rift eastward into Saskatchewan. The induced currents continue northeastward.

Conductivity Models for Western Canada. The 1980A array left a large gap in the data in a crucial place just off the edge of the model conductive layer, across the Rocky Mountains. As the 1981A array filled this gap, the modelling program was shelved until transfer functions became available from that array. We now have Z responses at 13 stations from the two arrays, for periods 10 and 25 minutes. The extremely sharp changes in Z responses between the middle of the Main Ranges (Icefield Parkway) and the Trench, cannot be modelled with the edge effect of a horizontal conductor alone. W.D. Parkinson has run about 90 models including many with a vertical sheet of conductor at the edge of the horizontal conductor, and between the Icefield Parkway and the Trench. Some of his models give a good fit to the Z responses at 10 minutes but do not fit the larger responses at a period of 25 minutes.

Magnetotelluric Soundings in the Rocky Mountain Trench and adjoining mountains. The field work was located in the central part of the 1981A array. Results for the frequency range 500-0.01 Hz are now available at the stage of rotated apparent resistivities and phases and one-dimensional Monte Carlo inversions. Stations in the Trench show low resistivities in the surface sediments and a second low-resistivity layer at depths of a few km. Stations along two logging roads in the Rocky Mountains and one in the Cariboo Mountains, northeast and southwest respectively of the Trench, show resistive rock underlain by very low resistivities (a few ohm metres) at depths of 10 km or less. The results are generally in good agreement with expectations based on the 1981A magnetometer array.

The 1983 Magnetometer Array Study. This array was bisected by the Rocky Mountains from the Thompson Highway/Icefield Parkway intersection nearly to the United States border. To the west it extended beyond Kootenay Lake to Revelstoke, B.C. and to the east in Alberta to Drumheller. The objective is to find out whether the current flow under the southwestern Main Ranges and Trench, mapped by the 1981A array, continues along the mountains to the southeast of that array. Previous workers have indicated that the edge of the conductive layer under British Columbia leaves the Trench to run along Kootenay Lake due south to the United States border. The problem is compounded by the "rift valley" conductor which runs across strike of the mountains. The 1983 array should elucidate the conductive structures, which are likely to present an interesting problem.

Collaboration with Chinese Institutions. The origin of our collaboration, with the Institutes of Geophysics of the State Seismological Bureau and Academia Sinica, was described last year. Mr. Chen and Mr. Wang are very active participants in all aspects of

the 1983 array work. In Peking the manufacture of 6 Gough-Reitzel type magnetometers is proceeding. The first array study in China will probably use the permanent magnetic observatories of eastern China with the six GR magnetometers filling gaps. The Chinese set of magnetometers will later be expanded to 30, on present plans. The Alberta set of 33 may be sent on loan to China in 1986, after the EMSLAB experiment (see below).

The EMSLAB experiment. This large international ElectroMagnetic Sounding of the Lithosphere and Asthenosphere Below was the subject of a Workshop convened on San Juan Island by J.R. Booker of the University of Washington in September, 1983. The intention is to make EM soundings along the Juan de Fuca Ridge, across the Juan de Fuca Plate and on land over the states of Oregon and Washington. About 100 three-component magnetometers on land (29 from Queen's University and 33 from the University of Alberta) and 20 on the seafloor will record magnetovariation events simultaneously. About five broadband MT systems will make soundings along a transect from the coast across Oregon. Provided the necessary funding is obtained the field work is scheduled for the summer of 1985. The observations will traverse an active ridge, an oceanic plate covering the age range 0-6 Ma, a subduction zone and the melt structures and volcanoes of the Cascade Ranges.

(ii) Magnetotelluric Studies (D. Rankin, F. Pascal, R. Singh). Refined interpretational techniques including the inversion method of Rankin and Pascal (1982) have produced consistent and repeatable results on the data processed to date.

(iii) Numerical Modelling Studies (F.W. Jones, H.-L. Lam). The perturbation of uniform and nonuniform electromagnetic fields by two-dimensional and three-dimensional electrical conductivity anomalies is being investigated by numerical techniques. The electromagnetic response of a subducting slab, in which the electrical conductivity is derived from the thermal regime obtained from the heat flow modelling work, has been studied and the effects of shear strain heating and upward movement of partial melt has been considered. Work on local anomalies associated with subsurface temperature anomalies is in progress.

(d) Memorial University of Newfoundland (J.A. Wright, B.K. Pal)

A geomagnetic survey along a profile crossing the Gander Zone/Avalon Zone tectonic boundary in Newfoundland has been completed. The experiment was designed to study in more detail the conductive structure previously identified (Wright and Cochrane). The results of the study indicate that the conductive structure is best modelled by a slab at about 5 km depth with a resistivity of 25 Ω -m. This is interpreted as a remnant oceanic slice emplaced during past subduction associated with the closing of the Iapetus ocean. The conductive feature extends about 25 km east of the zone boundary. The resolution of the survey is such that the effect of different closure models cannot uniquely be differentiated. Two-dimensional modelling shows that the field data are inconsistent with either an east-dipping subduction or an obduction tectonic process.

(e) Queen's University (D.V. Woods, A.F. Prugger, M. Allard, H. Geiger)

Magnetometer array data collected in 1969 by H. Porath and others from the University of Texas at Dallas over the mid-continent gravity high in the mid-west U.S. have been re-analysed to better define the electrical conductivity structure of this crustal tectonic feature. Single-station anomalies were found in the vicinity of localized fault zones and areas of high heat flow, however there appears to be no overall conductivity anomaly associated with the mid-continent gravity high structure.

The lack of any significant geomagnetic variation anomaly at periods greater than 20 minutes enables a one-dimensional analysis of the 1969 mid-west U.S. array. Substorms, storms and quiet daily variations were digitized from the original film records and then analysed by the horizontal spatial gradient technique. The results indicate that the upper mantle is relatively resistive to depths as great as 400 km where there is an abrupt increase in conductivity from less than 0.1 s/m to greater than 1.0 s/m. The lack of a conductive layer at asthenospheric depths (100-200 km), although not precisely resolved by the available data, is perhaps indicative of an absence of partial-melt asthenosphere

beneath the stable interior of the North American craton; a result previously demonstrated from Australia and the Soviet Union.

In late 1981, D.V. Woods obtained the University of Texas at Dallas set of 30 Gough-Reitzel magnetic variometers. These instruments were originally built in 1965-68 and were in a state of disrepair when obtained. During the past two years they have been repaired and modified for future array studies in Canada and the United States. They are presently undergoing tests of operational efficiency for field deployment next summer. It is planned to utilize them in a joint Canada-U.S. electromagnetic induction study of the Pacific coast region in 1985.

(f) University of Victoria

(i) Theoretical Studies (J.T. Weaver, D. McA. McKirdy, A. Dolling). New extensions to existing numerical modelling programs have been developed over the past year. The two-dimensional finite difference program (Brewitt-Taylor and Weaver, 1976) has now been implemented on the Department's VAX 750 computer, and new methods of calculating the derived field which avoid interpolations between grid points have been worked out and programmed. These are especially useful when calculations of apparent resistivity and phase are required. This program will be used by the University of Victoria group in the COMMEMI project (an international project in which modelling programs will be compared for accuracy and effectiveness for eventual recommendation to the International Laboratory of Numerical EM Modelling in Finland).

The two- and three-dimensional thin sheet programs have been extended to include a layered substructure and, for the three-dimensional case, a thin resistive sheet under the surface conductive sheet. This has been used to re-examine the problem of channelling between two oceans when a thin resistive layer, which inhibits vertical flow, is present beneath the oceans.

(ii) Geomagnetic Laboratory (H.W. Dosso, W. Nienaber, R. Charters, G. Heard, W.B. Hu). Electric and magnetic field measurements for stations over land and at the surface of the ocean (using the ice as a platform) in the Assistance Bay region for the 8 Hz Schumann resonance field have been analysed and compared with laboratory analogue model measurements. This work was carried out in collaboration with J.E. Lokken, Defence Research Establishment Pacific.

Model measurements of induced electromagnetic fields in a laboratory model of the Hainan Island region of China have been carried out and the analysis of the results is underway. One of the interesting features in this study is the response of a seamount as a function of period for the period range 5 min - 500 min.

An analogue model of the Tasmania region has been constructed and model electric and magnetic field measurements are underway. It is planned to employ these results as an aid to interpreting field station measurements for Tasmania. This work is being carried out in collaboration with W.D. Parkinson, University of Tasmania.

5. Paleomagnetism and Rock Magnetism

(a) Earth Physics Branch (J. Roy, P. Lapointe, J. Park, E. Tanczyk, B. Chomyn)

(i) Precambrian Program. Several units of the Upper Proterozoic Mackenzie Mountains supergroup of the Northwest Territories, including the Redstone River Formation, the Katherine Group, and the Tsezotene Formation, are currently under study. Results from another unit of the supergroup, the Mudcracked Formation of the Little Dal Group, are in press (Canadian Journal of Earth Sciences). The Michael gabbro suite in Labrador is under investigation. Results from the Mealy dykes of Labrador are in press (Canadian Journal of Earth Sciences). A compilation of the Precambrian paleomagnetic data from North America, and a study of Proterozoic sutures in Canada, have been completed.

(ii) Appalachian Program. A synthesis of the paleomagnetic record of the Appalachians was published in a special volume of the IGCP, Project 27. A map of all paleomagnetic Appalachian studies, with accompanying notes on each study, is in

preparation. A review of the Carboniferous paleomagnetic data from North America was also published. A study of the Permian formation of Cap-aux-Meules (upper and lower members) of the Iles-de-la-Madeleine in the Gulf of St. Lawrence, is presently under way.

(iii) St. Lawrence Platform Program. As a complement to Appalachian studies, efforts are being made to obtain paleomagnetic poles from the Paleozoic craton of North America. Some Paleozoic sedimentary rock units were sampled this summer in the Kingston area. Results from another unit, the Cambrian anorthosite body at Sept-Iles, Quebec, are in preparation for publication.

(iv) Arctic Program. Investigation of the Red River Canyon formation from Ellesmere Island is currently in progress.

(v) Technical and Analytical Program. The Earth Physics Branch and Geological Survey of Canada are co-sponsoring the development by CTF Systems of a SQUID (Superconducting Quantum Interference Device) magnetometer. A magnetometer for measuring at high or low temperatures is under development at the Geomagnetic Laboratory of the Earth Physics Branch. The high mode is in operation, and is currently being tested.

(vi) Nuclear Fuel Waste Management Program. The paleomagnetism section of the Earth Physics Branch is responsible for the rock magnetic property task within the Nuclear Fuel Waste Management Program/AECL. The magnetic properties of the East Bull Lake gabbro (remanence, bulk susceptibility, and anisotropy of susceptibility), have been measured and synthesized in the form of surface variation maps. These magnetic parameters have provided excellent control for geological interpretation.

(b) Pacific Geoscience Centre (E. Irving, P.J. Wynne)

Extensive collections were made in 1983 in Axel Heiberg Island (Permian and Cretaceous) and the southern Cordillera (Jurassic and Cretaceous) in collaboration with the G.S.C. Vancouver and I.S.P.G. Calgary and most are already processed. The Permian rocks from the Arctic reveal a 35° anticlockwise rotation in N.E. Sverdrup Basin, and the Cretaceous samples provide information about the Cretaceous Quiet Zone (normal polarity) and reversals associated with the underlying M sequence of magnetic anomalies observed at sea. In the southern Cordillera, work on the Spuzzum batholith is complete; it indicates a 20° southerly displacement of the southern Coast Plutonic Complex in mid-Cretaceous times. Work on the Jurassic Bonanza Volcanics of Vancouver Island also indicates a large southerly displacement.

Studies on the Carboniferous (Deer Lake Group) and Late Devonian (St. Lawrence Granite) of Newfoundland in collaboration with Memorial University are now completed. The Carboniferous results do not support the idea of large displacement in the Appalachians at that time.

Work on 2.2 Ga intrusives (Easter Island dyke and the Blackford Complex) of the Slave Province carried out in collaboration with the G.S.C. Precambrian Division give pole positions different from those for the Superior Province at that time indicating that relative motion occurred between the two during the Hudsonian orogeny.

(c) University of Alberta

(i) Archeomagnetism (M.E. Evans, G.S. Hoyer, M. Mareschal, W.I. Gough, V. Frnoch). Results from preliminary collections of baked archeological features (mostly kilns) in southern Italy indicate that the apparent pattern of secular variation is sufficiently complex that the limited data currently available are inadequate for most geophysical purposes. An effort is therefore underway to improve the data base. The combined sampling, up to and including the 1983 field season, has now yielded suitable material from some fifty archeological features ranging in age from the 8th Century B.C. to the 4th Century A.D. In addition a start has been made on extending this work from Italy to Greece, where a collecting expedition is currently being organized for the 1984 field season.

Paleointensity experiments have been carried out on two specimens from each of eleven basalt flows erupted by Mount Vesuvius between 1631 and 1944, using the well-known method of Shaw. The majority of the specimens (19 out of 22) underwent significant physico-chemical change during laboratory heating, as evidenced by non-linear relationships between anhysteretic remanence (ARM) demagnetization spectra before and after heating. This contrasts markedly with Shaw's original results which had a "success rate" of about 90%. Two points emerge: the validity of Kono's factor is questionable, and the basalts of Vesuvius are generally unsuitable for paleointensity determinations.

Paleointensity work is also being carried out on 21 specimens from archeological kiln walls. This material is much more suited to this kind of work and the results so far available look considerably more promising. Directions of magnetization are very stable in all cases, and coercivity spectra indicate median destructive fields generally in the range 10-30 mT, thus well-suited to Shaw's alternating field demagnetization procedure.

A third set of paleointensity samples will be investigated before the end of the year by the rapid heating method on small samples. This material consists of amphorae fragments (dated by inscriptions), collected from a site in Imperial Rome. As a result of a kind invitation from M.J. Aitken, F.R.S., this work will be carried out at the Research Laboratory for Archaeology, Oxford University, where the method was developed.

(ii) Crowsnest Volcanics (M.E. Evans, W.I. Gough in collaboration with E. Irving, J. Wynne, PGC). An earlier preliminary study which yielded good paleomagnetic results ($N = 11$ sites, $D = 351^\circ$, $I = 67^\circ$, $k = 79$, $\alpha_{95} = 5.2^\circ$) has been extended by sampling a total of 15 sites (89 cores, 8 hand samples). The intent of this work is to provide a well-dated point for the Cretaceous polarity time-scale, and to contribute to our understanding of the complex tectonics involved in the evolution of western North America.

(iii) Quaternary and Tertiary Volcanics in France (M.E. Evans and M. Mareschal). An investigation of basalt flows in southern France has been started. Several new K-Ar dates are now available and this project should therefore help refine our knowledge of the secular variation and polarity reversal pattern over the last few million years. This work is being carried out in conjunction with several laboratories in France.

(d) Dalhousie University (J.M. Hall)

The Centre for Marine Geology Laboratory at Dalhousie was mainly concerned with extending study of the Iceland Research Drilling Project, 3.5 km vertical section of Icelandic crust, and in starting work on several projects related to a major re-appraisal of the Troodos, Cyprus, ophiolite.

Major problems arising from initial paleomagnetic work on the Iceland section concerned depth trends in J_n and K , and the occurrence of mixed polarity flows beneath 2.8 km crustal depth. The occurrence of mixed polarities indicates at least partial loss of original remanence polarity and has implications for the nature of the base of the "tape" of the tape recorder within oceanic crust, wherein initial cooling geomagnetic polarity history is reliably recorded. The approach to studying these phenomena has been to accumulate systematic rock magnetic and oxide petrographic data. These include J_s , J_{sr} , Curie point, primary magnetite, deuteric, hydrothermal and low temperature oxidation state, and amount of secondary magnetite. Secondary magnetite is restricted here to oxide formed well after initial cooling, probably as the result of dike intrusion. To date it has been possible to demonstrate downwards increase in Curie point in the section, and decrease below 1.6 km in J_s corresponding to similar decrease in J_n and K . It has also been possible to separate the effects of reduction in primary oxide content as a result of extensive regional hydrothermal alteration from increase in secondary oxide as a result of dike intrusion. Magnetic carrier nature has been identified from petrographic work and the J_{sr}/J_s ratio: effective grain size at the lower end of the PSD range is characteristic of both flows and dikes in the section.

Initial work on material from the Troodos ophiolite includes study of the inverse relationship between susceptibility and argillization in high temperature upwelling zones in the extrusives, on the variation of magnetization in downwelling zones and within

the lower part of the sheeted complex and the upper part of the plutonic complex.

Two cores from the Alpha Cordillera area of the Arctic Ocean have been studied paleomagnetically. Plots of stable inclinations versus depth in the cores show the presence of distinctive normal and reverse polarity chrons resembling those observed elsewhere, and correlation with the accepted paleomagnetic stratigraphy is attempted. An average sedimentation rate of 1.00 mm/1000 years is calculated based on the Brunhes-Matuyama and Matuyama-Gauss transitions. The oldest sediments represented in the cores were deposited between 4.5 and 4.2 Ma BP.

(e) Université Laval (M.K. Séguin)

Extensive paleomagnetic sampling of Archean rock units (lavas, gabbros, tuffs, tonalites and granites) from the Frotet-Evans greenstone belt, Quebec. Paleomagnetic study undertaken by E. Gahé and M.K. Séguin in collaboration with A. Simard from the Quebec Department of Energy and Natural Resources.

Write-up stage of the paleomagnetic study of the gabbro sills of the northern sector of the Labrador Trough. M.K. Seguin in collaboration with T. Clark and D. Fournier from the Quebec Department of Energy and Natural Resources.

Write-up stage of the paleomagnetic study of the alkaline suite of Mount Megantic, Quebec, and surrounding rock units. M.K. Seguin in collaboration with B. St. Hilaire, Petro-Canada, Quebec.

Nova Scotia. The paleomagnetic research done by M.K. Séguin and K.V. Rao in collaboration with E.R. Deutsch (Memorial) is under way. Two papers in Cambrian rock units from the Avalon Zone have been submitted for publication.

New Brunswick. Paleomagnetic study of Lower carboniferous lavas and redbeds from central New Brunswick was initiated in the summer of 1983. Collaboration M.K. Séguin and L. Fyffe, New Brunswick Department of Natural Resources.

Québec. Iles d'Anticosti et Mingan, Golfe Saint-Laurent. M.K. Séguin et A.A. Petryk (MERQ) ont continué leur étude paléomagnétique détaillée des sections-types: Ordovicien-Silurien.

M.K. Séguin with the collaboration of J. Desbiens and G. De Broucker (students) has undertaken a large paleomagnetic study of the Upper Palaeozoic basic dykes from the eastern Gaspé Peninsula.

Baltic Shield (Norway, Sweden and Baltic islands). A joint paleomagnetic project between Université de Laval (M.K. Séguin) and the University of Lund in Sweden (G. Bylund) with the collaboration of P. Nystrueen (Norway) started in late 1981 and is now underway. The paleomagnetic study of tillites of Vendian age and most of the Cambrian (Lower, Middle and Upper) sequence is completed. Lithological units having a very low intensity of remanent magnetization were measured with a cryogenic magnetometer.

An important paleomagnetic study (over 50 sampling sites) was undertaken in the summer of 1983 by M.K. Séguin in collaboration with T. Feininger (now at EPB). This investigation is aimed at a better understanding of the formation of the Andean mountain chain. In Ecuador, the sampling was carried out in different metamorphic and unmetamorphosed terranes from the Sierra, Oriente and Costa regions. In Peru, the sampling was carried out in sedimentary, volcanic and granitic rocks of Cretaceous and Tertiary age.

(f) Memorial University of Newfoundland (E.R. Deutsch, J.P. Hodych, G.S. Murthy, R.R. Patzold, O. Ozdemir, S. Gower, J.N. Prasad)

(i) Paleomagnetism. G. Murthy and C. Brown sampled the Proterozoic Ramah Group from the Saglek-Little Ramah Bay areas of northern Labrador during the summer. Ultramafics, diabase sills, quartzite and basalt dated ~ 1,800 Ma and pre-Ramah diabase dike samples were collected.

J. Prasad collected early Paleozoic, chiefly carbonate rocks in the Humber Zone of western Newfoundland to initiate doctoral studies with the aim of greatly improving the Cambrian-Ordovician paleomagnetic data base for this part of the North American craton. Preliminary measurements indicate that the stable remanence in the limestones resides predominantly in sub-microscopic magnetite.

J.P. Hodych, R.R. Patzold and K.L. Buchan (1983) found a stable, single-component remanence in the oolitic hematite ores of Birmingham, Alabama. This remanence was stable enough to have survived major folding, but a negative conglomerate test and the direction of remanence show that the remanence was very likely acquired in the Pennsylvanian - about 130 million years after Silurian deposition of the ores.

G. Murthy and S. Gower have studied the paleomagnetism of the Uppermost Member of the Middle Ordovician Long Point Formation from western Newfoundland. A positive fold test suggests that the isolated magnetization with directions (331.1° , -13.7°) is primary and probably representative of the uppermost Middle Ordovician times. By comparing with the published data from cratonic North America, it is concluded that a rotation of western Newfoundland by about 10° is not unlikely.

A paleomagnetic investigation of Paleozoic rocks of the Avalon Zone was continued by E. Deutsch in co-operation with M.K. Séguin (Laval University). In 1983 this work centered on rocks in Nova Scotia.

Continuing a paleomagnetic program in the Irish Caledonides, E. Deutsch collected volcanic and sedimentary rocks of Lower Ordovician to Lower Silurian age from the Tourmakeady-Glensaul inlier, Sheeffry Hills and Finney areas in Mayo and Galway Counties, western Eire. These rocks form synclinal structures amenable to a fold test.

Paleomagnetic comparisons with southeastern British and Irish localities may tell whether (1) the wide Proto-Atlantic Ocean previously inferred from mid-Ordovician rocks in NW and SE Ireland can be traced to the early Ordovician; (2) the ocean had partly or fully closed by the early Silurian; and (3) the Tourmakeady-Glensaul arc is primary.

(ii) Rock Magnetism. J.P. Hodych extended earlier measurements (Hodych, 1982) on hysteresis as a function of low temperature in rocks, finding further evidence of magnetostrictive control of coercive force in multidomain magnetite. For some of these samples, magnetic susceptibility was also measured as a function of low temperature, providing evidence that susceptibility is also magnetostrictively controlled. These studies also yield a new method for estimating self-demagnetizing factor (Hodych, 1983).

A magnetic/thermomagnetic study of 17 flows of N, R and transitional polarity in the Miocene Columbia River Basalts (NW United States) was completed (Deutsch, Murthy, Patzold, in collaboration with C. Radhakrishnamurty of the Tata Institute, Bombay). Paleomagnetism of the exposures had been done previously (Watkins, 1965 and others). The main conclusions are: (1) The (titano) magnetite (TM) in these basalts seems to comprise mainly fine to hyperfine singledomain particles; (2) In some samples the TM is highly cation-deficient; (3) Magnetic behavior associated with multidomain magnetite is rare; (4) High-titanium ($\geq 50\%$ ulvospinel) TM sometimes occurs, contrary to its reported absence in the (older) Deccan and Rajmahal Traps; (5) The hysteresis and thermomagnetic properties of the high-Ti samples strikingly resemble those reported for samples of similar composition from drilled oceanic basalts and from synthetic TM's; (6) There is no conclusive correlation of magnetic properties with polarity.

O. Ozdemir (Post-Doctoral Fellow) and E. Deutsch studied oolitic iron ore from the Lower Ordovician Wabana Group, Newfoundland, examining the roles played during heating by the iron-bearing minerals hematite, siderite and chamosite. Dramatic peaks observed in the thermal demagnetization curves resemble earlier findings by K.V. Rao (M.Sc. thesis, Memorial University) and are attributed to a chemical change of the siderite during repeated laboratory heating. X-ray analysis confirmed magnetite as the newly formed material. The siderite-free rocks gave a very stable high-temperature remanence residing in hematite, with a virtual pole at 34°N , 114°E .

(g) University of Toronto, Rock Magnetism Group (D.J. Dunlop, O. Ozdemir, C.J. Hale, K.S. Argyle, H. Hyodo, F. Heider, R. Enkin, V. Costanzo, K.G. Burns, R. Van de Water, L.E. Hale)

(i) The CRM resulting from oxidation of magnetite to hematite depends both on the initial remanence (e.g., ARM) and the applied field H_{CRM} . For H_{CRM} perpendicular to J_{ARM} the CRMs lie on a great circle path between the two, in a position determined by the relative strengths of H_{CRM} and J_{ARM} . A magnetostatic coupling of the CRM to H_{CRM} and J_{ARM} is suggested by a linear plot of $J_{ARM}(500^{\circ}C)/H_{CRM}$ vs. $\tan(\text{CRM inclination})$. The same type of experiment was done for the oxidation of magnetite to cation-deficient magnetite close to maghemite. The CRMs retain the direction of J_{ARM} and are unaffected by H_{CRM} . The different results from the two oxidation reactions can be explained by the crystal structures of the oxidation products. The superexchange interaction between the iron magnetic moments is not maintained during the formation of a rhombohedral lattice (hematite) from an inverse spinel lattice (magnetite). In the oxidation to cation-deficient magnetite, the lattices are compatible and the superexchange is not broken. Consequently, the CRM remains parallel to the ARM.

(ii) The relative intensities of CRM and pTRM have been studied using the inversion of titanomaghemite and maghemite. CRM intensity is proportional to pTRM carried by magnetite or hematite, and CRM coercivity spectra are similar to those of pTRM. This raises the possibility that paleointensity information may be recovered from CRMs. The blocking temperatures of CRM tend to be tightly grouped but vary systematically with the strength of the inducing field. These characteristics may be useful indicators of CRM in natural samples.

(iii) A new study is being initiated to attempt to duplicate in the laboratory the variation of the properties of remanent magnetization (intensity, stability and direction) during low-temperature oxidation of submarine basalts. The experiments will be carried out on Al-doped synthetic monodomain $x = 0.4$ and 0.6 titanomagnetites. CRM will be studied during the titanomagnetite to titanomaghemite oxidation. The initial remanence of the titanomagnetites will be a TRM.

(iv) Paleodirectional and paleointensity results from the ~ 3.5 Ga Komati Formation of South Africa are now complete. The Komati paleopole is the oldest dated pole position from terrestrial rocks. Paleointensities do not differ significantly from the present geomagnetic field strength, implying that the core was fully formed at ~ 3.5 Ga. The nearly polar paleolatitude of Archean Africa may have important implications for Archean global tectonics. This position was apparently still occupied by Africa during the early Proterozoic. The essential lack of continental drift for ~ 1 Ga may imply that the plate tectonic mechanism was not yet operative. This work has been submitted for publication to Geophysical Research Letters.

(v) The late Archean (2580 Ma) Shelley Lake granite of the western Superior Province in Ontario has two distinctive NRM vectors, frequently superimposed in single samples. The characteristic (high- T_B , high- H_C) NRM is a primary TRM with perhaps some coupled later CRM. The other NRM is a CRM acquired in the later Proterozoic, probably in a mild heating event related to initial Keweenaw rifting detected by $^{40}\text{Ar}/^{39}\text{Ar}$ dating. This work and supporting rock magnetic studies have been submitted to Canadian Journal of Earth Sciences.

(vi) The study of remanence resetting NNW of the Grenville Front in the Temagami and Sudbury areas described in last year's report is largely complete. Matachewan-like overprints of Nipissing diabbases are confirmed at 7 sites in the Temagami area, all within 5 km of the Front. Grenvillian overprinting extends similar distances from the Front, except around Lake Wanapitei, where it is detected 9 km N of the Front. Archean granodiorites and greenstones have the same overprint as Nipissing diabbases.

(vii) Relatively low-grade intermediate to felsic pyroclastic rocks have been sampled near Madoc, Ontario. The object of the study is to recover a paleopole predating the Grenvillian orogeny and to test whether the Grenville Province has always been part of cratonic North America.

(viii) Domain state energy calculations have been made for submicron magnetite cubes, based on a model consisting of planar domains of uniform magnetization $\pm J_s$ separated by 180° domain walls (DWs). The magnetization within a DW is assumed to rotate uniformly, resulting in a net DW magnetization $\pm(2/\pi)J_s$. Equilibrium states are determined by the minimization of the magnetic energy.

Zero-field domain structure configurations have been determined for cube widths from $a = 0.05$ to $0.20 \mu\text{m}$. The single domain to two domain transition occurs at $0.06 \mu\text{m}$ where the single DW fills 97% of the particle volume, decreasing to 66% as a increases to $0.13 \mu\text{m}$. In this range, the single particle remanence, which is due entirely to the DW, decreases from $J_r/J_s = 0.62$ to 0.42 . The three domain state extends from $a = 0.13 \mu\text{m}$ to $0.20 \mu\text{m}$. The particle remanence increases from $J_r/J_s = 0.02$ to 0.10 as the fractional particle volume filled by the DWs decreases from 98% to 90%. This work has been submitted to Geophysical Research Letters.

Further calculations are being made to determine equilibrium domain states in the presence of static magnetic fields. In particular, it is possible to synthesize magnetization curves for different particle sizes and for different orientations of the applied field.

(ix) Synthetic samples of three magnetites in the low PSD size range (average particle sizes of 0.7 , 0.3 and $4.8 \mu\text{m}$) have been made and their magnetic properties are being studied. The anisotropy that controls the magnetization process is being determined from hysteresis measurements as a function of temperature from 77K to the Curie point. The properties of ARM, IRM and TRM that characterize PSD behavior in this particle size range have been determined from thermal, AF and low-temperature demagnetization. TRM experiments are underway to test current models of the PSD mechanism.

(h) The University of Western Ontario

(i) Powdermill Volcanics (H.C. Palmer and H.C. Halls, University of Toronto). Paleomagnetic data from 44 sites within the Powdermill Volcanics (formerly the South Range Traps) of Michigan and Wisconsin have been analyzed. The sites are distributed along a strike length of 100 km and cross a maximum stratigraphic thickness of 6 km . Because of the range of dips from our sites we have been able to demonstrate that the simple structural correction (rotation about the line of strike by the value of the dip) is appropriate for these rocks. We are able to conclude from the data in hand that: (1) most Powdermill Volcanics contain a pronounced overprint; (2) the South Range "normal" magnetization reported by Books (1968) from the lowermost flows is not confirmed. His normal site has been resampled by us and the samples do not contain consistently directed stable components; (3) two sites, part way up the stratigraphic succession, possess normal Keweenawan directions and are in rocks with hornfelsic textures. This normal zone cannot be traced laterally and is probably the result of a localized middle Keweenawan intrusive; (4) we cannot confirm that the Powdermill normal division precedes the Powdermill reverse division and thus the connection between 1.2 Ga equatorial poles and the high latitude 1.1 Ga Keweenawan reverse poles is undocumented.

(ii) Precambrian Dike Swarms - Southern and Superior Province Boundary (H.C. Palmer). Pre-Huronian dikes north of Elliot Lake and having a trend of 325° are characterized by Matachewan type directions ($206^\circ - 05^\circ$, $\alpha_{95} = 13^\circ$). Thus no post-Matachewan differential rotation between the type area and the Elliot Lake area is in evidence. Both NE-trending and NW-trending tholeiitic dikes in the Elliot Lake area share a common paleomagnetic direction ($275^\circ + 70^\circ$, $\alpha_{95} = 8^\circ$). This direction is similar to that reported from ENE-trending tholeiitic dikes in the Timmins area ($267^\circ + 63^\circ$, $\alpha_{95} = 4^\circ$) as reported by Irving and Naldrett (1977).

(iii) Paleomagnetism of Great Lakes Sediment (C.M. Carmichael and J. Mothersill, Lakehead University). The study of piston cores collected in co-operation with the Canada Centre for Inland Waters is continuing. The magnetic measurements of cores from Lakes Erie and Ontario have been completed. Pollen count correlations are being done as an aid to dating to supplement ^{14}C dates. These give satisfactory relative dates but due to non-organic carbon content their absolute ages are too high. Many of the Lake Erie cores record a magnetic inversion inferred to be about $9,000$ years old. Whether this represents

a magnetic or sedimentological event is uncertain. At present magnetic measurements are under way on a long core from the deep basin south of Manitoulin Island in Lake Huron.

(i) University of Windsor (D.T.A. Symons, C.P. Gravenor, M. Stupavsky)

(i) Reconstruction of Laboratory. A new 4 m x 3 m x 3 m magnetically shielded room has been built using 3 layers of electrical grade steel, for a total cost including labour of ~ \$8,000.00, which reduces the Earth's ambient magnetic field to an average of ~ 70γ. A new CTF cryogenic magnetometer is currently being installed. It and the Schonstedt magnetometer have been interfaced to an Apple 2+ computer system for complete on-line data analysis.

(ii) Algonian Banded Iron Formations in Ontario. Results on rock magnetic and paleomagnetic analysis of > 2,000 specimens from the Griffith Mine site have been reported. Also a summary article on this, and on the Moose Mountain, Sherman, and Adams Mine data, has been published under an OGS Research Agreement. A computer analysis of ~ 400 aero magnetic anomalies in a test area of northeastern Ontario has been completed that led to the identification of 8 anomalies that have economic potential as iron deposits and a similar number of marginal anomalies. This work was also sponsored by the OGS.

(iii) Huronian of Ontario. A 300 clast conglomerate test on the Gowganda Formation, undertaken as an M.Sc. thesis project by K.A. Saad, is in the final write-up stage.

(iv) Western Canadian Cordillera. Results of thermal demagnetization studies on the Topley Intrusions and Guichon Batholith in the Stikinia subterrane have been published, and lead to a revision of earlier poles based on AF data only. This resolves the conflict caused by the earlier poles in current geotectonic models for the area.

(v) Glacial Sediments. Detailed sampling using various techniques in soft glacial sediments shows conclusively that some sampling methods (e.g., push-in cubes) can lead to severe systematic errors in magnetic fabric and paleomagnetic results.

6. Bibliography

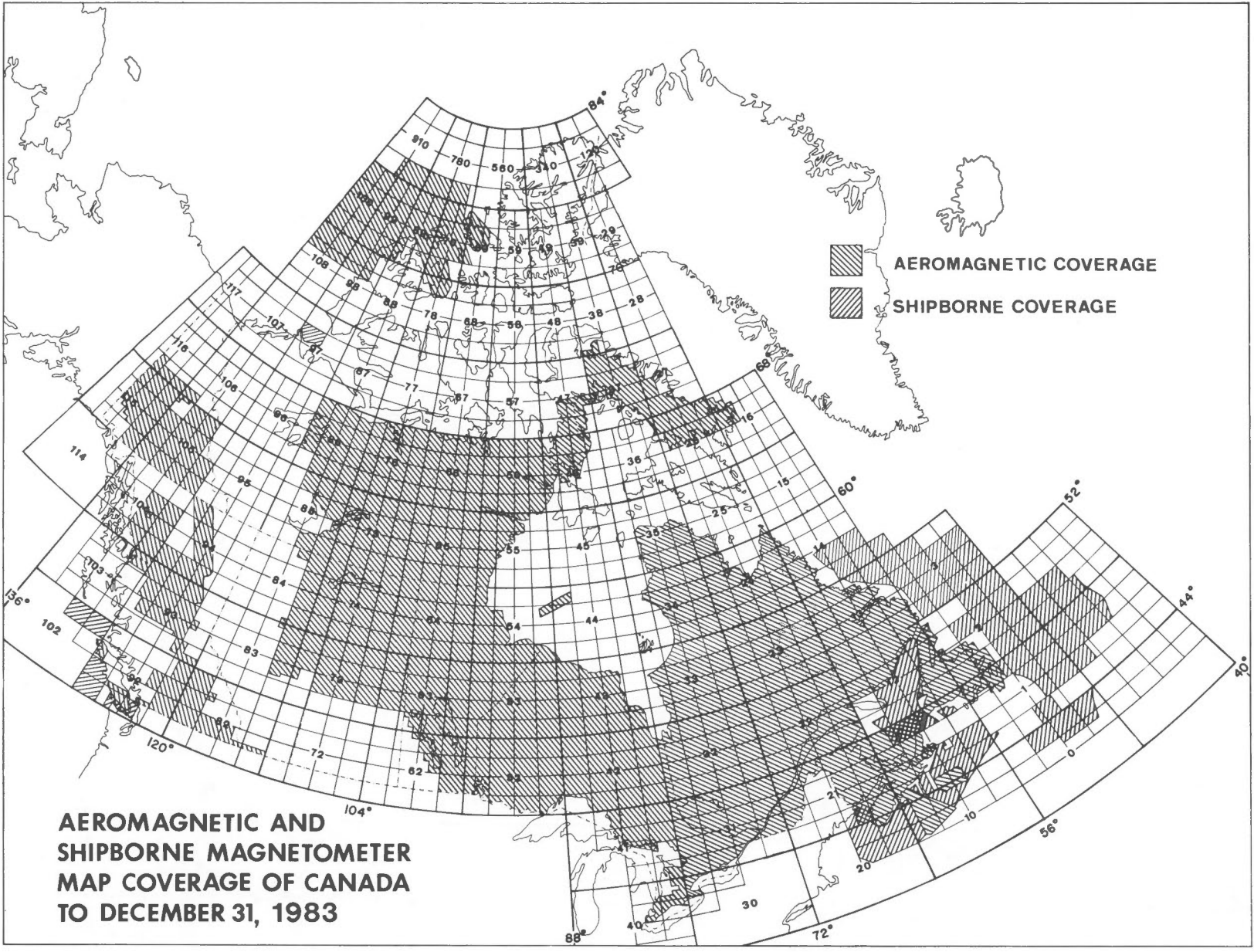
- Bailey, M.E. and Dunlop, D.J. 1983. Alternating field characteristics of pseudo-single domain (2-14 μm) and multidomain magnetite. *Earth Planet. Sci. Lett.*, 63, 335-352.
- Clark, J.F. 1983. Magnetic survey data at meteorite impact sites in North America. Earth Physics Branch Open File Report 83-5.
- Daly, L. and Irving, E. 1983. Paléomagnétisme des roches carbonifères du Sahara central; analyse des aimantations juxtaposées; configuration de la Pangée. *Ann. Géophysicae*, 1, 207-216.
- Dawson, E. and Newitt, L.R. 1982. The magnetic poles of the earth. *J. Geomag. Geoelectr.*, 34, 225-240.
- Dawson, E. and Newitt, L.R. 1982. Comparison of IGRF models with North American magnetic data. *J. Geomag. Geoelectr.*, 34, 393-440.
- Dunlop, D.J. 1983. Determination of domain structure in igneous rocks by alternating field and other methods. *Earth Planet. Sci. Lett.*, 63, 353-367.
- Dunlop, D.J. 1983. On the demagnetizing energy and demagnetizing factor of a multidomain ferromagnetic cube. *Geophys. Res. Lett.*, 10, 79-82.
- Dunlop, D.J. 1983. Viscous magnetization of 0.04-100 μm magnetites. *Geophys. J. Roy. astr. Soc.*, 74, 667-687.
- Dunlop, D.J. and Schutts, L.D. 1983. Proterozoic magnetic overprinting and tectonics of the Laurentian Shield. *Geol. Soc. Amer. Memoir*, 161, 35-45.

- Gibb, R.A., Thomas, M.D., Lapointe P. and Mukhopadhyay, M. 1983. Geophysics of proposed Proterozoic sutures in Canada. *Precambrian Research*, 19, 349-384.
- Gough, D.I. 1983. Electromagnetic geophysics and global tectonics. *J. Geophys. Res.*, 88, 3367-3377.
- Gough, D.I. and Ingham, M.R. 1983. Interpretation methods for magnetometer arrays. *Rev. Geophys. Space Phys.*, 21, 805-827.
- Gupta, J.C. 1983. Harmonic coefficients from solar and lunar daily variations from long series of hourly geomagnetic data from Canada. Earth Physics Branch Open File Report 83-1.
- Gupta, J.C. 1983. Pcl pulsation activity at Ottawa. *J. Geophys. Res.*, 88, 2075-2082.
- Gupta, J.C., Kurtz, R.D. and Camfield P.A. 1983. An induction anomaly near the west coast of Hudson Bay, Canada. Earth Physics Branch Open File Report 83-29.
- Haines, G.V. 1983. EPB aeromagnetic data (1953-1976). Aeromagnetic Data Workshop November 16-18, 1982 Boulder, Colorado, Workshop Proceedings - 1, National Oceanic and Atmospheric Administration, National Geophysical Data Center, Boulder, Colorado, 5-19.
- Hamilton, T.S. and Evans, M.E. 1983. A magnetostratigraphic and secular variation study of Level Mountain, northern British Columbia. *Geophys. J. Roy. astr. Soc.*, 73, 39-49.
- Hebert, D., Dosso, H.W., Nienaber, W. and Wright, J.A. 1983. Analogue model study of electromagnetic induction in the Newfoundland region. *Phys. Earth Planet. Inter.*, 32, 65-84.
- Hodych, J.P., Patzold, R.R. and Buchan, K.L. 1983. Paleomagnetic dating of the transformation of oolitic goethite to hematite in iron ores. *EOS*, 64, 683.
- Hood, P. 1983. Mineral exploration: trends and developments in 1982. *Can. Min. J.*, 104(1), 14-45.
- Hood, P. and Sawatzky, P. 1983. Bourget aeromagnetic calibration range. *Geol. Surv. Can. Paper* 83-1A, 483-485.
- Ingham, M.R., Bingham, D.K. and Gough, D.I. 1983. A magnetovariational study of a geothermal anomaly. *Geophys. J. Roy. astr. Soc.*, 72, 597-618.
- Irving, E. 1983. Fragmentation and assembly of the continents, mid-Carboniferous to present. *Geophys. Surveys*, 5, 299-333.
- Irving, E. and Sweeney, J.F. 1982. Origin of the Arctic Basin. *Trans. Roy. Soc. Canada*, 20, 407-416.
- Jackson, H.R. 1983. Rotation poles for the eastern Arctic and implications for Nares Strait. 18th General Assembly of the International Union of Geodesy and Geophysics, Hamburg, Germany.
- Jackson, H.R. and Reid, I. 1983. Oceanic magnetic anomaly amplitudes: variation with seafloor spreading rate and possible implications. *Earth Planet. Sci. Letters*, 63(3), 368-378.
- Jansen van Beek, G. and Coles, R.L. 1983. Annual report for magnetic observatories - 1980. *Geomagnetic Series*, Earth Physics Branch, No. 23.
- Jansen van Beek, G. and Coles, R.L. 1983. Annual report for magnetic observatories - 1981. *Geomagnetic Series*, Earth Physics Branch, No. 24.

- Krentz, D.H. 1983. Interpretation of the Wopmay Fault Zone using audiomagnetotellurics; Unpublished B.Sc. Thesis, Queen's University, Kingston, Ontario.
- Kurtz, R.D. and Niblett, E.R. 1983. Magnetotelluric survey over the East Bull Lake gabbro-anorthosite complex, AECL Report RW/GPH - 184-83.
- Lapointe, P. 1983. Book Review, "The Road to Jaramillo: Critical years of the revolution in Earth Sciences", by W. Glen, Stanford University Press. Geoscience Canada, 10, 139-140.
- Lapointe, P., Chomyn, B.A. and Morris, W.A. 1983. Annual report 1982-1983 - Rock magnetic properties task, Rock Properties Activity. Earth Physics Branch Open File Report 83-4.
- Lapointe, P., Chomyn, B.A., Morris, W.A. and Coles, R. 1983. Significance of magnetic susceptibility measurements from the Lac du Bonnet Batholith, Manitoba, Canada. In: Geophysical Investigations in connection with Geological Disposal of Radioactive Waste. Nuclear Energy Agency, OECD, 297-309.
- Macnab, R. 1983. Multiparameter surveys in the offshore: broadening the dimensions of hydrography. In: Proceedings of Centennial Conference, Canadian Hydrographic Service, Ottawa, 149-156.
- Macnab, R. 1983. Multiparameter mapping off the east coast of Canada. Geol. Surv. Can. Paper 83-1A, 163-171.
- Macnab, R. 1983. SHIPAC: A software package for the shipboard processing of marine geophysical survey data. Geol. Surv. Can. Paper 83-1B, 327-330.
- Miller, R.O., Macnab, R., Amos, C.L. and Fader, G.B. 1983. Canadian east coast multiparameter surveys, 1982. Geol. Surv. Can. Paper 83-1B, 331-334.
- Murthy, G.S. 1983. Paleomagnetism of the Deadman's Bay diabase dikes from northeastern central Newfoundland. Can. J. Earth Sci., 20, 195-205.
- Murthy, G.S. 1983. Paleomagnetism of diabase dikes from the Bonavista Bay area of northeastern central Newfoundland. Can. J. Earth Sci., 20, 206-216.
- Nienaber, W., Hebert, D. and Dosso, H.W. 1983. Induction arrows for a buried conducting plate. Phys. Earth Planet Inter., 32, 306-311.
- Pal, B.K. 1983. Geomagnetic induction studies in eastern Newfoundland. Unpublished M.Sc. Thesis, Memorial University of Newfoundland, 93 pp.
- Palmer, H.C., Baragar, W.R.A., Fortier, M. and Foster, J.H. 1983. Paleomagnetism of Late Proterozoic rocks, Victoria Island, Northwest Territories, Canada. Can. J. Earth Sci., 20, 1456-1469.
- Radhakrishnamurty, C., Likhite, S.D., Deutsch, E.R. and Murthy, G.S. 1982. On the complex magnetic behavior of titanomagnetites. Phys. Earth Planet. Inter., 30, 281-290.
- Ramaswamy, V., Doss, H.W. and Winter, R. 1983. An electromagnetic model study of the Rhinegraben Anomaly. J. Geomag. Geoelectr., 35, 17-27.
- Rankin, D. and Pascal, F. 1983. A practical method for the inversion of magnetotelluric data for a layered Earth. Geophys., 48, 736-744.
- Reynolds, P.H. and Murthy, G.S. 1983. Devonian dikes from north central Newfoundland: a radiometric paleomagnetic study. Geophys. Res. Lett., 10, 432-435.

- Roy, J.L. 1983. Paleomagnetism of the North American Precambrian: a look at the data base. *Precambrian Research*, 19, 319-348.
- Roy, J.L. and Morris, W.A. 1983. A review of paleomagnetic results from the Carboniferous of North America; the concept of Carboniferous geomagnetic field horizon markers. *Earth Planet. Sci. Lett.*, 65, 167-181.
- Roy, J.L., Tanczyk, E. and Lapointe, P. 1983. The paleomagnetic record of the Appalachians. In: *Regional Trends in the Geology of the Appalachian-Caledonian-Hercynian-Mauritanide Orogen*. P.E. Schenk (Editor), IGCP project 27 NATO ASI Series. Reidel Publishing Company Dordrecht-Holland, 11-26.
- Russell, R.D., Narod, B.B. and Kollar, F. 1983. Characteristics of the capacitively-loaded fluxgate sensor. *IEEE Transactions on Magnetics*, Mag-19, No. 2, 126-130.
- Samson, J.C. 1983. Pure states, polarized waves and principal components in the spectra of multiple geophysical time series. *Geophys. J. Roy. astr. Soc.*, 72, 647-664
- Samson, J.C. 1983. The spectral matrix, eigenvalues and principal components in the analysis of multichannel geophysical data. *Ann. Geophysics*, 1, 115-119.
- Séguin, M., Sharma, K.N.M., Woussen, G., St. Seymour, K. and Symons, D.T.A. 1983. Paleomagnetism of the Archean volcanics and Proterozoic dikes in La Grande Riviere area of Nouveau Quebec. *Can. J. Earth Sci.*, 20, 339-343.
- Shih, K.G. and Macnab, R.F. 1983. Computer contouring of marine survey data: choosing the best technique for gridding input data. *Geol. Surv. Can. Paper 83-1A*, 173-178.
- Shih, K.G., Doherty, F. and Macnab, R. 1983. A fast polynomial approximation of the International Geomagnetic Reference Fields. *Geol. Surv. Can. Paper 83-1A*, 486.
- Soffel, H.C., Deutsch, E.R., Appel, E., Eisenach, P. and Petersen, N. 1982. The domain structure of synthetic stoichiometric TM10-TM75 and Al-, Mg-, Mn- and V-doped TM62 titanomagnetites. *Phys. Earth Planet. Inter.*, 30, 336-346.
- Stupavsky, M. and Symons, D.T.A. 1983. Penokean remagnetization of the basal Huronian volcanics near Elliot Lake, Ontario. *Can. J. Earth Sci.*, 20, 49-56.
- Stupavsky, M., Symons, D.T.A. and Gravenor, C.P. 1982. Evidence for metamorphic remagnetization of upper Precambrian tillite in the Dalradian Supergroup of Scotland. *Trans. Roy. Soc. Edinburgh*, 73, 59-65.
- Symons, D.T.A. 1983. A low cost magnetically shielded room for paleomagnetic research. *EOS* 64, 220.
- Symons, D.T.A. 1983. New paleomagnetic data for the Triassic Guichon batholith of south central British Columbia and their bearing on Terrane I tectonics. *Can. J. Earth Sci.*, 20, 1340-1343.
- Symons, D.T.A. and Osmani, I. 1982. Magnetization characteristics of the Algoman iron formation and host rocks at the Griffith Mines, Red Lake, Ontario. *Ont. Geol. Surv. Open File Rep.*, 5447, 19-57.
- Symons, D.T.A. and Stupavsky, M. 1982. Component magnetization of Algoman banded iron formations and deposits in Ontario. *Ont. Geol. Surv., Open File Rep.* 5447, 1-18.
- Turner, G.M. and Gough, D.I. 1983. Magnetic fabric, strain and paleostress in the Canadian Rocky Mountains. *Tectonophysics*, 96, 311-330.
- Vogt, P.R., Kovacs, L.C., Bernero, C. and Srivastava, S.P. 1982. Asymmetric geophysical signatures in the Greenland-Norwegian and southern Labrador seas and the Eurasia Basin. *Tectonophysics*, 89 (1/3), 95-160.

- Walker, J.K. 1982. Extremely quiet nighttime currents and magnetic baselines at Canadian observatories for the separation of external and internal fields. *J. Geophys. Res.*, 87, 7525-7538.
- Wynne, P.J., Irving, E. and Osadetz, K. 1983. Paleomagnetism of the Esayoo Formation (Permian) of northern Ellesmere Island: possible clue to the solution of the Nares Strait dilemma. *Tectonophysics*, 100, 241-256.



III (B) AERONOMY AND SPACE PHYSICS

Compiled by: D. Venkatesan

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2. University of Calgary, Space Science Group
3. University of Victoria, Department of Physics
4. University of Saskatchewan, Institute of Space and Atmospheric Studies
5. University of Western Ontario, Centre for Radio Science
6. York University, Centre for Research in Experimental Space Science
7. Earth Physics Branch, Energy, Mines and Resources
8. Communications Research Centre, Radio Propagation Laboratory
9. Herzberg Institute of Astrophysics, NRC, Ottawa

1. University of Alberta, Space Physics Group

The study of the modulation of ULF pulsation activity by magnetospheric substorms indicates that substorm expansive phase features and ULF auroral oval pulsations are all manifestations of the Kelvin-Helmholtz instability at the interface between low latitude boundary layer and magnetospheric central plasma sheet. A complete study of morning sector ULF activity was carried out (G. Rostoker, J. Samson, and L. Spadinger). A superposed epoch study of several tens of individual substorm expansive phase onsets revealed a brief growth in pulsation power about 90 minutes ahead of the substorm expansive phase onset, coincident with a southward turning of the interplanetary magnetic field (IMF). The expansive phase onset, itself, was triggered by a northward turning of the IMF and appeared to involve a significant growth in pulsation power in the Pc 5 band. Theoretical studies are presently underway to explain how these observations relate to the frequency shift of Pc 5 pulsations across noon which are associated with substorm expansive phase activity. G. Rostoker and M. Jeremy also are investigating how the morning sector ULF activity varies with changes in auroral electrojet, field-aligned current and IMF fluctuations. Another study (G. Rostoker, M.G. Connors and D.S. Salopek) of the behaviour of the eastward auroral electrojet activity in the pre-midnight quadrant, has found instances where the strength of the eastward electrojet in the Alberta sector was (unexpectedly) larger than in the Alaska sector to the west. Ratios of the current strengths in the Alberta sector to that in the Alaska sector as high as 24:1 have been detected during episodes of substorm activity. Model studies can explain the result in terms of ionospheric current flow generated close to the location of the upward current flow associated with the development of a westward travelling surge.

The development of discrete auroral arcs (M.S. Tiwari and G. Rostoker) has been studied through a theoretical study of the mechanism by which electrons are accelerated downward (near altitudes of about 1-2 R_E thereby creating intense auroral luminosity). They found that large amplitude Alfvén waves incident on the topside ionosphere would steepen into shocks due to a sharp discontinuity of mass density as a function of altitude near 1-2 R_E . Using the method of characteristics, they found that the parallel electric field associated with the propagating shock was quite capable of accelerating electrons to about 1-10 keV in a few tens of km.

J. Samson and M. Connors have developed a field-aligned and ionospheric current model of substorm-triggered Pi 2 pulsations. It successfully predicts the polarizations and localizations of the Pi 2, and suggests that the Pi 2's are associated with a rapid westward (10-30 km/sec) motion of transient field-aligned current, in turn probably associated with the westward expansion of the auroral arc brightening. Most of the wave-polarization features of this model agree with the data published by Samson and Harrold (1983). J. Samson and B. Harrold have continued their study of Pi 2's by measuring the phase velocities and frequencies near the onset of the substorm. While most phase velocities equatorward of the onset are westward, near the onset the results are mixed (eastward and westward). J. Samson and K. Yeung have extended their studies of polarization and pure state filters for multichannel geophysical data. Three estimators have proven to be useful in estimating the polarization "directions" in the spectral representation of the multichannel time-series, and these estimators have been

incorporated in a revised version of the FORTRAN program for filtering and estimating pure states. J. Samson has also completed studies on sample-bias in polarization estimators. Much improved estimators can be obtained by using the asymptotic expansions for the biases. K. Yeung is also studying aspects of the distributions of estimators of scalar invariants of the spectral matrix, including the degree of polarization estimator. The higher order statistics of estimators of the spectral matrix, and invariant, symmetrical functions of the form $(\text{tr} \underline{S}^k)^n$ (\underline{S} is the estimator of the spectral matrix) involve hypergeometric functions of matrix arguments, and analytic results are difficult to obtain. Methods using asymptotic expansion are being explored in order to overcome these difficulties (G. Rostoker, J. Samson).

2. University of Calgary, Space Science Group

The Space Science Group, an inter-faculty group, (chairman, D. Venkatesan) reporting directly to the Vice President (Research) is involved in a number of projects. The Canadian Corporation for University Space Science (CCUSS) at U. of C. functions under the same umbrella. The group acknowledges a small operating grant from the Research Grants Committee of the University. The Directors of CCUSS for the year 1983-84 are L.L. Cogger and D. Venkatesan.

The Annual Winter Workshop of the Division of Aeronomy and Space Physics/Canadian Association of Physicists (DASP/CAP) was organized by D. Venkatesan, at U. of C. on Feb. 17 and 18, 1983. About 50 participants from various Canadian universities and the Herzberg Institute of Astrophysics attended. The invited talks by T.A. Potemra and C.-I. Meng were on 'Field-Aligned Currents' and 'The Remote Sensing of the Auroral Oval' respectively; C.D. Anger talked about 'New Generations Detectors for Auroral Studies' and G. Rostoker talked about 'An Alternate Model of Magnetospheric Substorms'. There were a number of contributed papers.

(a) The HILAT Experimenters meeting

The HILAT program refers to an American polar orbiting satellite containing a vector magnetometer, electron spectrometer, a plasma monitor and a UV imager. The Canadian scientific community has been given access to the data in return for the operation of a ground telemetry station in Canada. CANOPUS is the Canadian Auroral Network for the Open Program Unified Study; Calgary has provided assistance in the design and specifications of an all-sky imager. A design contract has been negotiated with NRC and will lead to a specification/costing document. It was recommended by the CANOPUS science team that The U. of C. be awarded a second contract to build a working prototype all-sky imager based on CCD detector technology (expected to begin in April 1984). UARS: Our group has discussed reinvolvement in the major NASA UARS (Upper Atmospheric Research Satellite) program planned for the early 1990's. Specifically, Canadian scientists have been invited to collaborate with French scientists in the design and utilization of a Michelson interferometer to operate on the satellite and measure temperatures and winds in the upper atmosphere. CCUSS: The working address of the Canadian Corporation for University Space Science was shifted to the U. of C.; the corporate address is still London, Ontario. The officers for 1983-1984 are J. de Leeuw - President, Univ. of Toronto; D. Venkatesan - Vice President; L.L. Cogger - Secretary-Treasurer.

(b) Viking Ultraviolet Imager Project

A UV auroral imager (UVI) is being developed by our UVI science team, NRC and Canadian Astronautics Limited, for the Swedish spacecraft Viking (piggyback, French SPOT remote-sensing spacecraft, Ariane vehicle, launch scheduled, June, 1985). The science team is assisting in design effort, fabrication of some of the flight hardware and the ground calibration system. Calgary will play a major role in design and implementation of the ground station system for data handling and mission planning at Kiruna, Sweden.

(c) Optical Studies of the Upper Atmosphere

Collaboration with, Univ. of Michigan (P.B. Hays and J.W. Meriwether) continues. With assistance from NSF, a 15 cm Fabry-Perot spectrometer, a 1 m grating spectrometer, and a scanning photometer have been installed in a 40 ft observing trailer near Calgary (51°N,

114°W). Each instrument has a pointable mirror system. All procedures of operation are computer-controlled. The Fabry-Perot measures winds near 100 km using the Doppler shift of 5577 Å emission and F-region temperatures and winds using 6300 Å emission. The combination of photometer and grating spectrometer has allowed us to observe a number of airglow and auroral optical features. Identification and interpretation of the latitudinal and seasonal variations of the 5577 Å airglow (ISIS-2 observations) has been completed (J. Murphree, R. Eliphinstone, and L. Cogger). Airglow data have been combined with a model to calculate the atomic oxygen layer. This explains the major features by means of variations in the rate of production of atomic oxygen, in the amount of turbulence, and in the meridional thermospheric wind. In both October 1982 and 1983 successful campaigns were held at Cold Lake, Alberta, where good CCD all-sky camera data of the aurora were obtained simultaneously with auroral x-ray data taken by balloon-borne X-ray detectors (D. Venkatesan's group). Over 1600 individual images of 5577 Å were obtained during approximately a 4-hour period in support of the first flight. Preliminary results were presented at the AGU meeting in Dec. 1983. Further data analysis continues. An improved intensifier-CCD all-sky camera is being designed. The instrument will complement the CANOPUS BARS system and provide 20x20 maps in four wavelengths, and will also gather high resolution (256x256) data.

(d) CCD Group in Department of Electrical Engineering (EE)

The CCD Group in EE has continued to develop a CCD imager characterization facility, emphasising English Electric arrays in 1983. A basic characterization of five EEV arrays was performed for ITRES Research Ltd. during January 1 to June 31. A sophisticated image acquisition, storage, processing and display system is now in place and current efforts are proceeding to achieve overall noise levels below 50 r.m.s. electrons. B. Hriskevich's Ph.D. thesis, nearing completion, deals with imager characterization and output stage noise studies. A. Klassen has completed studies of photogate transmission line effects at high clock rates.

(e) Image Data Processing

A VAX11/750 has been acquired in the last year as prototype for the hardware system. Extensive software development is being carried out under the auspices of an NRC contract to U. of C. Further, the problem of handling large volumes of present and future data, from ISIS-2, VIKING, Galileo, WAMDII and CANOPUS, needs the development of a general purpose image analysis facility. The first phase is nearing completion. Specialized display and analysis hardware, coupled to our VAX11/750, will be controlled by an interactive command-driven interpreter (Bob King). The system, running under the UNIX operating system on the VAX, should be ready early in 1984. The two scanning photometers on ISIS-2 satellite still operate satisfactorily. In cooperation with CRC, analysis of auroral and airglow data over the entire lifetime (12 years) of the ISIS-2 satellite is envisaged. A comparison with Chatanika radar studies of ionization profiles and an attempt to determine the global temporal 5577 Å airglow distribution over an entire solar cycle are also underway.

(f) Image Processing System Control

Development of software for use in image analysis at Viking ground station including developing an image analysis language 'icon' (syntax similar to 'C' language but whose operators are generic and user defined) continues.

(g) Galileo Mission

Calgary is responsible for aspects of the NASA Galileo Jupiter Orbiter mission relating to imaging of dark-side phenomena on Jupiter and its satellites.

(h) Auroral X-ray and Solar Terrestrial Relations Group

Two papers in collaboration with the Applied Physics Lab/Johns Hopkins University (APL/JHU) and a third one in collaboration with APL/JHU and Univ. of Iowa were presented at AGU, San Francisco Meeting in Dec. 1983. These refer to analyses of data from spacecraft IMPs, VOYAGERS, PIONEERS, and DMSP satellites. The fourth paper was related to the

simultaneous observations of Bremsstrahlung X-rays recorded by balloon-borne payload and optical emissions by the ground-based CCD system.

(i) Solar Activity and Weather

L. Nkemdirim (Geography) and D. Venkatesan (Physics) of U. of C., have analysed the time series of temperature data for the past 70 years, from 13 Canadian stations. There is fairly clear evidence of an increase in the length of the frost-free season since 1940 (fifth paper presented at the AGU, Dec. 1983).

(j) Canadian Long Base Array CLBA

The Space Science Group, the University, and the Calgary community as a whole, have shown an interest in the development of the CLBA facility, a project which has excited the entire Canadian astronomy community in general and the radio astronomers in particular. A number of universities are interested in having the Headquarters for CLBA at their locations. The status of the project has not yet been decided; we await the results of government deliberation in the near future.

(k) Balloon X-Ray Astronomy

A balloon payload (X-ray astronomy) was launched from Gimli on a 22 M Cu ft balloon during August 1983. This was a collaboration between D. Venkatesan, R. Lieu and D. Leahy from the U. of C., and J.J. Quenby, A.R. Engel, and K. Beurle of Imperial College, London, United Kingdom, to study celestial X-ray sources, using a germanium detector.

(l) Infrared Group: Airborne Infrared Solar Physics and Aeronomy

(i) Balloon-borne Solar Observations

Study on the far infrared solar spectra obtained during a balloon flight from Gimli (summer 1982) continues. Solar steering to ± 1 arcminute, offset guiding, automatic sensor gain control, in-flight calibration and a high resolution (0.015 cm^{-1}) Michelson interferometer provided an excellent series of spectra over the range $20\text{--}90 \text{ cm}^{-1}$ of the Sun, the high-temperature calibration source, the remnant background and the absorption spectrum of the stratosphere to zenith angles greater than 90° . Some preliminary results are: an initial solar temperature estimate at depths bracketing the temperature minimum, from spectra calibrated in flight for the first time; the discovery of a series of H emission lines from high n Rydberg transitions (16-15, 15-14, 14-13) presumably caused by hydrogen recombination in the chromosphere; several weak lines have been identified in the low-angle spectra during sunset as being HCl and HF pure rotational lines from these minor stratospheric species.

(ii) 63 μm O I fine Structure Emission Line

Analysis of far IR emission spectra (ESA - University College, London balloon flight, Palestine, Texas, in conjunction with D.A. Naylor, Univ. of Lethbridge and ESTEC, Noordwijk, Holland) has provided an excellent in-flight calibrated night-time downward intensity of the $63\mu\text{m}$ emission from the fine structure ($^3\text{P}_1\text{--}^3\text{P}_2$) transition of O I. This intensity exceeds theoretical prediction by a small but significant factor.

(iii) Laboratory O₂ Magnetic Dipole Line Strength Measurements

Submillimetre spectroscopy (collaborator H. Wieser, Dept. of Chemistry) has demonstrated the basic correctness of the accepted theory of O₂ pure rotational line strengths for the first time. These measurements have a certain cosmological significance, in view of the use of low wavenumber lines from O₂ in the secondary calibration of balloon-borne measurements of the 3°K cosmic background radiation.

(iv) Airborne Total Solar Eclipse Expedition

The total solar eclipse (June 11, 1983) was observed in the near IR over Indonesia from the Calgary-based Lear 35 aircraft of Business Flights Ltd., even though turbulence from severe storms threatened to disturb the NASA-furnished gyro-controlled heliostat during the crucial totality period. Good data were obtained on extreme limb distribution of near IR solar intensity, including the spectral regions containing the important solar CO bands. Data analysis is continuing (C.D. Anger, S. Babey, R. Boreiko, T.A. Clark, L.L. Cogger, R.E. Elphinstone, B. Hriskevich, B. Hrivnak, R. King, P. King, A. Klassen, J. Haslett, Sun Kwok, D. A. Leahy, R. Lieu, E.F. Milone, S.R. Murphree, L. Nkemdirim, L. Varga, and D. Venkatesan).

3. University of Victoria, Department of Physics

Airglow Studies: Analysis of results of rocket releases of lithium vapour (Poker Flat Rocket Range, Alaska, April 1982) shows observations of enhanced emissions at Victoria, B.C. as a result of dispersion of the resulting vapour clouds. In the cases of two trail releases in the height range 210 km to 90 km, enhanced emissions were observed at Victoria after three days, consistent with earlier results. For a point release at 1200 km, enhanced emissions were not seen at Victoria until ten days after release. Diffusion from the exobase down to the 100 km level must therefore have required several days. A functional relationship was developed relating the expected apparent emission rate to time after release of a high-altitude puff, for an observer situated directly below the point of release. Such an observation made with a photometer with a known angular field of view enables estimates of the thermal velocity of the cloud and the height of the exobase to be made (H.M. Sullivan).

4. University of Saskatchewan, Institute of Space and Atmospheric Studies

(a) Auroral Physics

Campaign activities have been a major preoccupation in 1983 plus continuing interpretation of the CENTAUR 1981 dayside auroral campaign data, involvement in the summer auroral campaign August 1983, and preparations for the ARIES auroral modelling campaign in early 1984. The auroral study at Southend was productive (clear skies, auroras most nights, photometer in operation, August 1st to 15th). All of the meridian data have been processed and await intercomparison with the auroral radar data. A new suprathermal electron analyzer has been designed and built for rocket flight. It has a programmed energy scan from 250 eV to 1 eV in 64 steps with a complete spectrum obtained each second. This spectrometer is intended to bridge the gap in auroral electron measurements between the lower end of our current analyzers and Langmuir probes (use of the two Aries rockets, Feb. 1984, is anticipated). A LBS recalibration against world standards was carried out in August 1983 at Lindau. It is concluded that while large discrepancies have pretty well disappeared from the aeronomy scene there is clearly a need for more reliability and accuracy in photometry (as evidenced by apparent changes in some radioactive sources of up to 25% from 1981 to 1983) (D.J. McEwen).

During AURORAL MEASUREMENT CAMPAIGN, August 1-15, 1983, CW 50 MHz radars were operated so that scatter would be received simultaneously from paths parallel and perpendicular to the mean auroral electrojet. The experiment aims to check the type of Doppler spectrum received, in order to determine the probable type of plasma instability causing the scatter. European results (STARE system) indicate that spectra from directions nearly parallel to the electrojet flow are narrow and peaked near the ion-acoustic frequency, which itself is a function of the electric field present; this provides one means of obtaining the mean electric field in the scattering volume. However, this method is not very sensitive because the ion-acoustic velocity changes only slowly with the electric field. On the other hand, the Doppler spectra of scatter roughly perpendicular to the electrojet are very broad, and the spectral width appears to be closely related to the mean electron flow speed in the electrojet. This would happen if the number of secondary scatterers or the amount of plasma turbulence is proportional to the number and intensity of the primary waves produced along the electrojet, presumably by the two-stream instability. Preliminary spectral analysis shows a qualitative agreement between Canadian and STARE results. The CW radar system is such that the overlapping transmitting and

receiving antenna form a single large zone 150 km by 150 km in which no range resolution is possible. This is overcome by using McNamara's 48 MHz radar to Saskatoon, and obtaining Doppler spectra with high spatial resolution along virtually the same path perpendicular to the electrojet as the Gainsborough-Southend-Camrose path of the CW system. By comparing the results from both radar systems, the high spectral resolution advantages of the CW system and the high spatial resolution of the pulsed system will both be achieved, as well as serving as a check on the spectral results of both. The frequency of occurrence of aurora was not as great as that in the cleft and prairie campaigns in 1981 and 1982, respectively, as expected during this period of declining solar activity. Nevertheless, a number of very good scattering events occurred, providing an excellent data base for comparison with the optical and magnetic measurements taken by the other scientists involved in the campaign (G.J. Sofko, J.A. Koehler, A.G. McNamara).

(b) Aeronomy

The OASIS rocket was successfully launched on June 10/11, 1983 from White Sands, NM. All instruments operated and provided data which are currently being analyzed. Unfortunately vehicle failure to manoeuvre at apogee prevented the planned side-look observations, a fact greeted with mixed response by the different experimenters. The relatively hard impact and the high temperature on re-entry created problems; thus some instruments were non-operational after the flight. The completion of analysis of earlier flights has resulted in manuscript submission for publication. The green line in the airglow was re-analysed in terms of the two-step Barth mechanism with the precursor being vibrationally excited. It has been shown that in the atmosphere the upper vibrational levels of $O_2(C^1\Sigma_u^-)$ are most efficient in the excitation of $O(^1S)$. The problem of $N_2(A^3\Sigma_u^+)$ Vegard-Kaplan band quenching has been revisited and for the latest laboratory coefficients, it has been concluded that the atomic oxygen concentrations are close to those of the CIRA 72 model for both the new measurements and those existing in the literature. Thus the postulated reduction in atomic oxygen in the auroral ionosphere may not be correct. If $O(^1S)$ were small then some additional quenching of the N_2A state would be required. The possible excitation of $O(^1S)$ in the aurora from the N_2A quenching has also been studied and has indicated that for a consistent model the production of $O(^1S)$ far exceeds that needed in the altitude region below 160 km. A limitation on the efficiency of 1S production with vibrational excitation may alleviate the problem to some extent and we are presently reexamining the procedure used in the laboratory for the determination of 1S yield. The analysis of the solar eclipse data has been completed and has indicated an O^3 concentration that at 60 km was very high, $3 \times 10^{10} \text{cm}^{-3}$, and at 80 km was typical of summertime values. This reduction has been attributed to a warming that was in progress at the time of the measurement while the enhancement may have been due to particle precipitation during the eclipse (E.J. Llewellyn, I.C. McDade).

(c) Atmospheric Dynamics Group

The Saskatoon MF radar continues to run continuously through its sixth year, and the atmosphere continues to surprise us! The mean winds (tidally corrected) now form quite a unique continuous set from (Jan. 1978 - Dec. 1983). Studies of electron densities sensitive to solar/magnetospheric energy inputs continue. We are assembling radar wind cross-sections (global distribution) for incorporation in the revised CIRA. We are active in stratospheric warmings and winter dynamics studies (WINE, DYNAMICS of MAP). Saskatoon weekly data are included in the Berlin stratalerts. For the first MAP warming our winds and satellite temperatures show unexpectedly small scale structure (80-100 km). Several important tidal studies have been completed (with France and N.Z.) and comparisons with new theoretical models show these still lacking in many details. A new series of global campaigns (ATMAP) began in December. We have been running our new 3 station gravity wave system (GRATMAP of MAP) since May 1983. Interpretation is not simple; observationally little is yet known how these waves interact with the atmosphere. Early results show a tendency for phase velocities to be North-South, not East-West as required by the momentum-balance hypothesis (Lindzen, R.S., JGR, 86, 9707, 1981) (A. Manson, C. Meek).

5. University of Western Ontario, Centre for Radio Science

(a) Ionospheric Physics

Detailed analysis of electron content data from last year's mini-summer cleft campaign indicated that the characteristic cleft signature of enhanced content in the narrow latitudinal span of the cleft is much less pronounced or even absent in summer compared with winter. Again in cooperation with the University of Saskatchewan, a 'mini-summer-pulsating aurora campaign' was mounted at Southend this summer. Several 'Long Lines' were set up for convection measurements and a complete three station differential phase system was operated for content and angle of arrival measurements using the NNSS satellites. Data analysis is proceeding and it is hoped to hold a workshop with fellow experimenters next February (J.A. Fulford, J.W. MacDougall, G.F. Lyon).

(b) HILAT

The Canadian contribution to the HILAT program is just about on schedule. The Churchill station is being installed between January 4-18. It should be operational and routinely producing tapes immediately thereafter. Good progress is being made at UWO with the construction of the "transportable" Canadian station. Application under strategic program to NSERC to provide an HP1000(A700) computer for this equipment, to exploit the full potential of the station was refused. However, the Department of National Defence will lend the appropriate computer to the program and provide operator support. Thus continuous operation of the station for the year at Inuvik is possible. The Canadian HILAT science team are to get together to discuss preliminary results and to plan for use of the data. The team will also formulate plans for the campaign use of the satellite during the 1985-86 year (P. Forsyth).

6. York University, Centre for Research in Experimental Space Science

(a) WAMDII Project Instrument Development

Fabrication of the optics for the Wide Angle Michelson Doppler Imaging Interferometer (WAMDII) was completed at Bomem, Quebec City where it was installed in its mechanical and passive thermal housing. Tests reveal exceptional quality; undoubtedly this is the largest and best solid field-widened Michelson in existence. It will be integrated into the overall system at SED in Dec., lab tested in January and field tested at the University of Saskatchewan site in February. Spacelab flight is still not scheduled but is expected to be in 1987. W. Ward will operate his WAMI at Bird during the ARIES campaign.

(b) Modelling Program

The WAMDII atmospheric model generated by SED Systems has been augmented by the addition of routines to simulate the horizontal components of gravity waves in the OI(5577) emission layer. Plane waves of 100 second period, 12 km vertical wavelength, and 50 m/s amplitude should be clearly discernible in WAMDII wind profiles of the OI(5577) limb. The spectral constraints of this method are currently being studied. Useful information on gravity wave propagation direction will be made available by WAMDII's two-dimensional wind displays, according to the model. The limits of these determinations are also under current study. Temperature and intensity components of the gravity waves will be included in the model in the near future; this is being done by Rudy Wiems with advice from C. Hines (who has been acting as part-time consultant to the WAMDII project).

(c) Rocket Projects

B. Solheim is reducing the OASIS data for the CCD photometer (developed by him, supported by J. Pieau and J. Gilmar). This photometer organizes the data into 32 spectral bands centred on the O₂ Atm (0,0) band and will yield rotational temperatures as well as intensities. Noise apparently generated external to experiment, is a problem during ascent, but comparatively noise-free during descent. The same photometer is being reflown on ARIES-A. R. Koehler had a successful flight on a new triple-probe experiment for WATERHOLE III. Preliminary data for the rather short-lived event were presented at a fall

workshop. Detailed analysis and the reduction of data from an earlier CENTAUR TEOL probe experiment are proceeding. For ARIES-B, Robert Van Es has designed three side-looking photometers for 6300 A, 7320 A and 5200 A. These will be part of the assembly of tomographic scanners, and the software for tomographic image reconstruction of volume emission rates is under development.

(d) Presto

After its return from White Sands, NM, where it was used for O⁺(7320) twilight and O(5577) measurements in support of the OASIS experiment, PRESTO was set up on the York University campus to pursue a program of twilight observation of the same two emissions. Since the two spectral regions require different etalons, weeks of O⁺ observations alternate with weeks of OI(5577) and OI(6300) observations. Toronto's cloudy autumn weather severely limits the amount of data collected, but representative spectra are becoming more numerous.

(e) ISIS Data Analysis

B. Gertner is working on the in-flight calibration of the ISIS-II Red Line Photometer over its 12 years in orbit. V. Bhatnagar is working on studies of equatorial data and of mid-latitude 6300A emission. He is also collaborating in a study with B. Tinsley on mid-latitude emissions produced by neutral atom precipitation. New developments in software are being created on the VAX 11/780, using the IBM-type equipment more and more as a pre-processor.

(f) Airglow and Auroral Modelling

R. Link is continuing the development of his multistream electron transport/discrete energy degradation model to allow for higher auroral electron energies and energy-dependent pitch angle redistribution. Programs have been developed to calculate atmospheric photoionization frequencies, photoelectron spectra and related quantities using AE satellite solar EUV spectral measurements at approximately 1 A resolution. Detailed studies of photo-excited and photo-electronexcited airglow can now be performed for any date, location and solar zenith angle using the solar EUV spectrum appropriate to that date and the longitude-dependent MSIS thermospheric composition model. R. Gladstone is continuing the development of radiative transfer programs for the analysis of optically thick UV airglow and auroral emissions. A Monte Carlo program has been devised to handle very optically thick resonance lines, such as OI 1304 and 989 A, including the effects of partial frequency distribution and two-dimensional photon scattering. This model is now being extended to include the effects of thermospheric temperature gradients. In addition, a one-dimensional matrix method has been developed which can be used for (plane-parallel) airglow investigations. This program can handle frequency redistribution and temperature gradients. The electron and photon transport models are currently being used to analyze the first reported measurements of the EUV spectrum of the sunlit dayside cleft aurora, obtained from satellite STP 78-1, in collaboration with S. Chakrabarti (University of California, Berkeley). Analysis of cleft data from two CENTAUR rocket launches (with A.W. Yau, Herzberg Institute and A. Cristensen, Aerospace Corp.) and nightside auroral visible UV rocket data (with G. Schmidtke, Fraunhofer Institut, Freiburg, FRG) is also in progress (R.A. Koehler, J.C. McConnell, G.G. Shepherd).

7. Earth Physics Branch, Energy, Mines and Resources

A relationship found between magnetic storms and stratospheric warmings leads to an explanation of some solar-related weather and climatic effects. The study uses simultaneous magnetic activity indices (AE, Kp and Dst) and the NOAA NMC daily atmospheric models of the northern stratosphere over 1964-75; the former is related to the Joule and energetic particle heating of the upper atmosphere and reduced to daily power indices. The principal wave (spatial) and the polar cap mean of the polar vortex temperature and other parameters were determined from the stratospheric data. The stratospheric perturbations during 48 selected stratospheric warmings show a significant correlation with the total energy of the concurrent magnetic storms. This relationship is suggested to be initiated by a subauroral jet stream, caused by energetic particle and Joule electron heating of the upper mesosphere. A weakened polar vortex during such events

would probably result in reducing vortex outflow and permitting cyclonic weather systems to penetrate to higher latitudes, thereby resulting in more unsettled winter weather. During extended solar inactive intervals, the strong circulation of the undisturbed polar vortex would probably result in stable, cold and dry high latitude weather. It is proposed that a succession of such winters during inactive solar eras, or when the main dipole field is small during reversals, would result in long-term snow accumulation and ultimately in an onset of glacial period.

A manual has been prepared for the separation of magnetic field observations into external and internal fields, based on a new method using magnetic indices (AE, Kp and Dst), visual examination of the magnetograms and filtering magnetic data to determine very quiet nighttime levels over extended periods of time and then analysis to delineate the secular variation of the internal field. These are also ideally suited as reference for correcting local surveys for temporal variations and for the analysis of external sources (J.K. Walker).

An analysis of IMS data from Ottawa shows that the majority of Pcl pulsations observed possessed a period of 1 s and lasted less than an hour. Shorter period Pcl's are observed during summer than winter, during noon hours than morning and shorter during high magnetic activity intervals. The diurnal variation of period at Ottawa is different from that at high latitude stations; the calculated ratio of spacing to pulse period at Ottawa is 86, in good agreement with values found for higher and lower latitude stations. An IPDP (Intervals of Pulsations of Diminishing Periods) event occurred on April 19, 1977. The analysis supports the view that the energy dispersion of storm time protons and the earthward movement of the instability region due to increasing magnetic activity, are involved in the production of such events.

Relationships between SSC, Dst and the occurrence of Pcl pulsations are also examined. Sudden magnetospheric compressions taking place in the post-noon period (13-22 LT) frequently produced Pcl pulsations at Ottawa about 25-125 hours after occurrence of SSC's of amplitude 5-25 nT and duration 2-6 min. Pcl's also occur 20-40 hours after maximum Dst deviations in the range 50-110 nT, when the ring current has decayed to a considerable extent (5 nT < Dst < 25 nT). In agreement with Heacock and Kivinen (1972) it appears that during the storm recovery phase energetic particles of the ring current with anisotropic pitch angle distribution interact with the surrounding cold plasma of the plasmasphere. When stable trapping limit is reached, proton cyclotron instability is triggered and pulsations in the Pcl period range are generated (J.C. Gupta).

8. Communications Research Centre, Radio Propagation Laboratory

(a) Waves in Space Plasmas (WISP) Project

The Canada Centre for Space Science has contracted (June 1983) Canadian Astronautics Ltd., Ottawa, for design and development of the WISP/HF sounder system; flight hardware delivery scheduled for 1986, for subsequent integration with US equipment, and NASA launch of WISP facility and other AMPS-type instrumentation (September 1988). Funding uncertainties have made it difficult for NASA to define the payload with which WISP will be flown. The WISP/HF equipment will include a small expendable receiver mounted in a Plasma Diagnostics Package subsatellite. The baseline payload envisaged by NASA also includes the WAMDII instrument and a magnetic antenna plus VLF transmitter facility supplied by US military on a separate pallet. The WISP science team has called for a shuttle orbit, inclination 77°, perigee 325 km and apogee 500 km. WISP hardware development in US (includes a VLF transmitter and a central coordinating computer system) has lagged that in Canada; design activities by U.S. contractor, TRW, early 1984; preliminary design review of the WISP/HF system, mid-February, 1984. Science program description can be had from H.G. James.

(b) ISIS Programs

The ISIS-I and ISIS-II spacecraft were operated throughout 1983; most data collection was in support of collaborative VLF wave studies with foreign laboratories. Both sounder and VLF receiver data processed by CRC. ISIS data were recorded simultaneously with experiments on the Spacelab-1 mission, on the CHARGE experiment (tethered rocket system)

and during overflights of the HIPAS ionospheric heating facility in Alaska. Both DOC and DND (who have supported ISIS scheduling and data processing in the past) have decided to stop this by end of the fiscal year 1983-84. ISIS satellite controller, D. Boulding, will draft a letter to this effect for wide distribution in January 1984. But for a wide-spread reaction calling for continuing operations (accompanied by money) belief is that ISIS spacecraft operation will end. CRC management is presently investigating the means for continuing data processing at Shirley Bay to support scientists both within and outside of DOC.

Collaborative analysis of VLF signal broadening has been continued with Stanford University. Previous work dealt with upcoming transionospheric propagation observed on ISIS; present evidence is that waves coming down from the magnetosphere undergo scattering and exhibit Doppler broadening. Signal magnitudes observed on transionospheric Doppler-broadened waves indicate amplification of artificial signals. The relationship of the broadening and amplification of whistler-mode waves to energetic particle populations is being investigated by comparing Soft-Particle-Spectrometer and VLF-Receiver data.

A review of Alouette ISIS radio wave studies of the high latitude ionosphere concerning the cleft, auroral zone, trough and their associated irregularities was published in Radio Science, December, 1983. A study with S. Gross (Polytech. Inst., New York) on field-aligned ionization ducts having uniform spacing on several tens of kilometres, is continuing. Standing gravity waves may modulate the formation mechanism of ducts and hence account for their uniformly spaced distribution. Recently published HF heating observations at Arecibo with a 48 MHz radar diagnostic do not show a decay line in the scatter spectrum for the plasma line; only a growing mode is present. A possible explanation is that the propagation distance, within field-aligned ducts, is too short for the electrostatic waves responsible for the decay line to grow to the detection level. This distance is determined by the interference maximum, between the up-going and reflected waves, just below the reflection level (D.B. Muldrew, H.G. James).

9. Herzberg Institute of Astrophysics, NRC, Ottawa

(a) Space Physics

Plasma and Fields in the Ionosphere: A second ionospheric perturbation experiment (Waterhole III) to study auroral electrodynamics, flown into a bright multiple arc structure on February 7, 1983, involved ground-based and rocket measurements by scientists from five institutions (coordinator project scientist, B.A. Whalen). Instrumentation on the rocket detected the F region ionization depletion caused by water vapor released from the 180 kg explosive charge detonated at 315 km altitude. Brief (0.1 s) magnetic and electric effects were observed associated with the shock front passage. Precipitating auroral electron flux distributions were modified for 20 s after the release. The ionospheric depletion and associated effects from Waterhole III had a duration 5 to 10 times shorter than the smaller Waterhole I release which occurred in a sunlit ionosphere. Whalen et al. published an initial paper (1983). Modelling and interpretation of the measurements are continuing in preparation for a Waterhole IV Expt. in 1985.

The 'SABRE' sounding rocket expt. was successfully launched from Churchill on May 12, 1983. This Sequential Auroral Barium Release Experiment injected three barium ion clouds into the sunlit F region ionosphere above a stable pre-midnight auroral arc. Tangential electric field distributions along the arc were measured by tracking cloud motions optically from the ground and by in-situ field and plasma measurements from the rocket. A preliminary paper (Yau et al., 1983b) concludes that there was no strong ionospheric drift perpendicular to the auroral arc, in its frame of reference. More detailed analysis is continuing.

The Space Physics section is providing charged particle spectrometers and sensitive magnetometers for the ARIES (aurora modelling campaign) sounding rocket scheduled for early 1984. Similar instrumentation plus a radio frequency ion mass spectrometer are being provided for the MARIE rocket rescheduled for the 1984-85 winter (A.W. Yau, project scientist). Engineering studies for the OEDIPUS rocket experiment are in progress for a 1985-86 launch. It is designed to measure parallel electric fields in an auroral arc using a long tether wire between the main rocket body and an ejected nose cone

(B.A. Whalen, project scientist). Scientific definition of the Harang Discontinuity Electrodynamic Study (HADES) is being coordinated by D.D. Wallis. A study of Transversely Accelerated Ionospheric Ions (TAI) observed on rocket flights into the expansive phase of two auroral substorms has been completed (Yau et al., 1983). A study of wave-particle interactions observed when a rocket-borne electron gun injected an electron beam into the auroral ionosphere is reported by Duprat et al., (1983).

(b) Magnetospheric Studies

The group's activities continue to be directed toward studies of energetic composition, electric currents at high latitudes near the earth and theoretical analyses of plasmas under magnetospheric and ionospheric conditions.

Two review articles on ion composition studies by B.A. Whalen (1983a, b) were published. Studies using data from the Energetic Ion Composition Spectrometer (EICS) on the Dynamics Explorer I spacecraft have continued (Shelley et al., 1983). A comprehensive statistical study of the occurrence frequency distribution of upflowing ionospheric ions (UFI) in the high-altitude auroral and polar cap ionosphere has been completed (Yau et al., 1983c). It is found that O⁺ UFI have a marked occurrence frequency and intensity dependence on magnetic activity, where H⁺ UFI display little variation. The occurrence frequency of O⁺ conics decreases with altitude relative to H⁺ conics and various other spectral, latitudinal and local time patterns of the two ion species are reported. The DE-1 data promises to increase our knowledge of magnetospheric ion composition substantially during the next few years.

Analysis of the vector magnetometer data from the Magsat spacecraft is continuing. The statistical properties of large scale uniform perturbations transverse to the geomagnetic field in the polar cap are being analysed to determine their relationship to the auroral current systems, interplanetary magnetic field and solar illumination of the ionosphere. Quantitative modelling of three-dimensional current systems in the ionosphere and magnetosphere has been applied to data acquired during magnetically quiet days to separate external currents from crustal fields (Burrows et al., 1984). A. Hruska has extended his studies of collisionless two-fluid plasma using a single continuum description to study energy transfer between electromagnetic and mechanical energy sources and the kinetic and internal energy of the plasma. The reconnection process is treated and it is concluded that the 'merging' geometry should be regarded as a consequence of the plasma motion rather than its cause.

Design studies for a supra-thermal and energetic ion mass spectrometer to be flown on the Japanese magnetospheric satellite, EXOS-D, are in progress. The instrument will provide mass resolution of $\Delta M/M \approx 0.1$ in mass range 1 to 32 AMU/charge and energy range ≈ 10 eV to 10 KeV/charge.

(c) Cosmic Ray Studies

The network of four neutron monitor stations at Alert, Inuvik, Goose Bay and Deep River continues to operate under the supervision of M. Bercovitch. Studies of the high energy muon component continue with the large area horizontal telescope at the Ottawa laboratory.

The Cosmic Ray and Solar Particle Instrument (COSPIN) for the International Solar Polar Mission (ISPM) successfully completed qualification testing of the flight model during 1983. After its 1986 launch, the experiment will measure cosmic ray composition, spectra and angular distributions in interplanetary space between earth and Jupiter and over the poles of the sun (M. Bercovitch, R. Burrows, A. Hruska, D.D. Wallis, B.A. Whalen, M.O. Wilson, A.W. Yau).

(d) Planetary Sciences Section

(i) Auroral Photometry

Auroral spectra were obtained with echelle spectrograph in the 4400 to 5400 Å range with a slit width of about 2 Å. The results on atomic line multiplets were very

encouraging. Marked differences between proton and electron auroral spectra were observed. The 0.5 m spectrometer was installed at Sondre Stromfjord in November 1983, and is being operated by J. Meriwether. Simultaneous magnetic zenith observations were made with the 15-channel photometer and the incoherent scatter radar for several nights during a two-week period.

Extensive observations were made during Waterhole III including ground-based photometers, film and TV imaging systems, and rocket-borne photometers. The upper limit to the 6300 A emission brightness in the release region was placed at about 50 R according to results obtained with the TV imagers. Further, the upper limit for brightness of the cloud at OH 3064 A, as seen from the rocket at the cloud centre was 30 R. This is significantly less than the 1.6 KR observed during Waterhole I. The auroral morphology was well documented with the ground-based equipment.

For the SABRE project, ground-based imaging and photometric instrumentation were operated at Churchill, Gillam, and Thomson. Detailed studies of auroral morphology and cloud motion were carried out using triangulation methods with the star background as a reference. The data measurement phase is finished and completion of the analysis awaits a further refinement of the triangulation software. The inherent precision of the TV measurements is much lower than originally estimated, probably the result of low quality recording equipment.

Preparations for ARIES progressed throughout the year. A set of three 1° photometers was assembled to measure height profiles of various auroral emission features from selected isolated auroral arcs. The instrumentation will also include film and TV imagers, photometric scanners and zenith photometers, spectrometers, and magnetometers. Photometers to measure O₂ Atm(0,0) and (0,1) volume emission rates in aurora and nightglow will be flown on the payloads.

Ground-based and rocket observations were made during OASIS. The prime purpose of the ground observations was to verify a "no-aurora" condition during vehicle flight. Excellent data were obtained from the rocket photometers, and volume emission rate profiles for the nightglow O₂Atm(0,0) and (0,1) bands have been deduced. Both emissions maximize at 95 km and the brightness ratio is 21 (F. Creutzberg, R.L. Gattinger, F.R. Harris, A. Vallance Jones).

(ii) Radio Aurora

Our new high power pulsed Doppler radar was transported to Saskatoon in August 1983 to operate in a campaign mode with the c.w. radars of G. Sofko and J. Koehler. All the radar antenna arrays were directed to overlap their beams in a common volume about Southend, Saskatchewan. The objective was to obtain Doppler spectra with both high spatial and high spectral resolution at several aspect angles. The campaign was one of the continuing pre-BARS studies to investigate the radio scattering mechanism in greater detail. D.R. McDiarmid is at the MaxPlanck-Institut fur Aeronomie, Germany for about one year from July 1983, working on various investigations using the STARE radar data gathered in Scandinavia (A.G. McNamara, D.R. McDiarmid).

(iii) BARS

The contract to build the Bistatic Auroral Radar System was signed with Canadian Astronautics Limited on 24 October, 1983. Work has progressed rapidly; Preliminary Design Review scheduled for mid-January 1984. The target date to have the two radars operational at Nipawin and Red Lake is December 1984 (A.G. McNamara).

(iv) Space Science Program

Many members of the Planetary Sciences Section have been very active on scientific planning teams and in contract monitoring for the project CANOPUS, VIKING, WAMDII, WISP/HF, HILAT, and DAN.

(v) Plasma Probes

Probe experiments were flown on Waterhole III and SABRE at Churchill, and on OASIS at White Sands. The electron density hole was again clearly evident in WH III but it was significantly smaller in magnitude and in dimension than that which occurred in WH I. Effects due to plasma compression and oscillation were also observed. In the SABRE experiment, large increases in plasma density were caused by each of the three barium releases.

A detailed study of auroral radio wave absorption has been made using probe data from rocket AAF-IV-17. It is shown that the presence of a high energy tail in the electron distribution of the plasma at 86-90 km has a marked effect on the absorption coefficient. The work is being extended to examine more completely the characteristics of probe current collection in an auroral plasma.

An intensive study has been made of the effects of electron beam injection on the ambient plasma using probe data recorded on AAF-NVB-06.

Probe experiments have been constructed for flights on AAD-VIIC-08/09 (ARIES A/B), and AAF-XB-0-1 (MARIE), scheduled for the winter 83/84 (A.G. McNamara, J.M. Chaker).

(vi) Meteor Radar

The meteor radars at the Springhill Meteor Observatory were operated for a few days during each of the major meteor showers. Such data accumulated over a long period of time (now more than 120 years) determine the cross-section of a meteor stream and the distribution of particles around the stream. Differences in these distributions as a function of the size of the meteoroids are important in assessing the past and continuing evolution of meteor showers. Analysis was begun on the long series of radar observations of the Perseid meteor showers from Ottawa and from Ondrejov, Czechoslovakia. This shower is also of current interest since the comet associated with it is expected to come to perihelion some time in the present decade. Uncertainties in the period (about 120 years) and in perturbing effects lead to considerable uncertainty when, or even if, it will be observed again (B.A. McIntosh).

(vii) Infrasound

Further work was done on the study of the low frequency (0.01 Hz) waves associated with the 1979 solar eclipse and a paper has been accepted for publication. Similar waves, but of smaller amplitude and more frequent occurrence, which were observed on the Saskatoon infrasound array are believed to be associated also with the same mechanism as the eclipse waves. They may represent a type of atmospheric soliton (B.A. McIntosh).

(viii) Meteorite Research

Five events were recorded by the MORP camera network between December 1982 and October 1983 that appear to have dropped small meteorites of a few hundred grams. Educational campaigns were conducted among local residents in some cases. Considerable progress has been made in reducing the earlier MORP data and over 200 orbits of fireballs have been sent to the IAU Meteor Data Centre in Lund, Sweden. A study has been completed of the meteorite flux reaching the Earth's surface, based on exactly 9 years of MORP observations. Including an estimate for the mass of smaller fragments, it is found that 8 events per year drop at least 1 kg of meteorites in an area of 10^6 km² (I. Halliday, A.A. Griffin, A.T. Blackwell).

(ix) Halley Comet Meteoroids

Observational data on Halley Comet fragments were summarized in a paper presented at "Congres Astronomique 1983", Quebec City, 20-23 May. These data included bulk density estimates; fragmentation indices; meteor shower types; heights of appearance, maximum light and disappearance of the Halley Comet meteors in the atmosphere; meteor velocities and orbits; and types of Halley Comet meteor spectra. Halley Comet meteoroids

have a bulk density below average and fragment more readily than most cometary particles. Entering the earth's atmosphere at high relative velocity (66 km/s), the spectra exhibit strong lines of Ca, Mg, Si, and Fe in the singly ionized state. Neutral lines of Na are also strong (P.M. Millman).

IV VOLCANOLOGY

Compiled by: Léopold Gélinas

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1. Introduction

Fifty-seven reports have been submitted from twenty-four institutions including federal and provincial government groups, many universities and mining companies. Most of these reports concern new or continuing studies of Precambrian and Cenozoic geology - fewer concern Paleozoic, Mesozoic, and Quaternary rocks. The reports focus mainly on volcanic suites in support of mapping projects and on specific geological information relevant to stratigraphy, geochemistry, geochronology, paleomagnetic studies and economic geology.

2. Geological Survey of Canada

(a) Stratigraphy and geochemistry of Late Archean volcanic rocks of the Circum-Superior Belt (W.R.A. Baragar and N. T. Arndt, Max Planck Institute)

Mapping of the small islands of eastern Hudson Bay has been completed and work on the petrology is in progress. A mechanism for the development of pillow-massive flows, prominent in the Circum-Superior Belt, has been devised on the basis of field observations. Pillow tubes form at the leading edge of a flow and are eventually overridden by the on-coming massive lava. This yields a consistent disposition of massive over pillow types in the same flow.

(b) Sheeted dykes of the Late Cretaceous Troodos Complex, Cyprus (W.R.A. Baragar, M.B. Lambert, I. Gibson, and N. Baglow)

The distinctive chemistries that mark the upper and lower divisions of the pillow lava sequence are reflected in the dykes, but the compositional gap which is conspicuous in the pillow lava analyses is blurred or absent. Upper pillow lava-type compositions appear to be distributed randomly in dyke sections and are not necessarily the latest dykes. Hence, there appears to be overlap in the eruptive sequence. The dykes do not show a one-way chilling bias that would be indicative of a fairly narrow zone of intrusion.

Analyses and petrography have been done on selected dykes in each of the sections mapped. To obtain unambiguous relationships, all dykes in a few sections will have to be analysed. Then all results must be related to the sequential variations in composition that will be forthcoming from the completed drilled sections through the pillowed lavas and plutonic succession.

(c) Petrology of Natkusiak basalts (Haydrinian) Victoria Island, N.W.T. (W.R.A. Baragar (GSC), H.C. Palmer, M. Fortier, M. Foster (University of Western Ontario), and J. Dostal (Saint Mary's University))

The objectives are to determine the sources, the petrochemical evolution and the stratigraphy (including magnetostratigraphy) of the Natkusiak plateau basalts. Paleomagnetic studies have been completed and petrochemical studies are still in progress. In addition to study of major and common trace elements, REE are being investigated in collaboration with J. Dostal with a view to determining the sources of the magmas and their contamination enroute to the surface.

(d) Lower Paleozoic volcanics, northern Ellesmere Island (H.P. Trettin, ISPG, Calgary)

This study concerns the stratigraphy, petrography and tectonic significance of the volcanic rocks and forms part of a regional geological reconnaissance program in Ellesmere Island. Office and laboratory work on data and samples collected between 1975 and 1982 are continuing. A systematic report on the Lower Paleozoic geology of the entire region (parts of 9 map-areas at 1:250 000) is in preparation.

3. Indian and Northern Affairs Canada, Geology Division, Northern Affairs Program Yellowknife, N.W.T.

(a) Research into the geology of the Yellowknife volcanic belt (W.A. Padgham)

The objectives are to gain a better understanding of the Slave Structural Province. First draft of a field guide to the Giant Section of the Yellowknife volcanic belt has been prepared and a suggestion has been made for a revision of the stratigraphy of the belt in "Observations and Speculations on Supracrustal Successions in the Slave Structural Province". Further work on the transition from volcanic units to turbidites and other sediments is planned.

(b) Long Lake Park mapping project, Archean volcanics of the Kam Formation (J.A. Brophy)

To map a one-square-kilometre area opposite Yellowknife airport at a scale of 1:2,000 and prepare a guide. Detailed mapping is about half completed, and will be finished during the 1984 field season.

(c) Precambrian Geology of Western Hepburn Island area, North-western Slave Province, N.W.T. (NTS 76 M west) (G. Yeo)

Our objective is to produce adequate regional maps for the Hepburn Island area which is underlain by several greenstone complexes, some of which host important metal deposits. Five volcanic belts subsidiary to the major High Lake and Anialik River greenstone complexes were delineated. Although it was shown that some gneisses may be traced into greenstones, the relationship between the greenstone belts and other gneisses, particularly the polyphase Anialik River gneiss, was not resolved. More detailed mapping within the greenstone belts is planned. The problem of the relationship between the greenstones and possible basement gneisses will be pursued. Some of this work may take the form of graduate thesis studies supported by INAC and co-ordinated with our 1984 mapping program.

(d) Archean Geology of Quyk Lake area, Southern Slave Province, N.W.T. (G. Yeo)

Objectives of this study are to map in detail the last major unmapped part of the Yellowknife Greenstone belt, and to resolve the relationship between the latter and the Clan Lake Volcanic Complex. Mapping in 1983 revealed a small, previously unrecognized,

intermediate-felsic volcanic complex between Quyta and Sito Lakes. This may be correlative with both the Banking Formation to the south, and parts of the Clan Lake Complex to the north.

4. Ministry of Energy, Mines and Petroleum Resources, British Columbia

(a) Basalts of the Kamloops Group in the Salmon River area, B.C. (Eocene) (B.N. Church and S.G. Evans)

This study concerns the stratigraphic setting and petrology of Tertiary basalts which appear to be the source of landslides on the Douglas Lake road south of Westwood, B.C. The basalts are assigned to the Kamloops Group on the basis of two recent K/Ar determinations giving apparent ages of 49.4 and 48.6 ± 1.7 Ma. Landslides occur along tuffaceous bands and other incompetent zones where the rocks are altered, highly vesicular, or fragmental.

(b) Geology and mineral deposits of the Buck Creek Caldera, B.C. (B.N. Church)

The aim of current studies is to further delineate the elements of the Buck Creek Caldera with a view to shedding light on its history and associated mineral deposits. Sub-circular distribution of upper Cretaceous rhyolite beds in the Buck Creek area of central British Columbia is believed to delineate a caldera structure containing early Tertiary moat volcanics and a central resurgent dome in the vicinity of the Equity Mine near Groosly Lake. Weak porphyry copper and molybdenum mineralization is associated with upper Cretaceous granitoid intrusions, believed to be feeders to the rhyolites, on the rim and central area of the structure. Younger copper-lead-zinc vein deposits and higher temperature hydrothermal silver-copper fillings, disseminations, and replacements are correlated with the Tertiary igneous events and resurgence.

(c) Geology and magnetostratigraphy of Miocene basalts of the Okanagan Highlands, B.C. (B.N. Church and U. Suesser)

The aim of this research is to determine the significance of magnetic reversals in Miocene plateau basalts. Preliminary magnetostratigraphic studies, using a fluxgate magnetometer, indicate that the placer gravels are associated with "reversed" basalts of the lowest member in the basalt succession. Younger basalts have "normal" polarity, however, magnetic vectors show a marked range in azimuth and in angle of plunge. Success in the magnetic determinations was dependent in large measure on the near horizontal bedding of the basalts which did not require arbitrary rotation of magnetic vectors or other manipulations of the data to restore bedding attitudes.

(d) Geology and gravity survey of the Tulameen Basin, B.C. (B.N. Church and D. Brasnett)

The Tulameen basin is a faulted sub-circular structure of possible volcano-tectonic origin. New radiometric determinations of the rocks giving an Eocene age are comparable to previous K/Ar results on nearby basins such as Hat Creek and Princeton. A gravity profile delineated the basal volcanics, sedimentary rocks and coal measures. Recorded in 800 m of strata, comprising the basin, is a history of early volcanic eruption, sedimentation and coal formation, and finally infilling by coarse sandstones and conglomerates. Preservation of these rocks was effected by down faulting, folding and extrusion of Miocene basalt lavas. Rhyolite ash bands concentrated in the upper part of the coal measures may be the result of a resurgent volcanic event associated with high geothermal gradients. Evidence suggests that the anomalously high rock temperatures of this period are responsible for the comparatively high rank of the coal.

(e) Survey of the geothermal potential of B.C.; including Cenozoic volcanic rocks (B.N. Church and W. Young)

The objectives are to create a geothermal potential map of British Columbia showing thermal springs and aquifers, bottom hole temperatures, recent volcanic centres, Neogene volcanic deposits and major faults. The geothermal potential map combines information on geothermal gradients from deep drill holes with available data on thermal springs, young volcanic centres and the geotectonic setting of the Province.

The sampling of geothermal gradients across the Province, determined from drill hole temperature data, shows a range from low values of 13°C/km in the lower Fraser Valley area, 22°C/km in the Nechako trough, to a relatively high gradient of 42°C/km in the Fort Nelson area. Offshore gradients range from 20°C/km in the Tofino Basin area to an average of 27°C/km in the northern Hecate Strait area.

5. Ontario Geological Survey

(a) Effects of weathering on trace and rare-earth elements of volcanic sediments, Island of Hawaii, U.S.A. (R.M. Easton, M.N. Easton, and B.J. Fryer)

The objectives are to document the effects of alteration in recent rocks of known composition in order to better interpret trace and REE results from ancient volcanic sediments. The field work and analyses are completed, and indicate that significant REE mobility may occur in less than 20,000 years.

(b) Klip-Kirkland Lake program, study of alkaline volcanics of Archean Timiskaming Group, Abitibi Belt, Kirkland Lake Area (N.F. Trowell)

The objective is economic evaluation, specifically for gold and also base metals. Timiskaming alkaline volcanics or so-called trachytes comprise four distinctive chemical suites - tholeiitic (andesites, basalts) high Na + K calc-alkaline rhyolites, shoshonites and alkalic lavas (tephrites, leucitites, etc); true trachytes are rare.

(c) Black River-Matheson project, Northeastern Ontario, Abitibi belt (N.F. Trowell)

The objective is to obtain an economic evaluation of the area. This is the second year of the program. Initial chemical data indicate that the komatiite flows of Munro Township extend westwards and thin out into Beatty Township.

(d) Mapping in McComber and Vincent Townships (M.W. Carter)

The metavolcanic and metasedimentary Archean rocks are folded about an east-northeasterly axis into an isoclinal fold. The succession comprises mafic volcanics (flows), followed by sediments and intermediate volcanics (aphanitic tuffs). The supracrustal rocks are intruded by gabbros, felsic rocks and diabase dykes. The only rocks of Proterozoic age occur in a diabase sill.

6. Ministère de l'Énergie et des Ressources, Québec

Projet Joutel - Quévillon en Abitibi (M. Hocq)

Au cours de 1983, la cartographie s'est poursuivie dans les cantons de Dalet et Mazarin, afin de préciser la distribution des facies coussinés/massifs/pyroclastiques, de mettre en relief la position des failles et les traces de plans. Les objectifs de cette étude sont de déterminer la lithostratigraphie, la tectonique et de découvrir de nouvelles minéralisations.

7. Campbell and Associates, Geological Consultants

Prospector II (A.N. Campbell)

Prospector was a ten year research project in expert system development at SRI International and U.S. Geological Survey. Prospector II, developed by Campbell and Associates, is a second generation version of this work, and we are completing a project to incorporate a suite of volcanogenic exploration models. Research plans: 1) incorporate and test additional exploration models; 2) test accuracy of model predictions compared to the predictions made by authors of the models.

8. Canadian Occidental Petroleum Ltd., Minerals Division

Drill programs in Archean volcanic - volcanoclastic rocks, Quebec, Ontario (R.H. Wallis)

The aim of this research is to study petrography and some major and trace element geochemistry.

9. University of California at Santa Barbara

Geology and petrogenesis of Miocene Chilcotin Group basalts, south-central British Columbia (M.-H. Bevier)

The project is terminated. The objectives were to determine age, stratigraphic variation, geochemistry, and petrogenesis of a Mio-Pliocene plateau lava field in south-central British Columbia. See bibliography for results. In January 1984, it will be possible to do further work on REE contents of Chilcotin basalts in conjunction with G. Goles at U. of Oregon in Eugene.

10. University of British Columbia

Isotopic and petrochemical study of Cordilleran volcanic rocks (R.L. Armstrong)

Sr and Pb isotopic studies of ultramafic nodules in Cenozoic basalts of British Columbia, and neutron activation analysis of trace elements in Cenozoic basalts of British Columbia will continue.

11. University of Alberta

(a) Structure and properties of silicate melts (Scarfe, Fujii, Dunn, Dingwell, Shimada, Harris)

(b) Volatiles in magmas and mechanism of eruption (Scarfe)

(c) Petrogenesis of mid-ocean ridge basalts (Scarfe)

(d) Mantle xenoliths and their host alkali basalts, British Columbia (Scarfe)

12. University of Calgary

(a) Comparison of nephelinite lavas from oceanic and continental volcanic centres (Canary Islands, Hawaiian Islands, British Columbia, Recent-Quaternary) (J. Nicholls and M.Z. Stout)

The objective is to determine why such rocks are common on oceanic islands, but rarely found on continents. Whole rock analysis and analysis of constituent minerals by electron microprobe is continuing. With these data and the methods of chemical thermodynamics, inferences about the conditions of origin can be made. Such conditions include the temperature and depth in the earth at which the lavas formed and the mechanism for separating the melt from the surrounding solid earth.

(b) Petrology of Diamond Craters; S.E. Oregon - recent alkali olivine basalt lavas (J.K. Russell)

Thirteen major and minor elements, and 21 trace element analyses have been determined on 12 lavas. Analyses of all mineral phases are also completed for these same 12 lavas. (i.e. feldspar, olivine, titanite, Fe-Ti oxides). Research plans: 1) final completion of this project for publication; 2) continued analytical work on 22 Hawaiian lavas; 3) theoretical modelling of crystallization processes in basaltic melts.

13. University of Saskatchewan

Geochemical studies of Aphebian volcanic rocks in the vicinity of Flin Flon, Manitoba-Saskatchewan (L.C. Coleman)

The objectives are to evaluate magma sources and the geotectonic regime of volcanism and, it is hoped, the nature of the Aphebian upper mantle. Field examination, petrographic studies, whole rock analysis for major and selected trace elements and microprobe analyses of constituent minerals of Aphebian Amisk volcanics occurring near Flin Flon are approaching completion. Data compiled during this work are presently being evaluated and it is expected the results of the work will be submitted for publication in the near future.

14. University of Manitoba and Acadia University

(a) Physical volcanology in the early Paleozoic Flin Flon greenstone belt, Manitoba and Saskatchewan (L.D. Ayres, M. Dolozzi, N.A. Van Wagoner, S.L. Van Wagoner)

The objectives are the documentation of 1) lava flow morphology and the relationship of morphology to eruption rates and vent locations; 2) genesis of the abundant basaltic tuff sequences; and 3) volcano evolution using both physical volcanology and geochemistry. In the western part of the greenstone belt of Amisk Lake, Saskatchewan, a 9+ km thick sequence represents a periodically emergent, basaltic stratovolcano with a shield-like morphology; this is capped by a more typical andesitic to dacitic stratovolcano that has both subaerial and subaqueous facies. Komatiitic basalt flows form a single 100+ m thick unit near the middle of the sequence. Unlike much of the Archean Abitibi greenstone belt, subaqueous basalt flows are generally less than 10 m thick; many flows with spherical amygdules have brecciated tops; vertical gradations from massive to pillowed facies are rare. The main focus of the investigation has now shifted eastward to Flin Flon where basaltic flow sequences also show evidence of shallow water and local subaerial eruption, but have a much lower proportion of interflow fragmental material. Geochemical work is in progress in both the Amisk Lake and Flin Flon areas.

(b) Rheological modelling of early Proterozoic crust and mantle as a function of volcanic loading, Amisk Lake area, Saskatchewan (W. Moon, L.D. Ayres)

The main objectives are the determination of the size and shape of volcano and crust-mantle conditions that fit the amount of downsinking observed in the stratigraphic sequence. The Amisk Lake volcano is characterized by alternating sequences of subaerially and subaqueously erupted rocks. This alternation is a function of volcano sinking during eruption and a varying ratio between rates of sinking and volcano construction due to eruption. Modelling of the sinking on various types of crust and mantle indicates that the volcano was probably relatively large with slopes of 3° or less. It was thus unlike modern volcanoes.

(c) The Eocene (?) Skukum andesite-rhyolite volcanic complex, Yukon (M.J. Smith)

The Skukum Complex, which is 15 km north of the Bennett Lake Cauldron Complex, is a composite volcano comprising 1) a lower distal unit of andesitic to rhyolitic volcanoclastic sedimentary rocks, pyroclastic flows, and tuff; 2) a middle proximal andesite flow and fragmental unit; 3) an upper rhyolite flow and pyroclastic flow sequence. The lower unit is a valley-filling sequence related to volcanism outside of the present exposure. It was preserved because of the development of the capping andesite volcano and associated faults.

(d) A study of systematic fracturing - North Menan Butte, Idaho (Recent tuff ring) (W.C. Brisbin, W.J. Russell)

Within the tuff ring there are four systems of fractures related symmetrically to the morphology of the tuff ring. The orientation, character, displacement sense and continuity of each of these systems can be interpreted in terms of differential compaction and contraction due to desiccation and/or deflation.

15. University of Western Ontario

Nature and significance of the McDougall-Despina structure in the Precambrian Mine Series volcanic rocks, Noranda, Quebec (T. Setterfield)

The thesis evaluates the role of the McDougall-Despina structure in the extrusion and displacement of volcanic rocks, and its possible control on hydrothermal activity. The McDougall-Despina structure cuts volcanic rocks of the Mine Series in the Noranda volcanic complex. Vertical displacement across the structure is approximately 950 m, with lesser horizontal displacement. The structure is interpreted to have served as a vent to at least five formations in the Mine Series, and to have provided a channel way for hydrothermal fluids, which produced the Corbet Cu-Zn deposits. Dyke types occupying the structure include: diorite, andesite, massive felsic, felsic breccia and composite dykes. Complex relationships exist between individual dykes.

The McDougall-Despina structure's control on hydrothermal activity is to be better documented. Dykes within the structure will be examined in detail, in order to deduce their mode of emplacement and the relationship between dyke types. Finally, the role of structure in the development of the volcanic pile and the accumulation of base metal deposits will be evaluated.

16. University of Toronto

Late Cenozoic tephra beds in Alaska and the Yukon Territory (J.A. Westgate, R.C. Walter)

The objective is the application of late Cenozoic tephra to stratigraphic problems, i.e. tephrochronology. Current activity is focussed on numerous tephra beds in the loess deposits of interior Alaska. Chemistry suggests many of these are derived from vents in Wrangells. We have recently delineated a widespread unit - Old Crow Tephra that is likely 100 km³ in volume.

17. Queen's University

The geology of the southeastern Amer Lake area, district of Keewatin, N.W.T. with particular reference to the quartzite problem (K. Ashton)

The objective is to determine whether quartzite is part of the Archean metavolcanic suite in the area or whether it unconformably overlies it as a Proterozoic outlier. Field work is completed. Archean metavolcanic rocks are bimodal, mainly intermediate to felsic fragmented rocks and komatiites; mafic volcanics are rare. The quartzite problem is not yet solved, but the quartzite appears to overlie the metavolcanics rather than being a conformable part of the stratigraphy as in Prince Albert Group, District of Keewatin, N.W.T. U/Pb age dating of felsic metavolcanics, intrusive granites and quartzites is still in progress.

18. Carleton University

(a) Detailed geology and volcanological reconstruction of the Archean central Mine sequence volcanic stratigraphy, Noranda area, Northwestern Quebec (H. Gibson)

The objectives are 1) to produce a detailed geologic map of the area; 2) to reconstruct the volcanic stratigraphy and history; 3) to find models for extrusion/flow of subaqueous rhyolite and basalt lavas; 4) to describe alteration facies; 5) to discuss location and genesis of VMS deposits in light of volcanological reconstruction. Surface maps are completed, sub-surface isopach and contour maps near completion with petrography under way. Geochemical (whole rock) data await manipulation.

Research plans are 1) to analyse selected samples (50-75) for REE and trace elements in cooperation with I. Campbell (U. of T.); 2) oxygen isotope study of silicified and epidote-quartz altered volcanics (with BRGM-France).

(b) Stratigraphy, physical volcanology and geochemistry of the Belmont Lake metavolcanic complex, southeastern Ontario (J.R. Barlett)

The objective is to study the effect on physical volcanology of cyclical volcanism. The geochronology project was initiated in the fall of 1983: sampled andesites/dacites from middle of first volcanic cycle, rhyolite from top of third cycle, and altered tuff from middle of fourth cycle; first dates should determine spread in age from first to last (fourth) cycle (in collaboration with D.W. Davis, Royal Ontario Museum).

Possible further geochronological work will be done if the age spread between first and last cycles is large enough. Detailed mapping of central facies area of cycle I and detailed mapping of thin ash flow tuff unit in cycle II will be undertaken.

(c) Evolution of the Mount Harper volcanic complex (Late Proterozoic), Ogilvie Mountains, Yukon (C. Roots)

The objectives are to determine stratigraphy, geochemistry and U-Pb dating.

19. University of Montreal

(a) Volcanology of the rhyolitic complexes in the Rouyn-Noranda region, Abitibi, Quebec (L. Gélinas)

Detailed mapping of the various volcanoclastites and associated rhyolite porphyries in the Blake River Group, Archean age is in progress.

(b) Volcanological studies at Mt. Pelée, Martinique, Antilles Françaises (L. Gélinas)

(c) Étude du complexe volcanique archéen de Duprat, groupe de Blake River, Abitibi, Québec (P. Verpaerst)

(d) Studies of post eruptive phenomena influencing the morphology of pyroclastic flow deposits "nuées ardentes" (L. Gélinas)

(e) Volcanologie et géochimie de la ceinture volcanique archéenne Frotet-Evans (A. Simard, L. Gélinas et J.N. Judden)

(f) Characteristics of pyroclastic-flow deposits on Martinique (J. Lajoie)

The main objectives are to describe and explain primary structures and textures of the deposits.

20. Université Laval

(a) Roches volcaniques et subvolcaniques d'âge Siluro-Dévonien de la région sud du Mont Albert, Canton de Lemieux, Gaspésie (G. Lachambre, C. Dion, L. Pelletier, R. Laurent)

Le but de ce travail est d'étudier la cartographie, la pétrologie ainsi que les relations structurales des roches volcaniques et hypabyssales d'âge siluro-dévonien. Des études de reconnaissance ont été menées sur le complexe du Mont Hog's Back et celui du dôme de Lemieux, à la base de roches siluro-dévonienne situées au sud de la faille des Chic-Choc-Sud dans la région du Mont Albert. Deux thèses de maîtrise seront entreprises à l'été 1984, 1) Mont Hog's Back; 2) dôme de Lemieux. Il s'agit en majorité de roches de composition intermédiaire à acide, auxquelles sont associées des minéralisations en sulfures de Cu, Pb, Zn.

(b) Roches volcaniques d'âge Siluro-Dévonien de la Baie des Chaleurs, Gaspésie, Québec (J. Bélanger, R. Laurent)

Le but de ce travail est de présenter une carte géologique ainsi qu'une reconstitution du paléo-environnement en collaboration avec les études stratigraphiques et sédimentologiques de P.A. Bourque et de ses étudiants. La cartographie qui s'étend du NE (région du Mont Alexandre - Mont Observation) au SW (Lac McKay, Ristigouche) est terminée. Elle a nécessité trois étés de terrain. Le matériel récolté est étudié du point de vue pétrologique et géochimique dans trois coupes détaillées. L'étude de cinq

autres coupes détaillées se poursuit présentement. L'analyse et la synthèse de ces données seront réalisées au cours de l'année 1984.

(c) Étude pétrologique du complexe ophiolitique d'âge Cambro-Ordovicien de Thetford Mines, Appalaches Québécoises (Y. Hébert)

Ce travail constitue le sujet d'une thèse de doctorat couvrant les roches plutoniques et volcaniques du complexe ophiolitique de Thetford Mines, la création d'une carte géologique du complexe et le modèle de formation.

21. Université du Québec à Chicoutimi

(a) Hydrothermal alteration of Archean lavas (E. Dimroth, J. Carignan, A. Fowler)

We have examined the alteration of two Archean rhyolite flows (Don Rhyolite no. 5 flow and Destor rhyolite). Alteration effects are analogous to the alteration of a Miocene hyaloclastite ridge.

(b) Comparison of Archean and Cenozoic subaqueous volcanic rocks with particular emphasis on hyaloclastites (E. Dimroth)

During the last year, a large number of type localities of Miocene, Pliocene and Pleistocene volcanic rocks, as well as some Holocene volcanoes have been visited, and thin sections of the material collected have been prepared. Two papers have been submitted to journals.

(c) Paleogeographic evolution of the Archean sequence in the Chibougamau and Rouyn-Noranda areas, Abitibi greenstone belt, Quebec (E. Dimroth and assistants)

The objectives are to reconstruct the volcanic and sedimentary evolution of the Chibougamau-Chapais area and compare it with the evolution of the Noranda area. Investigations of the Blondeau, Bordeleau, Chebistuan, Stella and Haüy Formations are nearly completed. In total about 10 km of stratigraphic section and more than 800 thin sections have been studied. Two papers have been submitted. Future work will concentrate on the proximal facies of the Blondeau Formation and on pyroclastic rocks in the Roy Group.

22. Acadia University

(a) Segregation vesicles in mid-ocean ridge basalts as a rock orientation tool and indicator of depth of extrusion - North Atlantic and Pacific oceans and Iceland greenstone belts (N.A. Van Wagoner)

The objectives are 1) to determine the feasibility of using segregation vesicles to orient sea floor basalts recovered by dredge, submersible and drill core for paleomagnetic and structural studies and 2) to determine the water depth necessary for the formation of these vesicles.

Segregation vesicles can be used to orient sea floor basalt samples for structural and paleomagnetic polarity studies. They were used to orient dredge and submersible samples from the FAMOUS area and helped reveal the occurrence of reversely magnetized, but presumably Brunhes age crust. Application of the technique to DSDP drill cores from the North Atlantic revealed that this crust is structurally and magnetically heterogeneous, and in places, rock units are steeply dipping and even overturned.

(b) Volcanic evolution of the Proterozoic Flin Flon-Snow Lake greenstone belt, Saskatchewan, Manitoba (N.A. Van Wagoner, L.D. Ayres, S.L. Van Wagoner)

The objectives are 1) to determine the volcanic stratigraphy, evolution, tectonic setting and metallogenesis of the study area; 2) to establish and refine criteria which may be used to determine the paleo-eruptive environment and the paleogeography of volcanic terrains; 3) to establish volcanological criteria which may be used to help search for undiscovered mineral deposits. The volcanic stratigraphy of the Amisk Lake area of the belt indicates that the area evolved as a volcanic island which was subjected to

transgressions and regressions due to the effects of loading and subsidence. Above wave base deposits were clearly recognized by their distinctive characteristics and used to indicate the paleo-positions of sea level. The research plans include a comparative study of mineralized and unmineralized parts of the belt and continued detailed studies of flow and sedimentary structures as indicators of mode of deposition and paleo-volcanology.

(c) Geological and paleomagnetic study of subglacial pillow basalt formations, Iceland (N.A. Van Wagoner, J. Helgason, L.D. Ayres, I.B. Fridleifsson)

The objectives are 1) to determine the syn- and post-depositional deformation of the volcanic sequence; 2) to investigate the homogeneity of paleomagnetic directions within and between pillows; 3) to study the morphology of flows erupted beneath different subglacial thicknesses, and investigate the occurrence and significance of segregation vesicles in these flows.

(d) Pre-Carboniferous physical volcanology and metallogenesis of the Avalon Zone of Cape Breton Island and New Brunswick (N.A. Van Wagoner)

The objectives are 1) to determine the volcanic stratigraphy, evolution, tectonic setting and metallogenesis of the study areas; also, to establish and refine criteria which may be used to determine the paleo-eruptive environment and volcanological criteria that may be used to help search for undiscovered mineral deposits.

(e) Geochemistry of Carboniferous mafic volcanic rocks in New Brunswick (S.M. Barr, Acadia University), L.R. Fyffe (New Brunswick Department of Natural Resources)

The objectives are to describe the petrology and geochemistry in relation to the tectonic setting, and compare these rocks to others of similar age in the Atlantic region.

23. Saint Mary's University

(a) Geochemistry of non-orogenic volcanic rocks (J. Dostal)

A study of the geochemistry and petrogenesis of non-orogenic volcanic rocks, particularly continental tholeiites, is in progress. The purpose of the study is to 1) identify the role of crustal contamination during the genesis of the continental tholeiites and 2) characterize the source of the parental magmas of these volcanic rocks and the role of mantle metasomatism.

(b) Geochemistry and petrogenesis of Plio-Quaternary calc-alkaline rhyolites from Tuscany (Italy) and South America (J. Dostal)

The investigation will try to determine whether they are the result of fractional crystallization of mafic to intermediate magma or direct melting of crustal material.

24. Bibliography

Ayres, L.D. 1983. Bimodal volcanism in Archean greenstone belts, exemplified by greywacke composition, Lake Superior Park, Ontario. *Can. J. Earth Sci.*, 20, 1168-1194.

Bévier, M.L. 1983. Implications of chemical and isotopic composition for petrogenesis of Chilcotin Group basalts, British Columbia. *J. Petrol.*, 24, 207-226.

Bévier, M.L. 1983. Regional stratigraphy and age of Chilcotin Group basalts, south-central British Columbia. *Can. J. Earth Sci.*, 20, 515-524.

Brazier, S., Sparks, R.S.J., Carey, S.N., Sigurdsson, H. and Westgate, J.A. 1983. Volcanological implications of bimodal grain size distribution and secondary thickening in some distal and fall ash layers. *Nature*, 301, 115-119.

Church, B.N. and Young, W.M. 1983. Geothermal potential map of British Columbia. B.C. Ministry of Energy, Mines and Petroleum Resources.

- Church, B.N., Ewing, T.E. and Hora, Z.D. 1983. Volcanology, structure, and coal and mineral resources of early Tertiary outliers in south-central British Columbia. Joint Annual Meeting, Geol. Assoc. Can., Field Trip Guidebook No. 1, 8-14.
- Church, B.N. and Suesser, U. 1983. Geology and magnetostratigraphy of Miocene basalts of the Okanagan Highlands, British Columbia. In: Geological Fieldwork. B.C. Ministry of Energy, Mines and Petroleum Resources, Paper 1983-1, 32-36.
- Dostal, J. and Strong, D.F. 1983. Trace element mobility during low-grade metamorphism and silicification of basaltic rocks from Saint John, New Brunswick. *Can. J. Earth Sci.*, 20, 431-435.
- Dostal, J., Baragar, W.R.A., and Dupuy, C. 1983. Geochemistry and petrogenesis of basaltic rocks from Coppermine River area, Northwest Territories. *Can. J. Earth Sci.*, 20, 684-698.
- Dostal, J., Dupuy, C. and Keppie, J.D. 1983. Uranium and thorium in Paleozoic rhyolites of Nova Scotia. *Can. J. Earth Sci.*, 20, 266-274.
- Dostal, J., Dupuy, C. and Liotard, J.M. 1983. Geochemistry and origin of basaltic lavas from Society Islands, French Polynesia. *Bull. Volcanol.*, 45, 51-62.
- Dostal, J., Dupuy, C., Carron, J.P., LeGuen Kerneizon, M. and Maury, R.C. 1983. Partition coefficients of trace elements: application to volcanic rocks of St. Vincent, West Indies. *Geochim. Cosmochim. Acta*, 47, 525-533.
- Easton, R.M. and Easton, M.N. 1983. Geology of the Hawaiian Islands-Hawaii, Maui and Oahu, field trip No. 16, Victoria 1983. *Geol. Assoc. Can.*, 91 pp.
- Easton, R.M. and Easton, M.N. 1983. Circle-Island tour of the Island of Hawaii, field trip No. 16. Supplementary Guidebook No. 1, Victoria 1983. *Geol. Assoc. Can.*, 31 pp.
- Easton, R.M. and Easton, M.N. 1983. Oahu, field trip No. 16. Supplementary Guidebook No. 2, Victoria 1983. *Geol. Assoc. Can.*, 15 pp.
- Easton, R.M. and Easton, M.N. 1983. Kauai, field trip No. 16. Supplementary Guidebook No. 3, Victoria 1983. *Geol. Assoc. Can.*, 11 pp.
- Easton, R.M. and Easton, M.N. 1983. Molaka, field trip No. 16. Supplementary Guidebook No. 4, Victoria 1983. *Geol. Assoc. Can.*, 9 pp.
- Hébert, Y. 1983. Étude pétrologique du complexe ophiolitique de Thetford Mines, Québec. Thèse de Ph.D., Université Laval, Ste-Foy, Québec, 426 p.
- Hocq, M. 1983. Carte des Cantons de Dalet et Mazarin et parties des cantons adjacents (1/50,000). DP 83-25 (carte annotée).
- Hocq, M. 1983. Projet de Joutel-Quévillon, région de la rivière Gale. Dans: Rapports des travaux en cours à la division du Précambrien, ET82-01, Ministère de l'Énergie et des Ressources du Québec, 207-250.
- Nicholls, J. and Stout, M.Z. 1982. Heat effects of assimilation, crystallization and vesiculation in magmas. *Contrib. Mineral.*, 81, 328-339.
- Nixon, G.T. 1982. The relationship between Quaternary volcanism in central Mexico and the seismicity and structure of subducted ocean lithosphere. *Bull. Geol. Soc. Am.*, 93, 514-523.
- Roots, C.F. 1983. Mount Harper Complex, Yukon; Early Paleozoic volcanism at the margin of the Mackenzie Platform. In: Current Research, Part A, *Geol. Surv. Can. Paper 83-1A*, 423-437.

- Roots, C.F. and Moore, J.M. 1983. Proterozoic and early Paleozoic volcanism in the Ogilvie Mountains, an example from west-central Yukon. In: Yukon Exploration and Geology 1982. Indian and Northern Affairs Canada, 55-62.
- Setterfield, T., Watkinson, D.H. and Thurston, P.C. 1983. Quench-textured, pillowed metabasalts and copper mineralization, Maybrun Mine, Northwestern Ontario. CIM Bulletin, 76 (859), 69-74.
- Smith, M.J. 1983. The Skukum volcanic complex, 105 D SW: geology and comparison to the Bennet Lake Cauldron Complex. In: Yukon Exploration and Geology 1982. Dept. Indian and Northern Affairs, 68-72.
- Stout, M.Z. and Nicholls, J. 1983. Origin of the hawaiites from the Itcha Mountain Range, British Columbia. Can. Mineral., 21, 575-581.
- Van Wagoner, N. 1983. Critical evaluation of segregation vesicles in Mid-Ocean Ridge basalts as a rock orientation tool. J. Geophys. Res., 88, 8318-8332.
- Van Wagoner, N. and Johnson, H.P. 1983. Magnetic properties of three segments of the Mid-Atlantic ridge at 37°N: FAMOUS, Narrowgate and AMAR:AMAR 2. J. Geophys. Res., 88, 5065-5082.
- Van Wagoner, N., Moon, W., Ayres, L.D., Tang, R. and Carswell, A. 1983. Preliminary results of rheological modelling of a Proterozoic volcano and earth. Centre for Precambrian Studies, 1982, Ann. Rept. 128-150.
- Van Wagoner, S. 1983. A probable storm-generated turbidite association - Proterozoic Flin Flon-Snow Lake greenstone belt: Centre for Precambrian Studies, 1982, Ann. Rept. 115-127.
- Westgate, J.A. 1982. Discovery of a large-magnitude, Late Pleistocene volcanic eruption in Alaska. Science, 218, 789-790.
- Westgate, J.A., Hamilton, T.D. and Gorton, M.P. 1983. Old Crow tephra: a new late Pleistocene stratigraphy marker across Alaska and the Yukon Territory. Quaternary Research, 19, 38-54.

V. ISOTOPE STUDIES AND GEOCHRONOLOGY

Compiled by: A. Hayatsu

1. Introduction
2. University of Alberta
3. University of British Columbia
4. University of Calgary
5. Carleton University
6. Dalhousie University
7. McMaster University
8. Queen's University
9. University of Toronto
10. University of Western Ontario
11. Bibliography

1. Introduction

This report has been compiled from 11 contributions from 9 universities. No attempt has been made to summarize all activities in this field since the majority of researches reported here are studies of specific problems by means of various isotope methods.

2. University of Alberta - Department of Physics (G.L. Cumming, J. Gray, D. Kristic, L. Tober, C. Yonge), Department of Geology (H. McCullough)

(a) Instrumentation

We have taken delivery of a new HP9816 computer for use on the MM30 mass spectrometer. H. McCullough has made substantial progress towards programming a Motorola 6801 microprocessor for use on the 9" radius solid source machine. Data reduction will be carried out on a dedicated TI990-10 and programs are currently being modified from other instruments.

(b) Radiogenic Isotope Studies

Flin Flon We have completed a study of the variation of Pb isotopes from sulfide separates obtained from 14 deposits in the area. Most trace Pb isotope variation indicates that a major resetting of the Pb system occurred at the end of the Hudsonian orogeny (1730 Ma) or slightly younger than most Rb/Sr dates on volcanics and intrusives. There is, however, substantial variation in initial Pb isotope ratios for the deposits we have studied in detail. The range of variations suggests an ultimate source age of about 2300 Ma. There are some difficulties in reconciling the Rb-Sr dates in the area with a simple two-stage model for the development of the Pb isotope ratios but the general pattern seems consistent with the available Rb-Sr dates.

Pine Point We have reanalysed a large group of samples obtained from representative deposits throughout most of the Pine Point area. We now can demonstrate very small variations in ^{206}Pb and ^{208}Pb which are about 3 to 4 times the measuring error, but the ratios are remarkably constant in contrast with data from some other "Mississippi Valley type" deposits.

Sullivan Mine Pb isotope ratios from the Sullivan deposit have often been used as one of the data sets in the construction of Pb evolution models. We have examined 21 galena, pyrrhotite and pyrite samples in order to see whether this deposit does in fact fulfill the requirements for such models, one such requirement being constancy of Pb isotope ratios. We find that both galena and pyrrhotite isotope ratios are slightly variable, the data being suggestive of mixing of Pb from sources which have had different U/Pb ratios since about 3600 Ma ago.

(c) Stable Isotope Studies

Tree ring isotope ratio work is continuing at a reduced pace. Results of an extended study of the relationship between D/H and $^{18}\text{O}/^{16}\text{O}$ and climate variables have now been published in two papers. A third paper describing the mathematical modelling of this system has been submitted for publication.

Isotope studies of fluid inclusions are continuing and a number of systems are being studied. Subglacial precipitates from carbonate and granodiorite terrains are being investigated. Since all glaciers in the Canadian Rockies are presently in retreat, a wealth of calcite deposits formed at the previous ice-bedrock interface have been exposed. Since there is good temperature control on the formation ($\approx 0^\circ\text{C}$), stable isotope studies of calcite oxygen and carbon yield information about the ice from which they were precipitated. Thus a record of past precipitation is indirectly gained from successive layers of calcite. A problem occurs however in modelling the water-ice-calcite oxygen fractionation and hence deriving paleoclimatic significance from the calcites whose isotopic composition is close to that of the carbonate bedrock from which they are derived. We have collected calcite samples from a granodiorite terrain (Bugaboo Mountains) which have a very distinctive isotopic composition (close to atmospheric CO_2) and which are rich in fluid inclusions. It is hoped that by using stable isotope measurements of the mineral fluid, rigorous control on the ice-water-calcite fractionation model can be obtained.

3. University of British Columbia, Department of Geological Sciences

(a) Insular Belt

C. Isachsen completed geochronometry and chemistry on the West Coast Complex near Tofino. U-Pb, K-Ar and Rb-Sr dates for the plutonic rocks are Jurassic and Cenozoic. Sr isotope data for sediments of the Leech River Complex were included in the paper by Fairchild and Cowan (1982).

(b) Coast Plutonic Complex

T. Heah found that part of the Gambier Group is a bimodal basalt-dacite volcanic assemblages, subjected to low grade metamorphism 95 to 100 Ma ago. Trace elements and regional geology agree on a magmatic arc setting for those rocks.

J. Gabites has completed mapping of the Cogburn Creek - Old Settler area east of Harrison Lake and is now in the process of compiling field observations and dating plutonic and metamorphic rocks.

Armstrong, Parrish and Scott have continued their work on geochron traverses near Bella Coola and Alice Arm. A mid Cretaceous age (98 Ma) for the Ecstall Pluton near Prince Rupert was established by U-Pb dating (R. Parrish) of several zircon fractions. This work corrected an erroneous verbal report to L. Hollister and M.L. Crawford (1982 J.G.R. Paper) of a Jurassic age (due to a data processing error in the first zircon analysis).

(c) Omineca Belt

Zircon dating by R. Parrish of Frenchman's Cap core gneisses has supported the Rb-Sr age of ~ 2.2 Ga reported previously. Zircon studies have also included Sifton Range (R. Parrish, H. Gabrielse - 1.8 Ga), Deserters Range (R. Parrish, C. Giovanella - 0.72 Ga), and Valhalla (R. Parrish - 0.1 Ga) gneisses.

Samples related to the Columbia River Fault, supplied by L. Lane of Carleton, and of Trail-Castlegar area rocks, supplied by P. Simony of the University of Calgary, and of Quesnel gneiss, supplied by C. Rees of Carleton University, are also under study by Rb-Sr and U-Pb. In the Cariboo-Quesnel region two dating projects are underway involving J. Getsinger and L. Pigage.

Portions of the Kuskanax (J. Wheeler), Nelson (I. Duncan), and related batholiths have been precisely dated as of mid to late Jurassic age by U-Pb and Rb-Sr, respectively (173 to ~ 163 Ma). Other plutons, important to structural dating, are under study.

An Early Carboniferous, ~ 330 Ma, U-Pb zircon date has been obtained by R. Parrish for the Verity carbonatite, Blue River area in Monashee Complex, sampled by G. White.

R.G. Anderson, L. Pigage, and J. Mortensen have provided samples of mostly Mesozoic, and Paleozoic granitic rocks from the Yukon for Rb-Sr dating. Crustal anatexis and assimilation are indicated as major factors in magma genesis there, especially during early to mid Cretaceous time.

Rehrig et al. (1982) collected basement gneiss and Mesozoic-Cenozoic granites near Spokane, Washington, for Rb-Sr and U-Pb dating. Ages of ≥ 1.4 Ga, ~ 100 Ma, and 50 Ma are well established. A 50 Ma thermal-tectonic overprint is pervasive in the area.

(d) Pb Isotope Studies

A. Andrew is continuing Pb isotope studies of Cordilleran ores and igneous rock suites.

4. University of Calgary - Physics (H.R. Krouse, C.J. Bland, J. Case, A. Shakur); Geology (F.A. Campbell, A.A. Levinson, I. Hutcheon); Geography (S. Harris, M. Jeffries); Biology (E. Laishley, R. Guy); Chemistry (R. Roche, G. Ritchie); Kananaskis Centre for Environmental Research (A. Legge)

Projects include: carbon and hydrogen isotope analyses of separated gases and oil fractions using samples from Alberta, the Arctic, and Eastern offshore; carbon isotope monitoring of light gases produced in oil sand in-situ recovery operations; carbon and sulphur isotope composition of coal in Canada; carbon isotope fractionation during pyrolysis and combustion of fossil fuels; sulphur isotope composition of H₂S released during linear temperature increase pyrolysis of fossil fuels; H, C, O, and S isotope abundances in stratified water bodies in the Canadian Arctic; H and O isotope abundances in ice cores of the Ward Hunt Ice Shelf; S and O isotope abundances in evaporites; carbon isotope fractionation during photosynthesis by plants in salt stressed environments; isotope fractionation during bacterial conversions; sulphur isotope analyses of lake sediments, soil profiles, vegetation, surface waters, and atmospheric compounds for assessing industrial sulphur inputs to the environment in various locations in Alberta, Ontario, and California; isotopic studies of springs in western Canada; sulphur isotope abundances in food chains; C and S isotope abundances in kidney stones (paper in press *Geochim. Cosmochim. Acta*); disequilibrium of uranium and thorium minerals (paper on young U-deposits in Okanagan region of B.C. in press *Can. J. Earth Sci.*).

5. Carleton University - Department of Geology (K. Bell, J. Blenkinsop, K. Fadaie, J. Richardson, J. Sharpe, J. Wen), Department of Physics (T.J.S. Cole)

(a) Isotope Geochemistry

Our new Finnigan-MAT 261 mass spectrometer, the first multi-collector solid-source machine in North America, is now routinely producing analyses of high precision. Precision for Sr and Nd isotopic analyses approaches 0.001%.

Bell et al. (1982) reported on our finding of a linear correlation between age and initial ratio for a number of alkali complexes from Ontario and Quebec. The linear relationship implies a source for Sr in the complexes that has remained closed with respect to Rb and Sr from 2700 to 120 Ma and the Rb-Sr ratio of the source region is 0.018, indicative of a zone depleted with respect to the large lithophile elements. This finding forms the basis of much of the research being carried out in our group. Sharpe and Wen are carrying out more detailed geochemical and isotope studies of two complexes, Cargill (1800 Ma) and Oka (120 Ma). The isotopic and geophysical characteristics of the mantle underlying the African craton are being investigated in a study of potassic-rich lavas of the East African Rift (Fadaie, Blenkinsop, Ranalli). Carbonatites from North America and elsewhere (Bell) and kimberlites and their associated ultramafic xenoliths (Blenkinsop) are being analysed in order to provide more information about the depleted

zone. G. Tilton (U.C. Santa Barbara) and M. Gruenfelder (Zurich, Switzerland) are carrying out a Pb isotope study of the same complexes and P. Deines is undertaking stable isotope work.

Other projects include a geochemical study of the East Kemptville ore-body, Nova Scotia (Richardson, Blenkinsop, Watkinson). Isotopic data will be combined with other geochemical information in this study of the genesis of the ore-body.

(b) Instrumentation

Results from multiple collection indicate that multi-collector and double collector measurements yield equivalent precision for Sr, while double collection appears to produce somewhat better results for Nd. For smaller signals, however, multiple collection is superior in both cases (Blenkinsop, Cole). Automation of our other mass spectrometer is well underway (Ryan).

6. Dalhousie University, Departments of Physics and Geology (P.H. Reynolds)

Two mass spectrometer systems are in routine operation: (i) a modified MS10 now interfaced to an Apple computer, and (ii) a Micromass 602D which is equipped with a carbonate extraction line.

(a) K-AR and $^{40}\text{Ar}/^{39}\text{Ar}$ Geochronology

Work continues on studies which relate to the Paleozoic and late Precambrian paleomagnetic record. Recently completed (Reynolds and Murthy, 1983) is a study of a suite of diabase dikes from the Gander Zone, Newfoundland which concluded that probably all dykes have the same primary age. Also, recently completed and submitted (Reynolds, CJES) is a study of the ~ 1400 Ma old Mealy Dikes of Labrador. Biotites in these rocks give well-defined age plateaus at ~ 1000 Ma. Hornblende spectra, however, are discordant and suggest that the dike rocks were rather strongly over-printed by an approximately 1100 Ma old (Grenville) event. This study confirms an age of ~ 1000 Ma for the southern tip of the Grenville apparent polar wander paths; it also constrains the age of A paleopoles (Park and Emslie, CJES, in press) to the time interval 1100-1000 Ma. The latter poles define an eastern (descending arm) of the Grenville Loop.

Research continues on the metamorphic and intrusive rocks of southwest Nova Scotia. Results of a follow-up study to our previous report (Reynolds et al., CJES, 18, p. 386, 1981) will soon be ready for publication. An important new result is the 295 ± 3 Ma age obtained for muscovites from greisens associated with economic tin mineralization at East Kemptville, N.S. Deposits of very similar age exist in England and in Portugal. The extent and importance of a Hercynian metallogenic epoch is hereby emphasized (M. Zentilli, P. H. Reynolds). Elias has begun an extensive study of metamorphic rocks from the Meguma Zone.

Reynolds in collaboration with Brookfield (Guelph) and McNutt (McMaster) continues to work on the Indus Suture Zone. A paper will appear in *Geologische Rundschau*.

(b) Stable Isotope Studies

D. Scott and A. Aksu are continuing their oxygen isotopic studies of selected marine sediment cores.

Oxygen-carbon isotopic studies of the Gays River and neighbouring ore deposits have been completed. A paper (Reynolds, Zentilli and Akande) has been submitted to the *Journal of Exploration Geochemistry*.

7. McMaster University

(a) Stable Isotope Studies (C.E. Rese, H.G. Thode)

Carbon and sulphur isotope ratios in banded iron formations are being used to characterize depositional conditions and provide information on the possible role of living organisms in the early Precambrian.

Measurements of the four stable sulphur isotopes in meteorites and lunar samples are being continued in order to investigate the isotopic homogeneity of the early solar system and the history of the lunar regolith.

Studies are continuing of the isotope ratios and concentrations of various sulphur compounds in sediments, petroleum, oil bearing rocks and other materials. The information obtained is used to follow the details of such processes as sediment diagenesis, the formation, maturation and migration of oil, and the movement of sulphur between the various geochemical reservoirs.

(b) Rb-Sr geochronology and Sr-isotope studies (R.H. McNutt, L. Heaman, K. Connare)

Our study continues on the Rb-Sr geochronology in Chandos Twp. We continue to find intrusive events of four different times ca. 1250, 1180, 1125 and 1050 Ma. More detailed studies of the Methuen granite indicate a complex chemical history that is making the geochronology difficult to interpret.

In the Parry Sound area, we have established an "age" of 1240 Ma on the McKellar gneiss of the Parry Sound domain, an age that reflects the time of granulite grade metamorphism, and an age of 1340 Ma on the amphibole grade Nobel granite gneiss of the Britt domain.

Research into the $^{87}\text{Sr}/^{86}\text{Sr}$ of groundwaters and saline brines on the Canadian Shield continues (with P. Fritz and S.K. Frape, U. of Waterloo).

We will take delivery of a quadrupole mass spectrometer in the spring of 1984, which will be used for elemental determinations by isotope dilution, and for certain isotopic ratio measurements.

(c) Isotope Studies of Hydrogen, Oxygen, Carbon and Sulphur (H. Schwarcz)

We are continuing to study the carbon and oxygen isotopic composition of carbonates associated with gold deposits in the Abitibi Belt of the Canadian Shield. Massive replacement of volcanic rocks by carbonate was produced at a very uniform temperature by fluids of very uniform isotopic composition. Sulfur isotope studies of associated pyritic ore are being undertaken (with J. Crocket, A. Fyon).

The variation in O-18 content of quartz and magnetite as a function of grade of metamorphism and proportion of oxide to quartz is being studied, to learn about the temperatures of deposition and subsequent metamorphism (with N. Blum).

Collagen extracted from bones of vertebrates of Pleistocene age can be used to monitor changes in ^2H content of environmental water through time. The calibration of the method is being done with a pole-to-equator collection of deer (with A. Cormie).

Water content of small children can be safely determined by isotope dilution through administration of O-18 labelled water. This information is essential in studies of growth (with R. Whyte).

Tracing of sources of the acid component of meteoric precipitation can be done by measuring the stable isotope ratios of sulphur, oxygen (in sulphate), nitrogen, and hydrogen in the rain. We are testing the role of sulphur introduced naturally into the atmosphere by biological excretion of methylated sulphides (with J.R. Kramer and M. Wadleigh).

We are investigating the isotope systematics of carbon, oxygen, sulphur and hydrogen in carbonates, ore minerals (sphalerite and galena), pyrite, and fluid inclusions in the Nanasivik Proterozoic ore deposit in Baffin Island. At present fluid inclusion filling temperatures are contradictory to isotopic estimates (with D.C. Ford and F. Ghazban).

Oxygen and carbon isotope variations are being studied in stalagmites from N.W. England (with D.C. Ford and M. Gascoyne).

8. Queen's University, Department of Geological Sciences (E. Farrar, J.A. Hanes, D.A. Archibald, D.J. Kontak, L. France, S. Clark)

The argon extraction system has been rebuilt and is used on-line (to a modified MS-10 mass spectrometer) for conventional K-Ar dating and with a Lindberg furnace for high-resolution $^{40}\text{Ar}/^{39}\text{Ar}$ step-heating experiments. Recently a fission track dating facility has been reactivated. Several geochronological investigations are currently underway.

Investigations into the tectonic, magmatic and metallogenic evolution of the Cordillera Carabaya, S.E. Peru (D.J.K., E.F.) have revealed a close temporal and spatial relationship between Sn-W-base metal mineralization and specific magmatic and tectonic events. The combination of K-Ar geochronology (60 new dates), petrology, geochemistry (120 whole rock analyses), and ore deposit studies has permitted the development of a tectonic model to explain the distribution of rock types and ore deposits with respect to the surrounding Andean system.

A literature review combined with new K-Ar dates (E.F.) has permitted the time - space relationships of major alkalic volcanic centers of South Island, New Zealand, and the Campbell Plateau to be established. The observed relationship has been ascribed to the overriding of the Indian-Antarctic ridge of the Pacific Plate.

A study of the geology and geochronology of the southern Kootenay Arc, B.C. (D.A.A., E.F.), is nearing completion. The study comprises conventional K-Ar dating as well as $^{40}\text{Ar}/^{39}\text{Ar}$, U-Pb (with T. Krogh, R.O.M.) zircon dating and Rb-Sr studies (with R. L. Armstrong) of selected plutons. This study has succeeded in elucidating the thermal and tectonic history of the Kootenay Arc. Isotopic studies are being continued in selected areas in and bordering the southern and central Kootenay Arc. Samples have been collected from several mid-Cretaceous stocks and batholiths in the Purcell anticlinorium for fission track dating and $^{40}\text{Ar}/^{39}\text{Ar}$ experiments on K-feldspar. The Precambrian Hellroaring Creek stock and related amphibolite-facies metamorphic rocks have been sampled for a detailed isotopic study (U-Pb zircon, K-Ar, $^{40}\text{Ar}/^{39}\text{Ar}$ and fission track). It is anticipated that these studies will provide a complete tectonothermal history of the Purcell anticlinorium from Precambrian to Eocene time. A $^{40}\text{Ar}/^{39}\text{Ar}$ study of dykes in the Irene Volcanics (Windermere Supergroup near 49°N) should complement this study.

Additional work in the Canadian Cordillera (D.A.A.): a $^{40}\text{Ar}/^{39}\text{Ar}$ study of the west flank of Frenchman's Cap dome from the core zone to the Amstey pluton; a K-Ar and $^{40}\text{Ar}/^{39}\text{Ar}$ study of metamorphic rocks near the Purcell thrust; a study of the Boya claim group - a tectonically-transported W-Mo stockwork-skarn occurrence in N.E. British Columbia; and an isotopic study of selected intrusive bodies in the Selwyn Mountains north and east of Cantung, N.W.T.

An isotopic study of the Lake George antimony deposit (D.A.A.) in southern New Brunswick has been initiated.

In cooperation with A.H. Clark, a K-Ar study (D.A.A., E.F.) of selected Sn and W mining districts in Korea has been initiated. K-Ar dates (80 to 1700 Ma) and $^{40}\text{Ar}/^{39}\text{Ar}$ age spectra suggest a complex thermal history for these areas.

A $^{40}\text{Ar}/^{39}\text{Ar}$ study (D.A.A., with J. Percival, G.S.C.) of the sheared eastern margin of the KSZ is in progress. This study of sheared and unsheared granitic rocks has been undertaken in an attempt to resolve the time of brittle deformation.

9. University of Toronto, Department of Physics (R. M. Farquhar)

As part of a larger project being undertaken by the Nova Scotia Department of Mines and Energy, lead isotope analyses have been made on galenas occurring in the Cambro-Ordovician metamorphosed sedimentary rocks of the Meguma Series in Nova Scotia. The aim of the project is to determine if possible the source of the lead in the sulphide deposits. Preliminary data suggest that very small variations in isotopic ratios exist among the galenas. The ratios cluster about the growth curve of Stacey and Kramers and give model ages which agree with the ages of the sedimentary rocks in which they occur.

Lead isotope ratios in galenas occurring in veinlets and voids in the Ordovician rocks of the Niagara escarpment have a significantly different isotopic composition from galena in Phanerozoic age veins in Grenville rocks. The Niagara galena isotopic data set has been enlarged, and defines linear trends on $^{207}\text{Pb}/^{204}\text{Pb}$ vs $^{206}\text{Pb}/^{204}\text{Pb}$ and $^{208}\text{Pb}/^{204}\text{Pb}$ vs $^{206}\text{Pb}/^{204}\text{Pb}$ plots. The position of these trends suggests a more "crustal" affiliation than the leads associated closely with Grenville rocks. The source of this crustal lead component has not been identified.

Galena is a mineral collected in prehistoric times by the inhabitants of central and southern North America, and often placed in graves. Because of the broad range of lead isotopic ratios among lead-rich sulphide deposits in North America, these ratios can be used to "fingerprint" the sources from which the leads have come and so provide archaeologists with useful information on the extent of trading patterns among pre-historic tribes. Galena samples from pre-historic gravesites in the southern United States have been analysed and the results are being compared with data for mineral deposits in Missouri to determine the likelihood of these deposits as sources for the archaeological samples.

In collaboration with R.M. Farquhar, P.E. Smith has examined lead isotopic ratios and lead concentrations in sulphides from the Helen Mine iron formation, Wawa, Ontario. The lead concentrations in these sulphides are comparatively low and substantial variations in lead isotopic composition have resulted from in situ U and Th decay. The $^{207}\text{Pb}/^{206}\text{Pb}$ ages deduced from these variations are significantly less than the ages of the iron formation deduced from Pb-U ages on zircons from enclosing igneous rocks. Although they cannot be determined precisely, the initial $^{206}\text{Pb}/^{204}\text{Pb}$ and $^{207}\text{Pb}/^{204}\text{Pb}$ ratios suggest that a high proportion of crustal lead was incorporated into the sulphides, when they were initially introduced into the sedimentary sequence.

10. University of Western Ontario, Department of Geophysics (A. Hayatsu)

Projects include - isotopic equilibrium of argon between rock melts and atmosphere; and K-Ar dating of i) Malpeque Bay Sill, P.E.I. (with V.S. Papesik, Memorial U.), ii) Boxey Head Basalt, Nfld. (with J.P. Hodych, Memorial U.), iii) Diorite plutons in Cape Breton Island, N.S. (with S. Barr, Arcadia U.).

11. Bibliography

- Andrew, A. 1982. A lead isotope study of selected precious metal deposits in British Columbia. M.Sc. Thesis, University of British Columbia, Vancouver, B.C..
- Andrew, A., Godwin, C.I. and Sinclair, A.J. 1982. Preliminary examination of gold metallogeny in the Insular Belt of the Canadian Cordillera using galena-lead isotope analyses. B.C.M. of E.M.P.R. Paper 1982-1, Geological Fieldwork 1981, 202-217.
- Andrew, A., Godwin, C.I. and Sinclair, A.J. 1983. Age and genesis of Cariboo gold mineralization determined by isotope method. B.C.M. of E.M.P.R., Paper 1983-1, 304-313.
- Armstrong, R.L. 1982. Cordilleran metamorphic core complexes - from Arizona to southern Canada. Annual Rev. Earth Planet. Sci., 10, 129-154.
- Armstrong, R.L. 1982. Late Triassic-Early Jurassic time scale calibration in British Columbia. In: Numerical Dating in Stratigraphy, G.S. Odin (Editor), 509-513.

- Armstrong, R.L., Harakal, J.H. and Hollister, V.F. 1982. Eocene mineralization at Mount Tolman (Keller) Washington and Silver Dyke, Montana. *Isochron/West No. 33*, 9-10.
- Armstrong, R.L., Harakal, J.H., Brown, E.H., Bernardi, M.L. and Rady, P.M. 1983. Late Paleozoic high pressure metamorphic rocks in northwestern Washington and southwestern British Columbia - the Vedder Complex. *Bull. Geol. Soc. Amer.*, 94, 451-458.
- Bell, K., Blenkinsop, J., Cole, T.J.S. and Menagh, D.P. 1982. Evidence from Sr isotopes for long-lived heterogeneities in the upper mantle. *Nature*, 298, 251-253.
- Brown, E.H., Wilson, D.F., Armstrong, R.L. and Harakal, J.E. 1982. Petrologic structural and age relations of serpentinite, amphibolite and blueschist in the Shuksan Suite, North Cascades, Washington. *Bull. Geol. Soc. Amer.*, 93, 1087-1098.
- Cecile, M.P., Shakur, M.A. and Krouse, H.R. 1983. The isotopic composition of western Canadian barites and the possible derivation of oceanic sulphate ^{34}S and ^{18}O age curves. *Can. J. Earth Sci.*, 20, 1528-1535.
- Davis, G.A., Anderson, J.L., Martin, D.L., Krummenacher, D., Frost, E.G. and Armstrong, R.L. 1982. Geologic and geochronologic relations in the lower plate of the Whipple detachment fault, Whipple Mountains, southeastern California. In: *Mesozoic-Cenozoic Tectonic Evolution of the Colorado River Region, California, Arizona and Nevada*, E. Frost and D. Martin (Editors), 409-432.
- Ding, T.P., Thode, H.G. and Rees, C.E. 1983. Sulphur content and sulphur isotope composition of orange and black glasses in Apollo 17 Drive Tube 74002/1. *Geochim. Cosmochim. Acta*, 47, 491-496.
- Fairchild, L.H. and Cowan, D.S. 1982. Structure, petrology and tectonic history of the Leech River complex northwest of Victoria, Vancouver Island. *Can. J. Earth Sci.*, 19, 1817-1835.
- Fletcher, I.R. and Farquhar, R.M. 1982. The procontinental nature and regional variability of the central metasedimentary belt of the Grenville province: lead isotope evidence. *Can. J. Earth Sci.*, 19, 239-253.
- Fletcher, I.R. and Farquhar, R.M. 1982. Lead isotope compositions of Balmat ores and their genetic implications. *Econ. Geol.*, 77, 455-464.
- Godwin, C.I. and Sinclair, A.J. 1982. Average lead isotope growth curves for shale-hosted zinc-lead deposits, Canadian Cordillera. *Econ. Geol.*, 77, 675-690.
- Godwin, C.I., Sinclair, A.J. and Ryan, B.C. 1982. Lead isotope models for the genesis of carbonate-hosted Zn-Pb, shale-hosted Ba-Zn-Pb and silver-rich deposits in the northern Canadian Cordillera. *Econ. Geol.*, 77, 82-94.
- Graustein, W.C. and Armstrong, R.L. 1983. The use of $^{87}\text{Sr}/^{86}\text{Sr}$ ratios to measure atmospheric transport into forested watershed. *Science*, 219, 289-292.
- Halas, S. and Krouse, H.R. 1983. Isotopic analysis of nano-mole gas samples by means of dynamic flow mass spectroscopy. *Rev. Sci. Inst.*, 54, 437-443.
- Halas, S., Shakur, A. and Krouse, H.R. 1982. A modified method of SO_2 extraction from sulphates for isotopic analysis using NaPO_3 . *Isotopenpraxis*, 18, 433-435.
- Hattori, K., Campbell, F.A. and Krouse, H.R. 1983. The start of sulphur oxidation in continental environments about 2.2×10^9 years ago. *Science*, 217, 549-551.
- Hattori, K., Campbell, F.A. and Krouse, H.R. 1983. Sulphur isotope abundances in Aphebian clastic rocks implications for the coeval atmosphere. *Nature*, 302, 323-326.

- Krouse, H.R. and Case, J.W. 1982. Sulphur isotope tracing of acid emissions into the environment in Alberta. Proc. Symp. Acid Forming Emissions in Alberta and their Ecological Effects. Edmonton, 207-232.
- Kuran, V.M., Godwin, C.I. and Armstrong, R.L. 1982. Geology and geochronometry of the Scheelite Dome tungsten-bearing skarn property, Yukon Territory: C.I.M. Bulletin, 75, (838), 137-142.
- Mathews, W.H. 1983. Early Tertiary resetting of potassium-argon dates in the Kootenay Arc, southeastern British Columbia. Can. J. Earth Sci., 20, 867-872.
- Mazor, E., van Everdingen, R.O. and Krouse, H.R. 1983. Noble-gas evidence for geothermal activity in Karstic Terrain: Rocky Mountains, Canada. Geochim. Cosmochim. Acta, 47, 1111-1115.
- McEwing, C.E., Rees, C.E. and Thode, H.G. 1983. Sulphur isotope effects in the high temperature oxidation of troilite. Geochim. Cosmochim. Acta, 47, 2059-2061.
- McEwing, C.E., Rees, C.E. and Thode, H.G. 1983. Sulphur isotope ratios in the Canyon Diablo metallic spheroids. Meteoritics, 18, 171-178.
- McMillan, W.J., Armstrong, R.L. and Harakal, J. 1982. Age of the Coldwater stock and Nicola batholith, near Merritt. B.C.M. of E.M.P.R. Paper 1982-1, 102-105.
- Medford, G.A., Armstrong, R.L. and Osatenko, M.J. 1983. Rb-Sr dating of Paleozoic(?), Mesozoic, and Cenozoic intrusive rocks, Okanagan Lake region, southern British Columbia, Canada. Econ. Geol., 78, 1375-1378.
- Odin, G.A. and 35 others, 1982. International standards for dating purposes. In: Numerical Dating in Stratigraphy, G.S. Odin (Editor), 123-150.
- Parrish, R.R. 1982. Cenozoic thermal and tectonic history of the Coast Mountains of British Columbia as revealed by fission track and geological data and quantitative thermal models. Ph.D. Thesis, University of British Columbia, Vancouver, B.C..
- Ratcliffe, N.M., Armstrong, R.L., Mose, D.G., Seneschal, R., Williams, N. and Baiamonte, M.J. 1982. Emplacement history and tectonic significance of the Cortlandt complex, related plutons and dike swarms in the Taconide Zone of southeastern New York based on K-Ar and Rb-Sr investigations: Am. Jour. Sci., 282, 358-390.
- Rees, C.E. and Thode, H.G. 1983. Sulphur isotopes in Lunar soils - surface vs. bulk properties. Lunar and Planet. Sci., 14, 634-635.
- Rosman, K.J.R., De Laeter, J.R., Boldeman, J.W. and Thode, H.G. 1983. Cumulative yields of stable and long-lived isotopes of tin in neutron-induced fission. Can. J. Physics, 61, 1490-1497.
- Slawson, W.F. 1983. Isotopic composition of lead from a paleoisland arc; Shasta, California. Can. J. Earth Sci., 20, 1521-1527.
- Thode, H.G. and Godwin, A.M. 1983. Further sulphur and carbon isotope studies of late Archean iron formations of the Canadian Shield and the rise of sulfate reducing bacteria. Precam. Res., 20, 337-356.
- van der Heyden, P. 1982. Tectonic and stratigraphic relations between the Coast Plutonic Complex and Intermontane Belt, west-central Whitesail Lake Map Area, British Columbia. M.Sc. Thesis, University of British Columbia, Vancouver, B.C..
- Woodsworth, G.J., Loveridge, W.D., Parrish, R.R. and Sullivan, R.W. 1983. Uranium-lead dates from the central Gneiss Complex and Ecstall pluton, Prince Rupert Map Area, British Columbia. Can. J. Earth Sci., 20, 1475-1483.

VI METEOROLOGY AND ATMOSPHERIC SCIENCE

Compiled by: E.J. Truhlar

1. University of British Columbia
2. Simon Fraser University
3. University of Alberta
4. University of Calgary
5. Western Research
6. Saskatchewan Research Council
7. University of Windsor
8. McMaster University
9. University of Toronto
10. Ontario Ministry of the Environment
11. Trent University
12. McGill University
13. Université du Québec à Montréal
14. Université de Sherbrooke
15. Environnement-Québec
16. Université Laval
17. MacLaren Plansearch
18. Agriculture Canada
19. Canadian Forestry Service
20. Atmospheric Environment Service
21. Bibliography

1. University of British Columbia, Department of Geography (J.E. Hay, D.G. Steyn, T.R. Oke)

Studies of sky radiance distribution, short-wave irradiance for inclined surfaces, mesoscale variability of solar radiation and satellite estimates of solar radiation at the Earth's surface continued. The effect of the El Chichon cloud on solar radiation at Vancouver has been analysed.

The observation and modelling of sea-breeze flows in the lower Fraser valley continued with profiling studies using a tether sonde at various locations. Sites are being selected to establish a wind field network in 1984.

Continuing studies on the energy and water balances of cities include observations of energy balance differences between urban and rural sites in and near Vancouver. A study of the annual water budget of a suburban area has been completed. Another study is seeking to verify three numerical urban energy balance models using data gathered in Vancouver.

2. Simon Fraser University, Department of Geography

Field research is being undertaken on the energy and mass exchange over various surface types, especially for alpine environments and environments not dominated by high solar irradiance.

3. University of Alberta, Meteorology Division and Institute of Earth and Planetary Physics (R.B. Charlton, K. Finstad, R. Goodson, K.D. Hage, B. Kochtubajda, E.P. Lozowski, Z. Misztal, D. Phillips, E.R. Reinelt, J. Roessler, C. Sackiw, L. Stovel, G. Strong, R. Wong)

A computer model has been developed for simulating time-dependent wind and temperature fields resulting from surface radiational cooling at night in a small valley. The model reproduces quasi-steady-state recirculation flows with near-surface wind and temperature profiles, in close agreement with observations.

Development continued also on a computer simulation model for wind, temperature and pollutant concentration fields in a valley of arbitrary shape, which clarified the formulation of the hydrostatic approximation for terrain-following coordinates. In addition, a full set of diagnostic relations was devised for testing conservation of mass, momentum and energy in this finite-difference model.

Wind-tunnel icing experiments have been carried out in cooperation with Mechanical Engineering. Comparisons between the experimental observations and the predictions of a new time-dependent rime-icing model are very encouraging. An airfoil icing model is also under development.

The results of a study on the sublimation of dry ice have been applied to cloud-seeding experiments carried out by the Alberta Research Council.

Analysis of the air-pollution and precipitation measurements, obtained during the Intensive Sulphate Study in Eastern Canada in August 1976, is nearing completion.

Work is continuing on the forecasting of convective weather, and the dynamical interaction between the synoptic and mesoscales of motion.

Work has been completed on airflow over mountains with barrier profiles of different aspect and orientation. Closed-form, analytical solutions have been derived for surface-pressure and wind fields generated by mountains with elliptical bases and cross-sections. These solutions enable exploration of the effects of barrier profile on wind and pressure at all transitional stages between the fully three-dimensional circular, bell-shaped mountain, and the two-dimensional, limiting case of an infinitely long ridge.

High-resolution satellite data have been used to discriminate between precipitating and non-precipitating convective clouds in Central Alberta. Temperature and brightness maps have been deduced from satellite imagery, and data have been correlated with rainfall collected in the standard gauges of the climate station network.

The cohesiveness of upper-air soundings in space and time is being examined by using meteorological data obtained in serial releases of radiosonde balloons. The principal aim is the design of an optimum upper-air network in hail-prone Central Alberta, capable of detecting and tracking atmospheric systems on a scale of a few kilometres.

Samples of snow falling from man-made cloud and fog have been collected during the 1982/83 winter in the petrochemical district of Edmonton, and chemically analysed.

4. University of Calgary, Kananaskis Centre for Environmental Research

Research activities in meteorology and atmospheric science form components of major projects on peroxyacetyl nitrates in urban atmospheres and the effects of sulphur dioxide and/or nitrogen oxides on vegetation.

5. Western Research, Division of Bow Valley Resource Services Ltd.

Radon emissions from gypsum tailings ponds have been evaluated with respect to meteorological parameters. A detailed diffusion climatology has been compiled for a foothills site lying about 25 km south of Calgary. Studies have been initiated into the behaviour of wind velocities within 500 m of the ground at an acoustic Doppler radar site located amid flat terrain near Edmonton. Research is being undertaken into the relevance of the dynamical equations to the description of turbulent atmospheres, and into the physical relevance of K theory.

6. Saskatchewan Research Council

Research studies in climatology and agrometeorology continue at the Climatological Reference Station, mainly on wind erosion potentials for Saskatchewan and evaporative water flux studies (an instrumentation approach).

Air quality computer modelling studies have commenced with a main purpose of offering local industries a real-time modelling capability to address many of their short-term problems. Long-range transport models for SO₂ designed to quantify acid deposition onto the Precambrian Shield have been verified.

The regional distribution of SO₂ was monitored near a local power plant. Topography proved to be the dominant forcing function in establishing zones of high sulphate deposition.

During the growing season a study was carried out on the vertical pesticide vapour flux from a field especially treated with a common pre-emergent pesticide used by farmers in western Canada. This was the first year that this type of pesticide was studied. Some of these pesticides have a very significant mass flux to the atmosphere: 20% or more of the initial application can be returned to the atmosphere; and most of the fraction returned can be detected as an atmospheric residue, in some cases months after application, implying that the crops are a continuous emission source.

A specially designed agricultural boom sprayer was investigated to determine the effect of sprayer shrouding on downwind drift patterns. The sprayer unit must be improved significantly to reduce the shrouding.

Several new meteorological instruments were developed: dew-point and temperature sensors with a solid-state memory recorder; air quality and acid rain samplers.

7. University of Windsor, Department of Geography

Research was carried out on: (a) Climatology and environmental change in the St. Clair River Delta, Ontario; meteorology and climatology of trace contaminant influx, Essex County, Ontario; paleoenvironmental studies, Frobisher Bay area, Baffin Island, N.W.T. (J. Jacobs). (b) Surface deposition of four contaminants in the Essex region; and heating degree-days in Alberta, (M. Sanderson).

8. McMaster University, Department of Geography

Studies by J.A. Davies include: use of multispectral radiation measurements to determine aerosol effects on radiation and to estimate particle size distribution parameters and mass loading in an urban atmosphere; experiments to determine the effects of solar heating and ventilation on the performance of the Eppley pyrgeometer for measuring infrared radiation (a joint study with AES); comparison of several models for estimating solar radiation as part of an International Association study using data for Europe, North America, Australia and New Zealand.

Studies by W.R. Rouse include: detailed energy and water balances of typical terrain units in the Hudson Bay lowlands, in the Churchill area; macroscale thermal advection, using AES climatic and ice cover data to identify regional patterns in the advective influence of Hudson and James Bays on terrestrial climate (these data will be used to initially assess the impact of climatic and ice cover variability); instrument traverses from the Hudson Bay shoreline inland to model the processes of advection during onshore and offshore winds.

9. University of Toronto, Institute for Environmental Studies (B. Boville, I. Burton, A.P. Grima, F.K. Hare, H.M. Hutcheon, R.E. Munn, P. Timmerman, A. Whyte)

The main objective of the Institute's interdisciplinary research is to improve the science of environmental management. Many of the areas covered involve atmospheric processes including air pollution, acidic deposition, climate impact assessment, the world carbon cycle and management strategies for snow and ice control. Specific research studies dealt with carbon pools in the Canadian boreal forests; trends in acidic deposition at Hubbard Brook (New Hampshire); methods of detecting trends; atmospheric dispersion from the proposed nuclear high-level waste site in Northern Ontario; and a screening of environmental impacts with respect to the proposed railway land development in downtown Toronto.

10. Ontario Ministry of the Environment, Air Resources Branch

(a) Air Quality and Meteorology Section

An Eulerian model for the long-range transport and deposition of acidic pollutants is still under development. A Lagrangian trajectory model of the long-range transport of sulphur oxides has been used to compute trajectories and sulphur concentrations and deposition values for the period 1978-1980. The resulting trajectory statistics were incorporated in the Statistical Model for assessment. A 3-D meso-scale wind field model has been developed, and will be tested in 1984.

Daily atmospheric and precipitation chemistry and meteorological data from 4 Ontario sites are being analysed to produce statistics relating to the chemical constituents in the air and precipitation to the place of origin of the air parcels and to the associated synoptic patterns. Attempts are also being made to discern the effects of variations in the pollutant emissions from various sources.

(b) Atmospheric Research and Special Programs Section

The air chemistry and atmospheric deposition was routinely monitored across Ontario. Much time was devoted to data analysis. Studies were carried out to determine the accuracy and precision of atmospheric deposition data from the APIOS network.

Work associated with the Nanticoke study area continued with routine monitoring, data analysis and the development of a mesoscale air quality model.

Planning commenced for an intensive study of ozone formation in the Sarnia area and the contribution of the local industrial emissions to ozone levels in southern Ontario.

11. Trent University, Department of Geography

Research continued on: studies of land snowpack, including energy balance work particularly in Northern Quebec/Labrador; the biological and hydrological roles of snow and ice on lakes in Labrador, Northern Québec and Axel Heiberg Island, N.W.T.; mass balance measurements of the White Glacier, Axel Heiberg Island; the cloud and radiation climate of the High Arctic, mainly on aspects of cloud-radiation interactions such as the cirrus greenhouse effect, seasonal patterns of cloudiness, aerosol effects and the effects of hidden cloud on the surface radiation budget; the origin and earliest evolution stages of the earth's atmosphere and hydrosphere; and the snowmelt and run-off in small catchments in southern Ontario.

12. McGill University, Departments of Meteorology and Agricultural Chemistry and Physics

As in past years, meteorological research has continued in such major areas as: large-scale dynamics and numerical weather prediction; physical meteorology with emphasis on radar meteorology, cloud physics, and cloud-environment interactions; and physical climatology, especially surface energy budgets.

Research in Agricultural Chemistry and Physics continued as described in CGB 1982. The aircraft measurements of CO₂ fluxes were made in collaboration with Agriculture Canada and the National Research Council. A study was initiated on the effects of meteorological variables on the loss of nitrogen in the form of ammonia from fields and surface-applied manure.

13. Université du Québec à Montréal, Département de physique

Dans le cadre du projet de la mesure des dépôts secs des polluants gazeux par la méthode des profils, une station micrométéorologique est en voie de parachèvement sur le campus du Collège Macdonald à Ste-Anne-de-Bellevue. Des mesures de la température, de la vitesse et de la direction du vent ainsi que des concentrations des polluants (SO₂ ou NO₂) seront effectuées à trois niveaux d'une tour de dix mètres.

En collaboration avec le "National Severe Storms Laboratory" (NSSL) une étude a été effectuée sur l'évolution du champ de divergence à la mésoéchelle dans les situations pré-convectives.

Une méthode d'analyse de la cinématique des orages à partir des données d'un radar Doppler (composante radiale de la vitesse et réflectivité) est en développement en vue de la prochaine installation du premier radar Doppler au Canada par le SEA.

En collaboration avec l'"Alberta Research Council" nous avons effectué une étude qui vise à l'optimisation de la résolution spatiale et de la quantité d'information à extraire des champs non uniformes de précipitation par les mesures de réflectivité radar.

En collaboration avec l'"Alberta Research Council" une étude d'évaluation théorique des performances des systèmes radar à polarisation multiple est en développement. Cette étude vise à l'amélioration des mesures de précipitation sous forme de pluie et de grêle dans le cadre de la modification du temps violent.

Avec le SEA, on étudie le comportement des paramètres prévus (mouvement vertical, tourbillon géostrophique, divergence, etc.) du modèle spectral de prévision en vue de filtrer les fluctuations rapide à la sortie. Un champ plus stable sera mieux adapté aux besoins des prévisionnistes.

On étudie aussi une méthode pour inclure les tendances de pression observées au sol dans la solution de l'équation d'oméga quasi-géostrophique, afin de mieux diagnostiquer le mouvement vertical à l'échelle synoptique.

14. Université de Sherbrooke, Département de géographie et l'Institut d'aménagement

Projets de recherche en cours:

(a) Laboratoire de télédétection (traitement visuel et numérique d'images satellites Landsat, HCMM, NOAA et par simulations aéroportées).

(i) Télédétection des propriétés thermiques de la surface terrestre: études, développement et application du concept d'inertie thermique pour la mesure de l'humidité des sols et des dépôts meubles, et des variations de textures; mesures en multispectrales et en infra-rouge thermique appliquées aux caractéristiques biophysiques et de croissance des végétaux cultivés ou non; cartographie de l'inertie thermique pour l'inventaire des ressources en eau en milieu aride ou semi-aride.

(ii) Études thermiques de l'hydrodynamique des eaux de l'estuaire et du golfe du Saint-Laurent (HCMM, NOAA).

(iii) Études de la couverture neigeuse et des glaces flottantes (NOAA, Landsat).

(iv) Corrections atmosphériques des images satellites et applications aux études de pollution atmosphérique.

(b) Laboratoire de climatologie.

(i) Climatologie régionale des Cantons de l'Est (1941-1981): climatographie de l'Estrie (1941-1970): types de temps estivaux en Estrie (1972-1981).

(ii) Étude des tempêtes dans le golfe du Saint-Laurent.

(iii) Implications pour la santé de la pollution de l'air à Thetford-Mines.

(c) Laboratoire de géographie physique.

(i) Système météorologique de prédiction des avalanches au mont Washington.

(ii) Influences microclimatiques sur l'évolution des cavernes de l'île d'Anticosti.

(iii) Paléoclimatologie quaternaire du nord du golfe du Saint-Laurent.

15. Environnement-Québec, Service de la météorologie

La climatologie de pluies quotidiennes extrêmes au Québec: Diverses méthodes d'analyse ont été comparées et c'est la méthode basée sur l'analyse stochastique des excédents qui a été retenue.

Projet international CAPTEX: Six expériences ont été réalisées dans le cadre du projet pour lequel trois stations du réseau climatologique québécois avaient été aménagées.

Statistiques sur la température: Pour quelque 150 stations du Québec, des statistiques sur les dates de gel et de dégel, sur les températures quotidiennes, de même que sur les degrés-jours au-dessus et au-dessous de divers seuils ont été calculées.

Guide d'interprétation climatique, 1^{re} partie: Une collection de quelque 80 cartes climatiques portant sur la pluviométrie et la thermométrie aux échelles annuelles et mensuelles présentent diverses statistiques basées sur la période climatologique 1951-1980. Un texte faisant ressortir les traits importants du climat du Québec méridional viendra compléter ces cartes.

Climatologie des pluies horaires: Une analyse des fréquences, intensités et durées des pluies horaires, de même que des épisodes pluvieux a été amorcée. La période mai à octobre (1960-1982) est à l'étude. Les connaissances des caractéristiques spatiales et temporelles des pluies estivales font l'objet du projet.

Prévision de fonte printanière: Un modèle mathématique faisant le suivi de l'épaisseur du manteau nival et l'estimation de la fonte est en voie d'être complété. Un algorithme tenant compte du vieillissement de la neige sera intégré au modèle qui utilise en temps réel les données de stations climatologiques et de lignes de prélèvement de neige.

Phénomènes météorologiques observés visuellement: Le nombre moyen d'occurrence de huit phénomènes météorologiques: brume-brouillard, verglas, orage-tonnerre, visibilité réduite, giboulée, poudrerie, vent violent, grêle ont été calculés sur des bases annuelles et mensuelles. Une analyse de la variabilité spatiale et de la représentativité de ces données a été mise de l'avant.

Climatologie des vents (BCG 1982): Des techniques permettant de vérifier l'homogénéité des données de même que leur représentativité ont été mises au point.

16. Université Laval, Département de physique (M. Baril)

Une étude de faisabilité de la cueillette de l'étude morphologique et de l'analyse chimique des aérosols atmosphériques a été entreprise au cours de l'été 1983. La cueillette est faite à l'aide d'un collecteur à impact inertiel similaire au mini-Andersen. Les aérosols sont déposés sur une feuille d'aluminium et observés à l'aide d'un microscope électronique à balayage. L'analyse chimique individuelle des aérosols est faite par spectrométrie de masse à bombardement ionique (SIMS). Le faisceau primaire de Ga⁺ a un diamètre d'un micron ce qui permet l'analyse individuelle. Compte-tenu des excellents résultats obtenus lors de l'étude de faisabilité, les recherches seront poursuivies pour essayer de trouver des empreintes caractéristiques des sources polluantes reliées aux précipitations acides.

17. MacLaren Plansearch

An excellent overall picture was provided for the climatology, meteorology and air quality of the area covered by the EIS of Mobil Oil Canada for Venture Development. All important parameters were discussed, including storm tracks, icing and freezing spray.

A three-year program was commenced to measure air and soil temperatures and rainfall at over 50 sites in the Annapolis, Cobequid and Northumberland shore areas of Nova Scotia in order to define more clearly the mesoscale agricultural climates at the farm level.

18. Agriculture Canada, Agrometeorology Section, Ottawa

Research activities include: a study of the possible impacts of climatic change on potential dry matter yields; a study of stomatal response during the onset and recovery from water stress; development and testing of a crop stress index as a method to monitor the potential impact on cereal yields from inadequate soil moisture supply; development of a numerical soil water model for soil moisture evaluation work in Québec and eastern Canada; field testing of a new lost cost sensor based on a miniature galvanic cell for application in the micrologging of duration of leaf wetness; field testing of a new capacitance type sensor for determining frost depth; computer analysis of 21 years of Ottawa winter soil temperatures and development of an empirical model; development and testing of a yield-protein model.

19. Canadian Forestry Service

(a) Newfoundland Forest Research Centre, St. John's.

Work on the development of climatic maps for the national map of Canadian ecoregions has been completed. Dendrochronological studies of red pine (see CGB 1982) are nearly finished. Studies have been conducted on Palsa in Labrador and a survey was made of surface winds in Newfoundland as determined by tree deformations. A colour phytogeographic map of Newfoundland has been published. Development continues on the study of the energy balance of Salix for short-rotation plantations.

(b) Maritimes Forest Research Centre, Fredericton.

Projects continue (see CGB 1982) on precipitation measurements at Acadia Forest Experiment Station (AFES) and in Kejimikujik National Park (within four forest stands), and on laboratory rainfall simulations. A study was initiated at AFES to evaluate the effects of different methods of collecting and storing rainwater on its chemical characteristics; preliminary results show that the concentrations of hydrogen, nitrate and sulphur definitely vary with method.

(c) Laurentian Forest Research Centre, Ste-Foy.

Meteorological and precipitation data are still being collected at the Montmorency and Lac Laflamme sites (see CGB 1981, 1982). A new collector for wet precipitation only has been installed at the latter site. Six permanent plots are maintained in a balsam forest at the Laflamme catchment in which throughfall, stemflow and soil percolates are collected to determine the fluxes of the major ions in the ecosystem. A new study will be undertaken to elucidate the effects of the spring melt acid shock on the rooting system of a balsam fir stand. The micro-climate and energy budget studies of A. Plamondon (see CGB 1981) have terminated. Climatological data are used in many projects such as: correlation of forest stand vulnerability to spruce budworm infestation; evaluation of silviculture treatments, insect and pathogen damage, sugar maple stand die-back and mortality; tree ring analysis of balsam fir; site characterization as done by LANDSAT imagery.

(d) Canadian Forestry Service Headquarters, Ottawa.

Activities continue dealing with the potential impact of CO₂-induced climate change on Canadian forests (see CGB 1982).

(e) Petawawa National Forestry Institute, Chalk River.

Instrumentation for an experiment to validate models of wind flow over rough forested terrain will be fully operational in 1984. A mathematical model of radiation in a clear-cut strip has been prepared that takes account of strip width, cloud, slope and atmospheric turbidity.

A report on the unique meteorological conditions surrounding the escape of a test fire in the Northwest Territories has been prepared.

Work is progressing on interpolation and extrapolation models of wind in forested areas. Work has been completed relating the monthly provincial wildfire statistics to sequences of dry days.

Temperature profiles are being measured in a red pine plantation frost hollow to determine the conditions under which frost damage to florets reduces seed production.

A method is under study for determining the roughness length and displacement height over sloping terrain.

(f) Great Lakes Forest Research Centre, Sault Ste. Marie.

Historical and current weather data are used as reported in Volume 35 of CGB (1982) and also in the LRTAP program, for the analysis of the performance of the Canadian Forest Fire Danger Rating System in Ontario, for entomological modelling of insect outbreaks, population dynamics and growth patterns, for spraying insects and evaluating the effects of spraying.

(g) Forest Pest Management Institute, Sault Ste. Marie.

Meteorological data on wind speed, turbulence and temperature in and above a pine canopy were obtained for studies of the meteorological effects on spray cloud dispersal and deposition, and the environmental impact of spray applications.

(h) Northern Forest Research Centre, Edmonton.

A water balance computer model was applied to data describing the climatic-streamflow relationship existing over the entire Marmot Experimental Basin in an attempt to determine if the effect of the Cabin subbasin cutting was evident at the main streamgauge.

Soil moisture and forest microclimate instrumentation were installed in clearings at the James River forest microclimate study site for a study of evaporation from the low vegetation or soil (in summer) and snow (in winter) in clearings.

Field data on thermal diffusivity and moisture content of green wood have been collected. Preliminary analysis indicates that theoretically derived moisture contents are consistently low by about 20%. This consistency means that the technique will likely be suitable for in situ dynamic determinations of wood moisture content with only minimal calibration.

Several studies continue on: frost damage in nursery container seedlings; ice nucleating agents (INA) that mediate freezing; the growing season climate for pine and spruce seedlings on clear-cut areas; and fire behaviour and management. A report on the forest fire environment of Pukaska National Park is nearing completion.

(i) Pacific Forest Research Centre, Victoria.

Climate and spore production data continue to be collected for the Inland Spruce Cone Rust Study. This season's data are more comprehensive than last year's and have provided some interesting observations. This year was notable because a very high proportion of basidiospores (which infect the seed cones) were produced. The continuing study of the dispersal of the Mountain Pine Beetle has resulted in information about the weather associated with the start of mountain pine beetle outbreaks, and the response of the beetle to weather-induced changes in host resistance. Methods for estimating missing daily maximum and minimum temperatures have been compared. Climate data at two field sites will be collected for one more season for the study of fertilization on snow.

20. Atmospheric Environment Service

(a) Meteorological Services Research Branch (MSRB)

The general program of the Branch remains as described in the 1979 Canadian Geophysical Bulletin.

The new version of the hemispheric spectral forecast model described in the 1982 Bulletin was put into routine operation by the Canadian Meteorological Centre (CMC). The code was converted to run on the CMC's new CRAY-1S vector computer which was installed in October and which will completely supplant the CDC CYBER 176 by June 1984.

The three-dimensional finite-element model now includes an interactive boundary layer with space and time varying mixing depth and diffusion coefficients based on the solution of a turbulent energy equation. It was found feasible to initialise this model using fields processed by non-linear normal mode initialisation with a closely related hemispheric spectral model. The latter model shares the same physical parameterization and it will be used eventually for global medium range forecasting.

A full three-dimensional limited-area model has been built incorporating semi-Lagrangian advection, which was found to lead to improved precipitation forecasts when used just for moisture advection in an otherwise fully Eulerian model. It was also found to be very accurate and efficient for the advection-diffusion part of a pollution transport model.

Work progressed on the long-range pollutant transport and deposition model for AES, the Ontario Ministry of the Environment and the Federal Republic of Germany. Meteorological fields required for the model will be based on the CMC analyzed or forecast fields.

Statistical regression equations were derived for more than 100 locations for wind forecasts based on CMC model output. Equations for ceiling and visibility forecasts are also being derived. A new flexible system has been designed to develop "perfect prog" equations, and can easily be extended to develop "model output statistics" equations. A survey of available marine data showed that sample sizes are large enough for all AES Atlantic marine forecast areas to permit meaningful equations to be obtained.

The digital ice data base system developed for the Ice Forecast Centre underwent operational evaluation and as a result a contract for enhancements was let. In a contract with University of Waterloo Research Institute Eulerian and Lagrangian formulations for ice models were compared; the latter offers some advantage for specifying the internal stress. An iceberg deterioration model was developed by Fenco Newfoundland Ltd. under contract. Tests on three cases gave reasonable results. Another contract study, by NORDCO Ltd., tackled the problem of deriving ocean currents from iceberg drift data for subsequent use in an iceberg drift forecast model.

Oil spill trajectory forecast models have been provided to several regional weather centres for fast response to emergency situations. A much more elaborate and state-of-the-art model has been implemented on the CMC computer facility. Both models were used successfully during the joint Government/Industry East Coast Oil Spill Sea Trials conducted by the Canadian Offshore Aerial Applications Task Force in September.

Operational systems to forecast significant wave heights and the probability of freezing spray were implemented on the CMC computer facility. The parametric wave model of Donelan was evaluated for use in the Great Lakes. The spectral wave models of Resio and the U.S. Navy Fleet Numerical Oceanography Center were acquired to evaluate their potential for applications in Canadian waters. A storm surge model has been developed for the Scotian Shelf by Atmospheric Dynamics Corporation and the Institute of Ocean Sciences, Patricia Bay. It will be tested and modified before implementation.

A system to automatically verify all public weather forecasts using the regional minicomputers is being developed.

Software has been developed to automatically generate Telidon pages of weather information, and to emulate the Telidon IPS to IPS communication protocol in the regional minicomputers (under contract with Genesis Corp.). The latter has been tested and is available.

The prototype RAINSAT system, which combines radar and GOES satellite data to delineate areas of rain, underwent extensive in-house evaluation and verification using a

second radar to verify predictions from another. RAINSAT products were also sent in real-time to the Quebec Weather Centre for operational evaluation.

The prototype TOVS system, which converts locally received NOAA satellite radiance measurements into temperature and humidity profiles, was demonstrated in real-time to the Ontario and Prairie Weather Centres. The products appear to be useful for severe convection prediction and for delineating the boundary between rain and snow.

The new image analysis system was used to study the classification of sea ice and to correct surface temperature determinations for atmospheric effects.

The manual de-aliasing of the two-week SEASAT scatterometer data set for September 1978 was completed and the results made available to the other project participants (NASA, JPL, UCLA). Specialised data sets were also made available to other members of the European scatterometer working group. As a result of information provided to the RADARSAT project a scatterometer is now the preferred second sensor for RADARSAT.

Comparisons between full-scale and wind-tunnel measurements of boundary-layer flow over Kettle's Hill, Alberta, were completed. The second field phase of the Askervein Hill experiment in the Scottish Outer Hebrides took place in October. A wind-tunnel model of the Askervein Hill was constructed and installed and measurements were commenced.

(b) Air Quality and Inter-Environmental Research Branch (AQRB)

(i) LRTAP. The AES Lagrangian long-range transport (LRT) model, in both its diagnostic and forecast modes, continued to be improved, evaluated and applied to a wide range of problems concerning the inter-regional transport and deposition of sulphur compounds. Model enhancements included an improved formulation for wet deposition, provision for a spatially and temporally variable dry deposition and an extension to include nitrogen compounds. An international LRT model intercomparison is planned for 1984/85.

Work is nearing completion on the quantification of the flow of air pollution leaving the North American continent to the east, over the Atlantic Ocean. The results will help to close the pollutant mass balance for eastern North America as well as assist in the estimation of this continent's contribution to global atmospheric loading.

Instrumentation for the continuous monitoring of peroxyacetyl nitrate (PAN) has been developed and field measurements have commenced to evaluate the contribution of PAN to the long-range transport of oxides of nitrogen and to oxidant-related problems.

The Canadian Arctic Air Sampling Network (CAASN) monitored the air at three sites in the North, and was integrated into the Canadian Air and Precipitation Monitoring Network (CAPMON).

Research continues on the development of methods to measure and parameterize the deposition of sulphur dioxide and ozone to natural surfaces. A field project was conducted at the University of Guelph, Elora Research Station. Analysis of data from the Illinois international intercomparison in 1982 has demonstrated the capabilities of our systems for gaseous deposition, provided proper corrections are made for instrument response times. Particle deposition velocities were small (less than 0.05 cm/sec) for particle sizes less than 0.5 μ m. Particle counting statistics were difficult to obtain for larger particles.

(ii) Toxic Chemicals. A second field study on aerial pesticide spraying in New Brunswick was undertaken. More detailed data on the behaviour and role of the spray aircraft wing-tip vortices were obtained. It is becoming clear that the vortices play an important, but yet poorly understood, role in spray fate, particularly as a function of atmospheric stability.

Several projects related to the pollution transfer across air-water interfaces continue. Since the transfer is enhanced in areas of rough seas (whitecaps) their areal extent is being studied using remote sensing. Methods to measure transfer rates using the

oxygen surrogate method are being developed. A project on Lake Ontario used a prototype automatic titrator for oxygen concentration in water. The importance of mixing and bubbling at the interface has been demonstrated, since the pollutant concentration in the foam at the foot of Niagara Falls has been found to be up to 2500 times that in the upstream water.

The experimental study of particulate and gaseous organics in the air in the Niagara River area continued during another sampling period in August. Analysis has focussed on ambient concentrations of phthalate esters, polycyclic aromatic hydrocarbons and polychlorinated biphenyls.

(iii) Great Lakes Water Quality. The atmospheric loading of nitrogen oxides, lead and toxaphene to the Great Lakes was estimated by applying a numerical air quality model to available data on pollutant emissions and characteristics. The results have been verified against available measurements and an inventory of atmospheric mercury emissions is being assembled in preparation for the modelling of its deposition to the Lakes.

(iv) Oxidants. In order to support atmospheric oxidant studies, equipment has been developed to collect and analyze ambient air samples for volatile organic components in the C₂ to C₁₀ molecular weight range.

(v) Environmental Impact Assessment (EIA). In support of the departmental EIA program and other agencies, several reports dealing with the air quality and meteorological aspects were reviewed including the rupture of a natural gas pipeline on the sea bed near Sable Island; an expansion of the Vancouver International Airport; a modification to a railway tunnel vent in the Rogers Pass; dispersion models used for the Bruce Heavy water plant; a NATO Handbook on Standards and Rules for the Protection of Civil Population against chemical toxic agents; air quality in a suburb of Whitehorse; and uranium mining in Northern Saskatchewan.

Contributions were made to the design and evaluation of an EMR contract project "on the impact of residential woodburning on urban air quality in Canada" and also in simulation of "air quality at the Simplot industrial site near Brandon, Manitoba".

(vi) Modelling. Some air pollution models developed by the U.S. Environmental Protection Agency have been purchased for application to EIA's. They are being adapted to the AES computer and have undergone preliminary testing.

The AQPAC (air quality package for environmental emergencies, see CGB 1982) version 2 was enhanced to include dry and wet deposition processes. The short-range dispersion models can now estimate in real-time for accidental releases, depleted air concentration, ground contamination and coordinates of threshold concentration or exposure.

Documents were completed for the Canadian Standards Association on "Guidelines for Calculation of Radiation Dose to the Public from an Accidental Release of Radioactive Material into the Atmosphere", and for the Ontario Nuclear contingency planning working group on "Recommendations for Meteorological Modelling and Monitoring".

(vii) Monitoring. On 1 April, AES integrated its various air and precipitation monitoring networks into one network (see CGB 1982), the Canadian Air and Precipitation Monitoring Network (CAPMoN), with the following monitoring components: CAPMoN (P), precipitation quality; (A), air quality; (T), atmospheric turbidity; (c), CO₂ and (N), arctic aerosol. CAPMoN (P) is an updated version of CANSAP with daily monitoring, improved instrumentation and improved sampling protocols, and is operational only in Eastern Canada and will be extended into Western Canada in the next two years. In addition to CAPMoN (c) AES is establishing a background air pollution monitoring laboratory (also a part of BAPMoN of WMO network) at Alert, N.W.T. to monitor CO₂ and other pollutants in gaseous and particulate phases.

(viii) Technology Transfer. The AQPAC (see CGB 1982) version 1 was implemented at all AES regional centres and the package will be used to provide air quality guidance in the event of accidental release of toxic chemicals into the atmosphere.

The Atmospheric Interactive Modelling System (AIMS, see CGB 1982) was put into operation with three point source models during the summer for a one-year trial. It will be used to provide a library of easy-to-use air pollution models from which air pollution concentrations can be calculated for various weather conditions and for a variety of pollutant sources.

(ix) Energy. A major international field experiment, the Askervein Experiment, on South Uist in Scotland was conducted in September. AES scientists led the experiment sponsored by the International Energy Agency with participation from four other countries. A good data set documenting the variation of airflow over an isolated high (~ 125 m) hill was collected. The data will form a benchmark test set against which physical and numerical models of airflow in complex terrain can be tested.

A wind energy resource assessment for the lower St. Lawrence Valley terminated in a one-year data set from three potential wind energy conversion system sites. Data are still being collected at a site on Iles-de-la-Madeleine.

Work continued on the development of a hierarchy of 3-D numerical models (MS3DJM) capable of predicting modifications of the airflow over complex terrain for variable roughness, and modest terrain situations with neutral and stable atmosphere stratification. Verification against the data collected at Kettles Hill and Askervein shows encouraging agreement.

(x) Dispersion of Heavy Gases. Experimental work continued on the dispersion of heavy gases, to help develop an impact prediction model for use during accidental releases. An improved gas release mechanism was studied in cold weather situations. Data collected so far have been used to intercompare two existing dispersion models.

A large data set has been collected in the UK Health and Safety Executive studies of Heavy Gas dispersion, which are co-sponsored by AES. The data will be of use in improving modelling capability for accidental spills of such gases as LNG, LPG, chlorine and ammonia. Further studies have been undertaken with fence and block obstacles downstream of the gas release.

(xi) Northern Studies. A project has commenced to develop and evaluate air quality assessment techniques for use in environmental assessment and review processes in the Arctic. A review has been made on the available information on pollutant dispersion in the North in preparation for an experimental field study program.

(xii) Core Research. During June AES participated in the 6th Remote Sensing Campaign of the Commission of European Communities at Fos-Berre, France, which involved a shoreline dispersion study of a complex configuration of industrial air pollution sources.

AES LIDAR is being enhanced to have a higher repetition-rate, and a multi-wavelength capability, to permit more rapid data gathering as well as the remote determination of pollutant species by means of differential absorption measurements.

(c) Canadian Climate Centre

The Canadian Climate Normals for the period 1953-80 were published for Hourly Atmospheric Pressure, Temperature and Humidity, and for Soil Temperature. Fifty-six temperature maps were completed and formed the first in a series of 17 sets of maps for the Climatic Atlas of Canada, which will be issued in 1985. Twenty issues of the new series Principal Station Data weather summaries were distributed. The periodical, "Monthly Record, Meteorological Observations in (Eastern/Western/Northern) Canada", was revised; effective with the January 1983 issue it became available only in microfiche format. Climate data were supplied in response to more than 12,000 requests. Another 600 requests were received for magnetic tape copy or special computer statistical analyses of digital data retained in the National Climatological Archive. Over 250,000 pages of climate documents were microfilmed.

(i) Hydrometeorology. Preparation of a new rainfall atlas for Canada was commenced and 106 maps were completed. A re-evaluation of the critical meteorological conditions

leading to the maximum flood on the Stikine River in northern British Columbia proved useful in developing relations between elevation and various meteorological parameters. The SCEPTRE radar archive is being modified to become more accessible to users.

Assessments of precipitation network adequacy and design were undertaken for the northern Great Lakes Watershed and Newfoundland/Labrador. The final report on the Lake Okanagan Evaporation Study was completed. The weekly production of national maps of water budget parameters continued.

In a joint project with Inland Waters Directorate, meteorological sensors on a Bristol data collection platform were installed and successfully tested on the Ottawa River. Because of the lack of snowfall, the field testing of eight prototype, large Nipher-type shields was extended to the winter of 1983-84. Comparison of snow cover analyses produced by several sources for the Canada-New Brunswick River Forecast Centre was undertaken. A hybrid analogue-digital image analysis procedure for the Saint John Basin was tested operationally during the snowmelt season.

Airborne passive microwave data, collected during the Canada/U.S. Joint Prairie Snow Cover Runoff Study received preliminary analysis. Tests were started on the U.S. National Weather Service River Forecast System's snowmelt model on small basins in southern Ontario for use in a snowpack acid shock potential model. Field tests in Dorset, Ontario commenced and include a snowmelt plot and an automatic climate station.

As a complement to a marine climatological statistics package (MAST), software systems were developed to analyse gridded ocean data (GASP) or conventional land data (LAST) to produce graphical and statistical summaries. The MAST/LAST system was used to produce a "Climatology of the East Coast Marine Areas". A state-of-the-art review of marine climatology on the Canadian East Coast pertinent to human safety was prepared for the Royal Commission on the Ocean Ranger Marine Disaster.

(ii) Climate Applications. Climate applications to agriculture, solar and wind energy, industry and northern development continued. New studies were initiated on meteorological influences on fast-ice movement in Lancaster sound; ice detention as it affects power transmission lines across Canada; synoptic weather conditions associated with severe forest fires; the effects of volcanoes on Canadian climate; development of new snowload values for use in building design; likely climate change and some of its impacts on Saskatchewan.

(iii) Monitoring and Prediction. Research continues on the use of the analogue method for long-range temperature forecasts, and involves experiments with modified versions of the Canadian 15-day temperature anomaly forecasts. The implementation of near real-time monthly temperature anomaly forecasts based on the autoregressive moving-average extrapolation of time series is almost completed.

The analysis of GOES-E satellite data in support of the International Satellite Cloud Climatology Project is continuing, now focussed on the information content of the spatial structure of images. A project to develop and apply cloud algorithms over Arctic regions using NOAA polar orbiter data has been initiated, and a case study using empirical classifications over the Beaufort Sea has been completed.

Three-Dimensional Model. Version I of the Canadian Climate Centre General Circulation Model (GCM) was used to continue a long-term climatological simulation and has been integrated for nine annual cycles. The first five years of the simulation have been analysed.

Simulations have been carried out of the model's response to an El Niño such as that experienced during the winter of 1982-83, as well as to a variety of other anomalous sea-surface temperatures. The simulations result in patterns that are similar in many respects to those observed in the atmosphere. The observed local and tropical response of the atmosphere to an El Niño is much stronger and more definite than the observed extra-tropical response. The potential for skillful monthly and seasonal predictions at middle latitudes based on equatorial sea surface temperature forcing is apparently not large but a real physical effect appears to be present.

A scheme for predicting cloudiness in the GCM has been developed and tested, and is fully interactive with the radiative transfer calculations in the model.

The scheme for moist convection was changed so as to represent more fully the effects of deep convection and permit a more physically realistic representation of cloudiness associated with regions of deep convection. This convective parameterization is still considered to be interim, however; in particular it does not account for the effect of deep cumulus convection on the large-scale momentum budget. Work on representing these effects with a physically more self-consistent parameterization of cumulus convection is under way.

The effects of including a parameterization of topographically generated gravity wave drag in the GCM has been studied, particularly the effects of allowing gravity wave energy to leak up into the model stratosphere. Considerable sensitivity to this parameterization has been found, especially in the upper atmosphere, and further formulations of the parameterization are being tested.

Radiative - Convective - Photochemical Modelling. Experiments have been carried out with a coupled 1-D radiative-convective and photochemical diffusion model to assess the possible effects of increased atmospheric CO₂, tropospheric O₃ and the El Chichon volcanic eruption on the vertical thermal structure of the atmosphere and on the surface climate. Numerical experiments were also continued with a 2-D time dependent radiative-photochemical-transport model to determine the effects of volcanic aerosols and NO_x injections on stratospheric O₃ and temperature structure.

(iv) General Circulation Diagnostics. Mass and energy budgets for January and July of the FGGE year have been computed and are being prepared for publication. Mass and energy budgets for January and July CMC forecast errors at 24, 48, and 72 hours have also been calculated.

Methods of diagnostic analysis of the atmospheric behaviour in spectral space have been used to study predictability and error in the CMC operational forecast system. The classical picture of error at small and large scales is apparent but, as well, the analysis allows an estimate of the scale-dependent error source due to mode deficiencies. It is found that this term is important especially at early times in the forecasts and that error is introduced at all scales.

A study of the divergence field from the observation of the FGGE year is under way and a divergence budget is being computed for January and July.

As a result of the many interesting features of the general circulation (especially in the Southern Hemisphere) that have been uncovered by a zonal wavenumber study of the FGGE-year data, a zonal wavenumber climatology has been started.

(d) Central Services Directorate

Ice reconnaissance and data handling activities continued as reported in the CGB 1982. Approval was given to expand the ice information services program to begin a new iceberg service in early 1986 and to greatly improve the present sea ice service by using a specially designed DASH-7R as a third ice reconnaissance aircraft, more remote-sensing equipment on all aircraft, and more advanced communications, computers and modelling methods. A new HF transceiver at the Ice Centre was operational so that ice charts can be received from the ice reconnaissance aircraft and from ice breakers. The brightness temperatures received from the passive microwave radiometer on Nimbus 7 were converted to sea ice types and the outputs displayed at the Ice Centre and contoured for ice concentration and for separation of predominantly old ice areas from first-year ice.

The Data Acquisition Services Branch is developing a precipitation occurrence sensor to detect the duration, type and amount of precipitation. The sensor is a small Doppler radar oriented vertically to measure the fall velocity of precipitation particles and is of the same type as used by police to measure vehicle speeds. The power spectrum of the Doppler return signal is used to determine the precipitation type from the peak and width of the spectrum, and the rate from the total spectral power.

21. Bibliography

Journal Articles

- Adams, W.P. 1983. Snow in geography. *The Monograph*, 34, 10-18.
- Baker, T.H.W., Davis, J.L., Hayhoe, H.N. and Topp, G.C. 1982. Locating the frozen/unfrozen interface in soils using time-domain reflectometry. *Can. Geotech. J.*, 19, 511-517.
- Blanchet, J.-P. and List, R. 1983. Estimation of the optical properties of Arctic haze using numerical models. *Atmos.-Ocean*, 21, 444-465.
- Boer, G.J. 1982. Diagnostic equations in isobaric coordinates. *Mon. Weather Rev.*, 110, 1801-1820.
- Boer, G.J. 1983. Homogeneous and isotropic turbulence on the sphere. *J. Atmos. Sci.*, 40, 154-163.
- Boer, G.J. and Shepherd, J.G. 1983. Large-scale two-dimensional turbulence in the atmosphere. *J. Atmos. Sci.*, 40, 164-184.
- Brach, E.J., Poirier, P., Desjardins, R.L. and Lord, D. 1983. Multi-spectral radiometer to measure crop canopy characteristics. *Rev. Sci. Instrum.*, 54, 493-500.
- Burton, I., Munn, R.E. and Wilson, J. 1983. Environmental impact assessment: national approaches and international needs. *Int. J. Environ. Monit. Assess.*, 3, 133-150.
- Chan, W.H., Vet, R.J., Lusic, M.A. and Skelton, G.B. 1983. Airborne particulate size distribution measurements in nickel smelter plumes. *Atmos. Environ.*, 17, 1173-1181.
- Chan, W.H., Tomassini, F. and Loescher, B. 1983. An evaluation of sorption properties of precipitation constituents on polyethylene surfaces. *Atmos. Environ.*, 17, 1779-1785.
- Coté, J., Béland, M. and Staniforth, A. 1983. Stability of vertical discretization schemes for semi-implicit primitive equations models: theory and application. *Mon. Weather Rev.*, 6, 1189-1207.
- Danard, M. 1983. On the role of the planetary boundary layer in cyclogenesis over the ocean. *Atmos.-Ocean*, 21, 466-470.
- Danard, M. and Thompson, W. 1983. Modelling winds in Lancaster Sound and Northwestern Baffin Bay. *Atmos.-Ocean*, 21, 69-81.
- den Hartog, G., Topham, D.R., Perkin, R.G., Smith, S.D. and Anderson, R.J. 1983. An investigation of a polynya in the Canadian Archipelago, 1. Introduction and oceanography. 2. Structure of turbulence and sensible heat flux. 3. Surface heat flux. *J. Geophys. Res.*, 88, 2888-2916.
- Dwyer, L.M. and Ivarson, K.C. 1983. Influence of woodlot floor topography on microbial decomposer distribution. *Holarct. Ecol.*, 6, 101-106.
- Fortin, J.-P., Morin, G. et Dupont, L. 1983. La rationalisation du réseau météorologique du Québec: stratégie d'intervention et méthodes d'analyse des données. *Atmos.-Ocean*, 21, 365-386.
- Garand, L. 1983. Some improvements and complements to the infrared emissivity algorithm including a parameterization of the absorption in the continuum region. *J. Atmos. Sci.*, 40, 230-244.
- Geleyn, J.-F., Girard, C. and Louis, J.F. 1982. A simple parameterisation of moist convection for large-scale atmospheric models. *Contrib. Atmos. Phys.*, 55, 325-334.

- Hamilton, K. 1983. Aspects of wave behaviour in the mid- and upper troposphere of the Southern Hemisphere. *Atmos.-Ocean*, 21, 40-54.
- Hay, J.E. 1983. Solar energy system design: the impact of mesoscale variations in solar radiation. *Atmos.-Ocean*, 21, 138-157.
- Hayhoe, H.N., Bailey, W.G. and Topp, G.C. 1983. Measurement of soil water contents and frozen soil depth during a thaw using time-domain reflectometry. *Atmos.-Ocean*, 21, 299-311.
- Hayhoe, H.N., Topp, G.C. and Edey, S.N. 1983. Analysis of measurement and numerical schemes to estimate frost and thaw penetration of the soil. *Can. J. Soil Sci.*, 63, 67-77.
- Ibrahim, M., Barrie, L.A. and Fanaki, F.H. 1983. An experimental and theoretical investigation of the dry deposition of particles to snow, pine trees and artificial collectors. *Atmos. Environ.*, 17, 781-788.
- Iribarne, J.V., Barrie, L.A. and Iribarne, A. 1983. Effect of freezing on sulphur dioxide dissolved in supercooled droplets. *Atmos. Environ.*, 17, 1047-1050.
- Jacobs, J.D. and Andrews, J.T. 1983. A note on solar radiation measurements on Cumberland Peninsula, Baffin Island, N.W.T. in summer, 1970-79. *Arctic Alp. Res.*, 15, 91-96.
- Kemp, W.P., Burnell, D.G., Everson, D.O. and Thomson, A.J. 1983. Estimating missing daily maximum and minimum temperatures. *J. Climate Appl. Meteorol.*, 22, 1587-1593.
- Kerman, B.R. 1983. Effective stratification for plume rise and boundary-layer growth computations. *Atmos. Environ.*, 17, 235-238.
- Kerman, B.R. 1983. Ground level concentrations due to fumigation into an entrained mixing layer. *Atmos. Environ.*, 17, 1029-1037.
- Kerman, B.R., Evans, D.L., Watts, D.R. and Halpern, D. 1983. Wind dependence of underwater ambient noise. *Boundary-Layer Meteorol.*, 26, 105-113.
- Kiehl, J.T. and Ramanathan, Y. 1982. Radiative heating due to CO: the role of HO continuum absorption in the 12-18 μm region. *J. Atmos. Sci.*, 39, 2923-2926.
- Knox, J.L. and Hay, J.E. 1983. Blocking signatures in the Northern Hemisphere: Rationale and identification. *Atmos.-Ocean*, 22.
- Leahey, D.M. 1983. Urban air pollution modelling. (Discussion). *Atmos. Environ.*, 17, 1855-1856.
- Leahey, D.M., Davies, J.J.E. and Bambrough, H.A. 1983. Values of NO₂/NO_x observed in the exhaust plume from a turbine driven compressor installation. *Atmos. Environ.*, 17, 991-997.
- Leighton, H.G. 1983. The influence of Arctic haze on the solar radiation budget. *Atmos. Environ.*, 17, 2065-2068.
- Mahendroppa, M.K. 1983. Chemical characteristics of precipitation and hydrogen input in throughfall and stemflow under some eastern Canadian forest stands. *Can. J. For. Res.*, 13, 948-955.
- Major, D.J., Brown, D.M., Bootsma, A., Dupuis, G., Fairey, N.A., Grant, E.A., Green, D.G., Hamilton, R.I., Langille, J., Sonmor, L.G., Smeltzer, G.C. and White, R.P. 1983. An evaluation of the corn heat unit system for the short-season growing regions across Canada. *Can. J. Plant Sci.*, 63, 121-130.

- Mathers, T.H. and Taylor, C.H. 1983. Rainfall interception on a small forested catchment within the Kawartha Lakes region. *Can. Water Resour. J.*, 8, 120-129.
- Meek, C.E. and Manson, A.H. 1983. Measurements of the structure and drift velocities of airglow ($\lambda = 557.7$ nm) irregularities: Saskatoon (52°N, 107°W), Canada. *J. Atmos. Terr. Phys.*, 45, 203-212.
- Mukammal, E.I., McKay, G.A. and Neumann, H.H. 1983. A note on indrivasular diseases and physical aspects of the environment. *Int. J. Biometeorol.*, 28, 140-152.
- Munn, R.E. 1982. The design of environmental monitoring systems: update 1982. *Prog. Phys. Geogr.*, 6, 541-548.
- Mustafa, M.A., De Jong, R., Hayhoe, H.N., and Topp, G.C. 1983. Intermittent infiltration and evaporation from soil columns. *Can. J. Soil Sci.*, 63, 303-314.
- Novak, M.D. and Black, T.A. 1983. The surface heat flux density of a bare soil. *Atmos.-Ocean*, 21, 431-443.
- Oke, T.R. and McCaughey, J.H. 1983. Suburban-rural energy balance comparisons for Vancouver, B.C.: an extreme case? *Boundary-Layer Meteorol.*, 26, 337-354.
- Olson, M.P., Voldner, E.C. and Oikawa, K.K. 1983. Transfer matrices from the AES-LRT model. *Atmos.-Ocean*, 21, 344-361.
- Powell, J.M. 1983. Richmond Longley and climatic variability in Canada. *Syllogeus*, 49, 337-343.
- Richards, W.G. and Crozier, C.L. 1983. Precipitation measurement with a C-band radar in Southern Ontario. *Atmos.-Ocean*, 21, 125-137.
- Rogers, R.R. and Smith, P.L. 1983. Radar meteorology. *Sci. Prog.*, 68, 149-176.
- Rogers, R.R. and Yau, M.K. 1982. Areal extent and vertical structure of radar weather echoes at Montreal. *Pure Appl. Geophys.*, 120, 273-285.
- Rogers, R.R., Olsen, R.L., Strickland, J.I. and Coulson, G.M. 1982. Statistics of differential rain attenuation on adjacent earth-space propagation paths. *Ann. Télécommun.*, 37, 445-452.
- Rouse, W.R. 1982. The water balance of upland tundra in the Hudson Bay Lowlands measured and modelled. *Naturaliste Can.*, 109, 457-467.
- Sanderson, M. 1983. Heating degree day research in Alberta: residents conserve natural gas. *Prof. Geogr.*, 35, 437-440.
- Stewart, D.W. and Dwyer, L.M. 1983. Stomatal response to plant water deficits. *J. Theoret. Biol.*, 104, 655-659.
- Street, R.B. and McNichol, D.W. 1983. Historical soil moisture in the Prairie Provinces: a temporal and spatial analysis in climate change in Canada. *Syllogeus*, 49, 130-143.
- Stuart, A., et al. 1983. Verification of Toronto temperature and precipitation forecasts for the period, 1960-1979. *Atmos.-Ocean*, 21, 243-262.
- Taylor, P.A., Walmsley, J.L. and Salmon, J.R. 1983. A simple model of neutrally stratified boundary-layer flow over real terrain incorporating wavenumber dependent scaling. *Boundary-Layer Meteorol.*, 26, 169-189.
- Thomson, A.J., Harris, J.W.E. and Silversides, R.H. 1983. Effects of elevation on the rate of development of western spruce budworm (Lepidoptera: Tortricidae) in British Columbia. *Can. Entomol.*, 115, 1181-1187.

- Torlaschi, E. and Zawadzki, I. 1983. An optimal radar reflectivity processing. *J. Climate Appl. Meteorol.*, 22, 1794-1799.
- Torlaschi, E. and Zawadzki, I. 1983. The dependence of microwave attenuation statistics on meteorological parameters. *Radio Sci.*, 18, 225-229.
- Trudeau, F. and Zawadzki, I. 1983. Note on influence of the vertical wind structure on convective precipitation. *J. Climatol. Appl. Meteorol.*, 22, 512-515.
- Uboegbulam, T.C. and Davies, J.A. 1983. Turbidity in Eastern Canada. *J. Climate Appl. Meteorol.*, 22, 1384-1392.
- Wallis, C.H., Black, T.A., Hertzman, O. and Walton, V.J. 1983. Application of a water balance model to estimating hay growth in the Peace River Region. *Atmos.-Ocean*, 21, 326-343.
- Walmsley, J.L. and Mailhot, J. 1983. On the numerical accuracy of trajectory models for long-range transport of atmospheric pollutants. *Atmos.-Ocean*, 21, 14-39.
- Warn, T. and Brasnett, B. 1982. The amplification and capture of atmospheric solitons by topography - a theory of the onset of regional blocking. *J. Atmos. Sci.*, 40, 28-38.
- Watt, W.E. and Nozdryn-Plotnicki 1983. Frequency analysis of short-duration rainfalls. *Atmos.-Ocean*, 21, 387-396.
- Whelpdale, D.M. 1983. Acid deposition: distribution and impact. *Water Qual. Bull.*, 8, 72-80.
- Whyte, A.V. and Harrison, M.R. 1983. Climate change - the public's perception. *Chinook*, 5, 23-26.
- Williams, G.D.V. 1983. Agroclimatic resource analysis - an example using an index derived and applied for Canada. *Agric. Meteorol.*, 28, 31-47.
- Williams, G.D.V. and Masterton, J.M. 1983. An application of principal component analysis and an agroclimatic resource index to ecological land classification for Alberta. *Climatol. Bull.*, 17, 3-28.
- Wong, R.K.W., Chidambaram, N. and Mielke, P.W., Jr. 1983. Application of multi-response permutation procedures and median regression for covariate analyses of possible weather modification effects on hail responses. *Atmos.-Ocean*, 21, 1-13.
- Woo, M.-K., Heron, R., Marsh, P. and Steer, P. 1983. Comparison of weather station snowfall with winter snow accumulation in High Arctic basins. *Atmos.-Ocean*, 21, 312-325.
- Yakimiw, E. 1983. Some additional properties of the spectral multiplication matrix. *Tellus*, 35A, 159-160.

Reports and Memoranda

(a) The University of Alberta

- Hage, K.D. and Hopps, P. 1982. A new air pollution model for Edmonton. Rep. RMD 82/14, Res. Manage. Div., Alberta Environment, 37 pp.
- Lozowski, E.P. 1983. The scavenging of solid and gaseous airborne pollutants by cloud processes - a review and some implications for long-range transport models. Final Tech Rep. under Contract No. KH-601-1-1452 to Environment Canada, 128 pp.
- Lozowski, E.P. and Oleskiw, M.M. 1983. Computer modelling of time-dependent rime icing in the atmosphere. Rep. 83-2, U.S. Army Cold Regions Res. and Eng. Lab., 81 pp.

(b) Western Research, Division of Bow Valley Resource Services Ltd.

Hansen, M.C. and Jones, M.D. 1983. An assessment of collection and handling of climate data by Alberta Government agencies. RMD Rep. 82/12, prepared for Alberta Environment, Res. Manage. Div., by Western Research, Edmonton, Alta., 45 pp.

Shewchuk, S.R. 1983. An acid deposition perspective for the Northwest Territories. Science Advisory Board, Government of the Northwest Territories, Yellowknife, ISBN 0-7708-8116.

Shewchuk, S.R. 1983. Continuous ambient monitoring for trace levels of organic pesticide. SRC Tech. Rep. No. 142, SRC Publ. No. E-906-1-B-83.

Shewchuk, S.R. and Grover, R. 1983. A micrometeorology system as it is applied to herbicide volatilization under field conditions. SRC Tech. Rep. No. 143, SRC Publ. No. P-780-5-B-83.

(c) University of Windsor

Jacobs, J.D. and Marchand, D. 1983. Meteorology. Chap. in: Toxic Contaminants in Essex Region. Rep. to D.S.S. Great Lakes Institute, University of Windsor.

Sanderson, M. and Marchand, D. 1983. Surface deposition. Chap. in Toxic Contaminants in Essex Region. Rep. to D.S.S. Great Lakes Institute, University of Windsor.

(d) McMaster University

Rouse, W.R. and Bello, R.L. 1983. The advective influence of Hudson and James Bays on climate in the Hudson Bay Lowlands. TASO Rep. No. 3, McMaster University, 25 pp.

(e) University of Toronto, Institute for Environmental Studies

Boville, B.W., Munn, R.E. and Hare, F.K. 1983. The storage of non-living organic carbon in boreal and Arctic zones in Canada. Final Rep. to the U.S. Dep. of Energy, Washington, D.C., 89 pp.

Hare, F.K. and Forester, A. 1983. Acid deposition in North America: a review of the documents prepared under the Memorandum of Intent. Roy. Soc. Can., 3 Vol.

Inst. Environ. Studies. 1983. Environmental and renewable resource issues and prospects. Submitted to the Royal Comm. on Economic Union and Dev. Prospects for Canada, 9 pp.

Munn, R.E. 1983. The ability of wet deposition networks to detect changes in regional air pollution emissions. Contract Rep. to the Atmos. Environ. Serv., Downsview, Ont., 33 pp.

Munn, R.E. 1983. Atmospheric dispersion from a point source over very long times. Contract Rep. to AECL, Whiteshell, Man., 25 pp.

Munn, R.E. and Rapport, D. 1983. Towards an integrated framework for resource accounting in Canada, Phase 1. Contract Rep. to Statistics Canada, 32 pp.

Munn, R.E., Pushak, R. and Byer, P.H. 1983. Potential health and environmental impacts of the railway lands development. Contract Rep. to the City of Toronto, 34 pp.

Munn, R.E. et al. 1983. A climatological analysis of the Hubbard Brook (New Hampshire) precipitation chemistry data. Final Rep. to the U.S. Dep. of Energy, Washington, D.C., 105 pp.

(f) Ontario Ministry of the Environment

Chan, W.H., Tang, A.J.S. and Lusic, M.A. 1983. Precipitation concentration and wet deposition fields of pollutants in Ontario, Sept. 1980 - Dec. 1981. ARB-61-83-ARSP.

Kirk, R.W. 1983. Acidic precipitation in Ontario study, annual statistics of concentrations and deposition - cumulative precipitation monitoring network, 1981. ARB-102-83-ARSP.

Kirk, R.W. 1983. Acidic precipitation in Ontario study, annual statistics of concentration - daily ambient air monitoring network, 1981. ARB-114-83-ARSP.

Kirk, R.W. and Chan, W.H. 1983. Acidic precipitation in Ontario study, summary statistics of observed concentration and deposition - daily precipitation monitoring network, 1981. ARB-86-83-ARSP.

Ley, B., Misra, P.K., Bell, R. and Yap, D. 1983. Falconbridge plume dispersion study. ARB-181-83-AQM.

Misra, P.K. 1983. Estimation of uncertainties in transfer matrix elements in long range transport modelling. ARB-82-AQM.

Nanticoke Environmental Management Program. 1983. Network data summary for 1981. ARB-144-83-ARSP.

(g) Trent University

Adams, W.P., Campbell, J., Wolfe, B. and Woods, L. 1982. An atlas of spatial and temporal trends of winter cover for Lake St. George, Ontario. Ontario Ministry of the Environment, 33 pp. - 58 maps.

(h) Université de Sherbrooke, Département de géographie

Bigras, P. et Hébert, A. 1982. Jees, un système météorologique de prévision des avalanches, Mont Washington, New-Hampshire. Rapport de B.Sc., 31 p.

Boisvert, J.J. 1983. Climatographie de l'Estrie 1941-1970. Bulletin de recherche, Collection hors série no. 2, 232 p.

Deschamps, M. 1983. Étude comparée d'images numériques NOAA et LANDSAT pour la couverture nivale et glacielle au Nouveau-Québec. Rapport de B.Sc., 57 p.

Proulx, H. 1983. Bilan hydrologique de la rivière Yamaska à la station de jaugeage de Farnham. Rapport de B.Sc., 120 p.

Royer, A. et Lavoie, A. 1982. Qualité des eaux et télédétection; principes et exemples d'application. Laboratoire de télédétection, rapport à A. Marsan et Ass., Montréal, 23 p.

Saint-Pierre, L. 1983. Morphogénèse de la caverne à la Patate, rivière à la Patate, île d'Anticosti, Québec. Rapport de B.Sc., 68 p.

(i) Environnement-Québec

Ferland, M. 1983. De la neige colorée est tombée au Québec. Feuille météorologique, XXII, 18-24.

Fréchette, A. 1983. Le réseau météorologique du Québec au 1er janvier 1983. Feuille météorologique, XXII, 1-5.

Houde, J. 1983. Temps violent à Québec le 7 juin 1983. Feuille météorologique, XXII 162-164.

Jacques, G. 1983. Représentativité moyenne quotidienne des observations horaires de vents (2e partie). Feuille météorologique, XXII 70-83.

Lamb, P. 1982. Description du contenu des sommaires climatologiques du Québec. M-82-7, Ministère de l'Environnement du Québec.

Leduc, R. et Lelièvre, C. 1983. Le calcul de l'humidité. Feuillelet météorologique, XXII, 5-15.

Rochette, P., Jacques, D. et Dubé, P.-A. 1983. Analyse de la variation inter-annuelle de certains paramètres agrométéorologiques dérivés de la température, 1^{re} partie: Saguenay - Lac St-Jean. 2e partie: Abitibi - Témiscamingue. Feuillelet météorologique, XXII, 144-157, 165-176.

(j) Canadian Forestry Service

Alexander, M.E. 1983. Analysis of the Canadian Forest Fire Weather Index for the 1968 Lesser Slave Lake fire. For. Rep. No. 28, Environ. Can., Can. For. Serv., North. For. Res. Cent., Edmonton, Alta., 8-10.

Alexander, M.E. 1983. Overwinter adjustment to spring starting values of the Drought Code. For. Rep. No. 28, Environ. Can., Can. For. Serv., North. For. Res. Cent., Edmonton, Alta., 5.

Alexander, M.E. 1983. Tables for determining spring Drought Code starting values in west-central and Northern Canada. For. Manage. Note 19, Environ. Can., Can. For. Serv., North. For. Res. Cent., Edmonton, Alta., 8 pp.

Harrington, J.B., Flannigan, M.D. and Wagner, C.E. 1983. A study of the relation of components of the Fire Weather Index to monthly provincial areas burned by wildfire in Canada, 1953-80. Inf. Rep. PI-X-25, Environ. Can., Can. For. Serv., Petawawa, Nat. For. Inst., Chalk River, Ont., 65 pp.

Newstead, R.G. and Alexander, M.E. 1983. Short-term fire retardant effectiveness in a lowland black spruce fuel complex. For. Rep. No. 28, Environ. Can., Can. For. Serv., North. For. Res. Cent., Edmonton, Alta., 3-4.

Peterson, E.B., Peterson, N.M. and Kabzems, R.D. 1983. Impact of climatic variation on biomass accumulation in the boreal forest zone: Selected references. Inf. Rep. NOR-X-254, Environ. Can., Can. For. Serv., North. For. Res. Cent., Edmonton, Alta., 355 pp.

(k) Atmospheric Environment Service

1. Research Internal Reports

Bloxam, R. and Mickle, R.E. 1983. Ozone profiles in a shoreline experiment. Rep. AQRB-83-004-L.

Burling, T. 1983. The Toronto mesometeorological network of the Meteorological Services Research Branch. Rep. MSRB-83-5.

Carriere, G. 1983. Verification of forecasts produced by the snow squall model, Jan. May 1983. Rep. MSRB-83-7.

Clodman, S. 1983. Testing and future application of the Donelan Lakeview Test Model. Rep. MSRB-83-4.

Girard, C. 1983. Conservative vertical discretizations of the primitive equations, Part I. Theoretical aspects. Notes scientifiques et techniques No. 11, 88 pp.

Goldberg, E. 1983. Objective analysis procedures in the operational environment. Rep. MSRB-83-6.

Khandekar, M.L. and Venkatesh, S. 1983. Ocean wind-wave prediction: a case for implementation of a spectral wave model. Rep. MSRB-83-3.

- Loiselle, M. and Wilson, L.J. 1983. An assessment of the small area model for application to real-time surface wind diagnosis at point locations. Rep. MSRB-83-2.
- Maarouf, A. 1983. Statistical wind forecasting using the Perfect Prog Method. Rep. MSRB-83-1.
- Mickle, R.E., Kobelka, W. and Reid, J.D. 1983. Airflow and aircraft vortex behaviour during a pilot field study near upper Blackville, New Brunswick. Rep. AQRB-83-003-L.
- Taylor, P.A. and Teunissen, H.W. 1983. Askervein '82: report on the September/October 1982 experiment to study internal boundary layer flow over Askervein, South Uist. Rep. MSRB-83-8.
- Walmsley, J.L. and Blanc, T.V. 1983. Computer-model results for the Beach-Escarpment-induced distortion of onshore wind flow at the northwest point of San Nicolas Island, California. NRL Rep. 8746, Naval Res. Lab., Washington, D.C.
- Yakimiw, E. 1983. Projet d'assimilation directe des données de radiance de satellites dans l'analyse objective optimale à RPN. Notes scientifiques et techniques No. 10, 177 p.

2. Canadian Climate Centre Reports

- Beckford, M., Berry, M., Raddatz, R. and Woronko, S. 1983. Climate forecasts and the Canadian Wheat Board. CCC Rep. No. 83-11, 18 pp.
- CCC Staff 1983. Canadian presentations at the WMO Symposium on Education and Training in Meteorology with Emphasis on Climatic Change and Variability. San José, Costa Rica, December 6-10, 1982. CCC Rep. No. 83-4, 54 pp.
- Higuchi, K. 1983. A look at the global carbon cycle. CCC Rep. No. 83-10, 37 p.
- Johnstone, K.J. 1983. A meteorological network design for the Mackenzie River Basin: final report. CCC Rep. No. 83-2, 43 pp.
- Johnstone, K.J. and Louie, P.Y.T. 1983. Water balance tabulations for Canadian Climate Stations. DS #8-83.
- Kertland, P.M. and McNichol, D.W. 1983. A mobile survey evaluation of the bioclimate of the Codrington Ontario area. CCC Rep. No. 83-5, 15 pp.
- Lachapelle, P.A. and Maxwell, J.B. 1983. Wind and waves in Lancaster Sound and Northwestern Baffin Bay. CCC Rep. No. 83-7, 80 pp.
- Manning, F.D. 1983. Climatic extremes for Canada. CLI-3-83, 28 pp.
- Manning, F.D. 1983. Winter snowfall averages and extremes at Principal Climatological Stations. CLI-5-83, 22 pp.
- Maxwell, J.B. 1982. Climate of the Canadian Arctic Islands and adjacent waters. Climatol. Studies No. 30, 589 pp.
- McNichol, D.W. and Leduc, R. 1983. A method of adjusting recorded sunshine data for the effects of an obstructed horizon. CCC Rep. No. 83-8, 22 pp.
- Newark, M.J. 1983. Severe local storms in Ontario during 1981. CLI-1-83, 31 pp.
- Newark, M.J. 1983. Severe local storms in Ontario during 1982. CLI-4-83, 37 pp.
- Newark, M.J. 1983. Tornadoes in Canada for the period 1950 to 1979. CLI-2-83, 88 pp.
- Raddatz, R., Tortorelli, R.R. and Newark, M.J. 1983. Manitoba and Saskatchewan tornado days, 1960-1982. CLI-6-83, 57 pp.

- Raphael, C. 1983. Models for estimating solar irradiance at the Earth's surface from satellite data: an initial assessment. CCC Rep. No. 83-1, 332 pp.
- Sargent, N.E. 1983. Realization of a spectral semi-implicit two-level GCM after Mintz-Arakawa. CCC Rep. No. 83-6, CCRN 12, 74 pp.
- Shabbar, A. 1983. A review of the Canadian climate from fall 1982 through summer 1983. CCC Rep. No. 83-12, 20 pp.
- Wilson, C.V. 1983. The summer season along the east coast of Hudson Bay during the Nineteenth Century. Part II. The Little Ice Age on Eastern Hudson Bay: Summers at Great Whale, Fort George, Eastmain, 1814-1821. CCC Rep. No. 83-9, 226 pp.
- Wolfe, G.L. 1983. The Dobbington, Ontario tornado of May 28, 1982. CLI-7-83, 19 pp.
- Zwiers, F.W. 1983. Statistical procedure for evaluating climate change experiments. CCC Rep. No. 83-3, CCRN 11, 49 pp.

3. Technical Memoranda

- Legal, L.R. 1982. A statistical study of rain versus snow at Comox, B.C. TEC 878, 12 pp.
- Raddatz, R.L. and Atkinson, G.B. 1982. Automated weather element input to forest fire severity forecasting. TEC 877, 15 pp.

(1) Miscellaneous Reports

- Valton, A.M., Dubois, J.M.M. et Boisvert, J.J. 1983. Projet d'évolution des littoraux du golfe du Saint-Laurent: les tempêtes et l'érosion des côtes. In: Peter J. Ricketts (Editor), Coastal Studies in Canadian Geography No. 2, Saint Mary's University, Halifax, 103-116.

Theses

(a) The University of British Columbia, Department of Geography

- Grimmond, S.B. 1983. The suburban water balance: daily, monthly and annual results from Vancouver, B.C. M.Sc. Thesis, 171 pp.
- Wanless, N. 1983. Satellite estimates of solar energy availability at the Earth's surface: impact of changes in the configuration of the satellite data. M.Sc. Thesis, 209 pp.

(b) The University of Alberta

- Hopps, P. 1983. A low-cost micrometeorological data acquisition system. M.Sc. Thesis (Meteorology), 109 pp.
- Kochtubajda, B. 1983. Theory and measurement of dry ice sublimation in clear air and simulated cloud. M.Sc. Thesis (Meteorology), 79 pp.
- Olson, R. 1983. Summer temperature variations in a small mountain valley in west-central Alberta. M.Sc. Thesis (Geography), 132 pp.

- Stovel, L. 1983. A two-dimensional numerical model of airflow within a small urban valley. M.Sc. Thesis (Meteorology), 163 pp.

(c) McMaster University, Department of Geography

- Bello, R. 1982. Evapotranspiration in greenhouses. Ph.D. Thesis, 112 pp.

- Gourlay, P. 1982. Near surface heat and water fluxes in different permafrost terrains. M.Sc. Thesis, 80 pp.
- McArthur, L.J.B. 1983. Measures and modelled solar radiation in an aerosol atmosphere. Ph.D. Thesis.
- Sawchuk, A.M.S. 1983. Application of the delta- D_M method for computing short-wave radiative fluxes in a vertically inhomogeneous atmosphere. Ph.D. Thesis.
- (d) Trent University, Watershed Ecosystems Program
- Pierson, D.C. 1983. The role of hydrologic and chemical processes in determining ion export from a low relief wetland watershed.
- (e) McGill University, Department of Meteorology
- Alvo, P. 1983. Feasibility study to measure differences in biomass production of large areas using aircraft-mounted sensors. M.Sc. Thesis.
- Dugas, B. 1983. Étude diagnostique de certains termes de l'équation du tourbillon stationnaire non-zonal selon les données de FGGE. M.Sc. Thèse.
- Gauthier, P. 1983. Ondes baroclines longues forcées par un échauffement local. M.Sc. Thèse.
- Gravel, S. 1983. Étude diagnostique de l'équation de thermodynamique pour la circulation globale asymétrique moyenne de janvier 1979. M.Sc. Thèse.
- (f) Université du Québec à Montréal
- Okossi, A.B. 1983. Méthode d'estimation du mouvement vertical à l'échelle synoptique. Mém. de maîtrise.
- (g) Université de Sherbrooke, Département de géographie
- Desrochers, J. 1983. La pollution de l'air dans la municipalité de Thetford-Mines: implications pour le comté et perception du risque pour la population. Mém. de M.Sc., 125 p.
- (h) Université Laval, Département de géographie
- Boutin, Y. 1983. Climatologie des extrêmes de pluie au Québec méridional. Thèse de maîtrise, 170 p.

VII OCEANOGRAPHY

Compiled by F.M. Boyce

1. Memorial University
2. Dalhousie University
3. Bedford Institute of Oceanography
4. Université du Québec à Rimouski
5. Centre Champlain des Sciences de la Mer, Pêches et Océans, Québec
6. GIROQ, Groupe Interuniversitaire de Recherches Océanographiques du Québec
7. McGill University
8. Marine Sciences and Information Directorate, Fisheries and Oceans, Ottawa
9. Bayfield Laboratory for Marine Science and Surveys, Burlington
10. National Water Research Institute, Burlington
11. National Water Research Institute, Western and Northern Region
12. National Water Research Institute, Pacific and Yukon Region
13. University of British Columbia
14. Institute of Ocean Sciences, Sidney, B.C.
15. Bibliography

1. Memorial University

(a) Centre for Cold Ocean Resources Engineering (C-CORE)

C-CORE has three research programs, a Radar and Remote Sensing Program, a Seabed Program and an Ice Properties Program.

The HF Technology Transfer Program was completed with a two station CODAR field project to map the surface circulation over the Ballard Bank at the southeast tip of the Avalon Peninsula. Ice cover was also mapped during the experiment. Similar work was undertaken in the Straits of Belle Isle during the summer. The Centre field-tested its HF wide aperture, narrow beam antenna which will be useful in testing the radar for the detection of sea ice and icebergs.

In the Seabed Program, the first phase of the iceberg-scouring study in the Davis Strait was completed. The Seabed Group also participated with the Atlantic Geoscience Centre in iceberg scour studies and seabed investigations on the Labrador Shelf. Research on hazards of iceberg scour, sediment transport, and erosion potential in the Hibernia area, northeastern Grand Banks was undertaken. Two new projects were initiated, a study of Quaternary sediments of the Hopedale Saddle, Labrador Shelf, and an initial evaluation of continental slope processes.

Within the Ice Properties Program new techniques and instruments to measure the mechanical properties of ice are being developed. These instruments were field-tested in the Beaufort Sea and off St. John's, Newfoundland. A detailed analysis of the ice sheet was conducted at Pond Inlet, N.W.T.

The project, Canadian Sea Ice Guide, will extract and compile available ice environment information relevant to loads on offshore structures and vessels. Information will be available in an online computer data base.

Two new projects in icebergs were initiated. The first is a study of their mechanical properties, and the second concerns the movement of bergy bits in waves.

2. Dalhousie University

Research interests at Dalhousie are concentrated on nearshore and continental shelf processes but there is increasing interest in the open ocean, and particularly in ocean mixing. A group from Dalhousie participated in the Canadian Coastal Sediment study which was sponsored and organized by Canadian Government agencies at a site near Pt. Sapin, New Brunswick. Data were collected with a tripod of flow-meters, a transmissometer, and optical back-scattering sensors. J. Haines is now examining the vertical structure of mean currents in and near the surf zone. C.S. Kim is studying wave groupiness and long-wave generation and reflection. D. Hanes, a Killam postdoctoral fellow, is studying sediment dynamics.

The program of research on sea-bed stress and sediment dynamics on the continental shelf is being continued. T. Chriss and D. Huntley are making detailed velocity measurements from 1 m to a few mm above the seabed. They are analysing data from a deep site on the Scotian Shelf. E. Bedell is studying boundary layer stresses under the combined influence of waves and currents using data from a coastal bay.

M. Mitchell, working at the Bedford Institute, is using measurements from moored instruments and from CTD's to estimate the importance to phytoplankton productivity of intrusions of water into a fjord-like bay. S. Waddell has developed a barotropic model for sub-tidal flows in the Canadian Archipelago. This model is revealing interactions between straits in the region. B. Toulany and C. Garrett have published their ideas on "geostrophic control" of fluctuations of the barotropic component of flows in straits. Garrett and F. Majaess find that sea level in the Eastern Mediterranean responds in a non-isostatic fashion to atmospheric pressure. They show that this behaviour is consistent with geostrophic control at the Straits of Gibraltar and near Sicily. Garrett, M. Bormans, and K. Thompson are attempting to explain the seasonal variability of the Mediterranean inflow. Garrett, Majaess and Toulany have used their frequency-domain multiple-regression programs to study how the response of the sea level at Nain, Labrador responds to atmospheric pressure and wind. They show that this response is not significantly affected by winter ice-cover and that it gives a clear indication of residuals that are not induced by meteorological forces.

J. Middleton, a research associate in the Department of Oceanography, is interested in the analysis of large-scale oceanic diffusion processes and oceanic turbulence. He is also comparing Eulerian and Lagrangian representations of flow, using both observations and theory.

A new venture by Garrett, Majaess, M. Hazen, and Middleton exploits the extensive data on iceberg trajectories collected on the Labrador Shelf by drill ships. They have shown that the data can be used to provide a statistical prediction of iceberg trajectories and to yield valuable information on tidal currents, wind effects, and Lagrangian and Eulerian statistics of meso-scale eddies.

K. Thompson has compiled a set of seasonal wind stress and Ekman upwelling maps, 1950-1980, as part of a study of the variability of the North Atlantic sea level and circulation. Biologists at Dalhousie are interested in relating this information to large-scale changes of plankton abundance and fish recruitment.

D. Kelley is developing a numerical model of an evolving thermohaline staircase in an effort to determine appropriate mixing parameterizations for oceanic use.

B. Ruddick is developing parameterizations of the effects of friction and double-diffusive mixing using theory, observations, and laboratory studies. He is collaborating with A. Bennett and C. Tang of the Bedford Institute on the analysis of Batfish data from the Warm-Core Ring cruise in the fall of 1981. Other projects involve theories of interleaving at fronts, friction in double diffusive systems, spindown of Mediterranean salt lenses, and salt-finger fluxes at low stability ratios. D. Hebert is working on the effects of friction on the Gulf Stream.

3. Bedford Institute of Oceanography

(a) Ocean Circulation Division

A major two-year study of eddy scale Gulf Stream dynamics has begun with the deployment of a five-mooring, 20-current meter, 75 km scale array in the Gulf Stream south of Nova Scotia. These moorings in conjunction with three other sets by Woods Hole will map the 75 to 150 km scale meandering and eddying within the upper and deep Gulf Stream. The moorings are to be replaced at the end of the first year and a hydrographic grid is being occupied over the mooring site at six-month intervals.

The year-long study of mixing and transport of heat and salt along and across the Polar Front in the south Labrador Sea was completed with the successful recovery of the four moorings placed across the North Atlantic Current and extensive mapping of the upper 200 metre temperature and salinity fields along the Polar Front from Flemish Cap to 50°N, 40°W. Initial results suggest that major intrusions of cold low-salinity waters into the North Atlantic Current system occur off Flemish Cap.

The study of the Labrador Sea continues with the publication of papers describing deep convection processes leading to renewal of Labrador Sea water. The long-term moorings sited in the Labrador Current are being maintained to further describe the interannual variations observed to date. Progress was made with the development of a diagnostic model of the Labrador Sea.

A program to study the general circulation in Baffin Bay was initiated with the deployment of four moorings within the boundary currents. Drogued drifters were released to provide Lagrangian information on surface currents. To date, their drift on the eastern boundary is quite different from the pattern that schematic pictures of the Baffin Bay circulation would have predicted.

There are several projects examining processes on the continental shelves. The study of the internal tide at the shelf break and its subsequent degeneration into short wave length, high amplitude internal waves continued with the completion of another field program in the Scotian Gulf and we now have a detailed description of the density and velocity field. Numerical models of the tidal rectification over topography have been advanced by a study of the details of the vertical velocity profile. The detailed study of tidal flow has been approached theoretically with applications to Georges Bank and southwest Nova Scotia. The work on the estuarine circulation in the Gulf of St. Lawrence continues with a comparison between field and model predicted variations in density.

Planning and instrument development continues in preparation for HEXOS, an international study of the humidity flux over the open sea. Pilot projects are to be completed over the next few years in advance of the major study slated for 1986. An in-depth re-evaluation of bulk formulas for incident short-wave radiation showed that existing formulas are not sufficiently accurate for proposed climate studies, including the commonly-used Budyko formulation. A revised formula based on data from Sable Island and Stn. P has been proposed for bulk calculations. Wave growth studies continue with improved instrumentation at selected sites offshore.

Work on a dynamic model of iceberg trajectory is progressing; analysis of archived data is completed and a field program was conducted to collect wind, current, morphology, and trajectory information for a number of selected bergs. The study of sea-ice dynamics and climatology in the Gulf of St. Lawrence and along the Labrador Coast has proceeded. An edited scientific data tape of archived AES ice observations is now completed. Statistical analysis and dynamic and thermodynamic modelling are underway. The group participated in the international field program MIZEX '83. Similar work near Greenland and Labrador is planned for next year.

The study of oceanic microstructure has continued to examine the relationship between temperature and velocity structure. Advances have been made in instrumentation required for planned field studies. Observations at depth, e.g. 1000 m, are now routine. Interaction with biological studies of productivity has been successful.

(b) Coastal Oceanography

Batfish data from the Warm-Core Ring Experiment have been analyzed to investigate mixing, interleaving and horizontal intrusion in the frontal region of a ring. Drifter data reveal the near-surface current pattern during the pinch-off of the ring.

Techniques for predicting properties of ocean currents near the Hibernia development site are under investigation, numerical and analogue models are under study and in-situ measurements of both currents and tidal elevations are being obtained. Numerical modelling of the Bay of Fundy/Gulf of Maine region continues and models are being developed for both the Scotian Shelf and Grand Banks.

Observational and modelling studies of tidal rectification in the vicinity of Cape Sable, Nova Scotia are continuing with the analysis of new data from a nearshore mooring (30 m isobath), where the effect is dominant, and with the development of a 3-D model for the structure of the tidal residual current. Field operations have also been carried out on Browns Bank as part of a joint fisheries and oceanographic experiment to study the ecology of haddock. Measurements with moored current meters and drogued drifters were used to determine the circulation on the Bank and surface-layer dispersion.

Wave studies of the seventies have been extended to include 1982 with the OCEAN RANGER storm in the analysis. It proved that 1982 was the year with the most severe seastate and 1970 the year with the least severe seastate of the thirteen-year period. Interannual variability and long-term changes are investigated on this time series. A three-dimensional energy model of the OCEAN RANGER storm was developed and built, at the request of the Royal Commission investigating the accident, to demonstrate the presence of two separate wave fields during the storm. For two hours, these two wave fields formed a ferocious sea which broke the porthole of the control room on the OCEAN RANGER, and lifted "green water" onto the helicopter platform of the nearby SEDCO 706, 21 m above mean sea level. Wave studies were also focused on the Sable Island area where Mobil Oil Canada Limited plans to develop the Venture gas field.

Environmental Impact Statements with wave studies of consultants were submitted for our critical review of the design properties.

(c) Chemical Oceanography

Trace element geochemistry investigations have involved increased emphasis upon the nature and inorganic composition of deep-ocean suspended particulate material at intermediate and extreme depths in the pelagic water column. An in-situ high volume pumping system, developed as part of the ocean technology program, is being used for these studies. In the nearshore, the exchanges of cadmium between aqueous, particulate and biological phases are being studied in intertidal areas of the North Sea in collaboration with Federal German institutions. This work complements coastal and estuarine geochemical and sedimentary investigations in the St. Lawrence estuary and other estuaries abroad.

Chemical oceanographic research in the Arctic was conducted at the CESAR Ice Camp and in Baffin Bay. At CESAR, the program was focused on the oxygen-nutrient-carbonate system with the goal of determining the origins of certain chemical features associated with particular water masses in the Arctic Ocean. Preliminary results suggest that shelf processes are important to the production of these features. In Baffin Bay, emphasis was placed on chemical processes occurring in sea-ice, on nutrient regeneration, and on residence times of deep water as determined by tritium concentrations.

Surveys of the chemical oceanographic conditions in the waters of the Labrador Shelf, northern Hudson Bay, and Hudson Strait have been carried out. These surveys will enable the completion of assessments of the incidence of low molecular weight hydrocarbons and petroleum residues in all eastern Canadian coastal areas. Low and uniform methane concentrations, and the absence of other light hydrocarbons, attest to the predominance of biological production as a source of these substances. No further evidence of natural hydrocarbon seepages, similar to those in the coastal zone of Baffin Island, have been found. Experiments are also being carried out to determine the rates and nature of geochemical alteration of Sable Island condensate in beach environments. Preliminary

results suggest that compositional alteration occurs considerably more slowly than might be anticipated from the limited literature on the subject.

Studies of surficial sediment composition on transects across the Scotian Shelf/Slope are being used to test the proposition that the upper Slope is a major area of recent organic matter deposition. Results to date indicate that the upper Slope has a hummocky topography and a mantle of sand and is not a primary depositional environment. Channels, some 400 to 500 metres in depth, which traverse the Shelf and Slope are the principal depositional areas. It therefore appears that the Scotian Slope is in an erosional phase of development and is not currently a site of major accumulation of organic matter, terrigenous or marine.

A study using inorganic and organic stable carbon isotope ratios to describe paleoclimates in Lake Melville has begun. Projects on sea-ice meltwater (using stable oxygen isotopes) in northern waters and on the cycling of organic carbon in the deep ocean continue. An examination of carbon isotope ratios in nearshore macroalgae, just completed, seriously questions the assumptions underlying the use of carbon isotope ratios as food-web tracers.

Further investigations of the distributions of radionuclides in the Arctic Ocean, including measurements of caesium-134, which will aid in determining the source of fission products, were included in the 1983 CESAR ice-island experiment following confirmation of a fission product anomaly at about 1500 metres depth in the Arctic Ocean during the 1982 FRAM III expedition. Studies of the geochemistry and vertical distributions of natural and artificial radionuclides in eastern North Atlantic sediments have been carried out collaboratively with U.S. and Dutch scientists as part of the Canadian contribution to the Nuclear Energy Agency's Research and Surveillance Program for Low-Level Radioactive Waste Dumping.

The environmental surveillance program associated with the Point Lepreau Nuclear Generating Station is now in its operational phase following the commissioning of the reactor. During the pre-operational phase, the incidence of both naturally-occurring and artificially-produced (nuclear weapons derived) radionuclides in various environmental media were determined and the ecological and oceanographic conditions in the adjacent marine environment were characterized. Current activities within the program include the selection and analysis of media that offer high signal-to-noise ratios for the detection of radionuclides released under normal operating conditions.

(d) Ocean Technology

Anemometers and thermistor chains for long-term, unattended operation on drifting buoys are being developed. First generation thermistor chains are going into routine use and a second generation system with salinity measuring capability is being considered. Fast CTD sensors and a dissolved oxygen sensor are being evaluated with a view to improving physical oceanographic parameter measurement. Substantial activity continues on biological sensor development, including a second generation vertical profiling pumping system with a servo-controlled winch for constant depth sampling and an optical zooplankton sensor designed to measure a wide size range of species. Analysis of engineering data is being carried out to answer both biological and engineering questions.

Applications of acoustic techniques to the study of the water column are being carried out with emphasis on the acoustic signature of internal waves and biological targets. Methods of digitizing and logging high frequency acoustic data have been developed and data obtained during the investigation of a dying warm ring will be analyzed. Acoustic positioning methodology is being used to study the behaviour of various oceanographic devices such as current meter moorings. New equipment is being acquired to improve the Institute's capability in mooring relocation, towed body positioning and sample site positioning. The use of acoustic doppler current profilers has become very prominent and engineering development is progressing rapidly.

Development of improved oceanographic moorings continues. During the 1983 field season losses were reduced to zero. Efforts are now being redirected toward creation of new mooring concepts. The use of servo-winch technology for heave compensation is being

expanded beyond its application to CTD's and new, streamlined instrument packages are being designed to exploit this technology. One such device is a mini-rosette water sampler and another is an in-situ particulate matter sampler. The latter will permit up to twelve large volume filtered samples from various depths to be collected under supervision from the surface.

4. Université du Québec à Rimouski, Département d'Océanographie (M. Arnac, J.-C. Brethes, J.R. Brindle, J.-P. Chanut, G. Desrosiers, J. Dionne, J.-F. Demais, M.I. El-Sabh, Y. Gratton, A.C. North, N. Khalil, J. Lebel, A Mucci, N. Silverberg, B. Sunby).

(a) Océanographie physique

Durant l'année 1983, nous avons poursuivi nos études sur la dynamique de circulation et le processus de mélange dans l'estuaire maritime et le golfe Saint-Laurent en utilisant une approche descriptive et théorique. Notre analyse récente des observations courantométriques prises en 1979 a montré le caractère complexe et la grande variabilité spatiale et temporelle du courant résiduel de l'Estuaire maritime (El-Sabh et al., 1982). L'analyse spectrale des mesures courantométriques montre que les basses fréquences dans l'Estuaire sont dominées par deux pics: l'un à 10-12 jours et l'autre à 70-80 jours. Le premier pic est associé au système météorologique (vents et pression atmosphérique). D'autre part, le deuxième pic est associé avec des séries de tourbillons cycloniques et anticycloniques avec une échelle spatiale de 50 km. À partir d'un modèle numérique simplifié, Lie et El-Sabh (1983) ont étudié les ondes côtières piégées, à basse fréquence, dans un chenal à 2 couches et de fond variable et ils ont appliqué les résultats à l'estuaire maritime du Saint-Laurent. On a trouvé que la caractéristique principale des tourbillons et courants transversaux peut être expliquée par la superposition des ondes barocliniques de plateau à longue période voyageant dans des directions opposées et qui sont vraisemblablement générées par les variations du débit d'eau douce. Des recherches ultérieures sont en cours présentement pour mieux comprendre la dynamique de ces tourbillons et courants transversaux.

La contribution spectrale des mouvements de basses fréquences (fréquences sub-inertielles) peut atteindre, dans certains cas, jusqu'à 40-50% de l'énergie cinétique observée dans le détroit de Georgie (Chang et al., 1976) et dans le Saint-Laurent (El-Sabh et al., 1982). La nature et les mécanismes générateurs de ces courants de basses fréquences sont encore mal connus. Ces mouvements semblent caractérisés par de grandes échelles temporelles, de courtes échelles spatiales et une intensification des mouvements de surface. Jusqu'à maintenant seules les ondes topographiques (Gratton, 1983) peuvent reproduire ces caractéristiques. Nous poursuivons donc l'étude des ondes topographiques de basses fréquences dans les eaux canadiennes. Les objectifs sont les suivants: 1) formuler la dynamique des mouvements de basses fréquences et reproduire les observations; 2) identifier leurs sources d'énergie; 3) découvrir l'importance des processus non-linéaires et l'influence des courants moyens.

Nous poursuivons aussi des travaux sur l'étude des équations du bilan d'énergie à une interface fluide, d'un point de vue phénoménologique et d'un point de vue tenant compte de la nature microscopiquement diffuse de l'interface et sur les couplages entre la circulation en surface et le régime des vents dans l'estuaire du Saint-Laurent.

(b) Océanographie chimique

Nous avons entrepris une recherche sur la contamination d'organismes par les métaux lourds dans le but d'utiliser les teneurs pour l'identification des stocks. Le but est de déterminer si des différences significatives entre les deux stations d'échantillonnage (Estuaire et Baie-des-Chaleurs) sont observées au niveau des variations des concentrations d'un métal donné en fonction du poids de l'animal, et ceci pour un organe particulier. Les mesures de contamination par les métaux permettraient d'ajouter certains éléments aux études électrophorétiques et à celles des matières organohalogénées déjà en cours, contribuant à élucider le comportement et les migrations de cette espèce. Les objectifs spécifiques sont les suivants: 1) étude organotropique: répartition des métaux dans les différents tissus (muscle, foie, gonades, peau); 2) variation des concentrations en fonction du poids de l'animal; 3) comparaison de ces variations entre les deux stations d'échantillonnage. Si, par exemple, deux populations de hareng constituent deux unités

distinctes, le séjour dans des zones ayant des caractéristiques environnementales différentes (au niveau de la pollution et des propriétés physico-chimiques) devrait se traduire par des phénomènes d'accumulations biologiques de ces métaux qui soient différents.

Nous poursuivons le même type d'études en examinant la bioaccumulation de composés organiques. Par une étude exploratoire, nous envisageons d'évaluer la présence de quelques produits halogénés et de comparer cette présence chez d'autres organismes identiques vivant dans d'autres milieux que le Saint-Laurent. Nous débutons avec le hareng sur lequel nous étudions les pesticides chlorés et nous le comparons avec du hareng du Pacifique et de l'Atlantique. Nous essayons par la suite de relier l'étude des matières organiques chlorées dans le milieu estuarien avec une étude en laboratoire sur la bioaccumulation d'une classe de produits halogénés soit les naphthalènes chlorés. Les naphthalènes chlorés sont utilisés dans l'industrie et leur mode de bioaccumulation ou biodégradation dans différents maillons de la chaîne alimentaire pose beaucoup de questions. Nous envisageons l'étude de quelques produits purs et de quelques mélanges sur deux zooplanctons différents vivant dans les eaux du Saint-Laurent. Nous essayons de vérifier l'hypothèse selon laquelle un naphthalène chloré n'est pas toxique sur du phytoplancton bien qu'il soit toxique chez les mammifères. Ceci explique notre choix du zooplancton, soit un maillon supérieur au phytoplancton. Ce dernier étant probablement un véhicule de transfert de ces matières organiques vers des niveaux supérieurs dans la chaîne alimentaire marine. Nous pensons que ces expériences nous aideront à comprendre le cheminement d'un naphthalène chloré dans la chaîne alimentaire.

Depuis l'été 1982, nous avons étudié la région de Baie-Comeau afin de déterminer la présence, la concentration et la distribution de polluants phénoliques. Nous comparons les concentrations observées à Baie-Comeau dans la colonne d'eau et/ou dans l'eau interstitielle avec celles observées dans les rivières et/ou estuaires Manicouagan, Godbout, Mistassini, ainsi que pour le fjord du Saguenay. Durant cette période, la mise au point d'une méthode d'analyse par chromatographie en phase liquide (HPLC) nous a déjà permis de mettre en évidence certains produits phénoliques dont le principal est la vanilline.

(c) Océanographie biologique

Une équipe du département s'intéresse actuellement à la dynamique des peuplements des sables fins terrigènes de la Moyenne Côte Nord du Golfe du Saint-Laurent (secteur des rivières Saint-Jean et Romaine). Dans les projets en cours, elle s'attache à définir l'influence des structures sédimentaires (bancs d'avant-côte) et de leur évolution sur la structure des peuplements benthiques en place. On a également cherché à observer l'effet de la crue sur un delta sub-tidal et les processus de recolonisation en postcrue, en parallèle avec des études temporelles sur un peuplement de même type moins affecté par les débits de rivière. L'équipe a également mis en place un projet qui étudie le comportement du crabe des Neiges (*Chionoecetes opilio*) en relation avec la pêche au casier appâté.

Un deuxième projet concerne l'étude de la structure du stock de harengs de l'estuaire du Saint-Laurent et de la Baie-des-Chaleurs. Les modèles de gestion des stocks du poisson donnent des résultats satisfaisants lorsque la structure d'un stock donné et les migrations de ses unités composantes sont bien connues. Nous analysons par électrophorèse les protéines de plusieurs tissus du hareng pour caractériser les unités de ce stock. Ce travail se fait en collaboration avec les travaux des chimistes sur le degré de contamination du hareng par les organohalogénés, les hydrocarbures aromatiques polycondensés et les métaux lourds. Nous espérons ainsi en apprendre davantage concernant le comportement et les migrations du hareng.

(d) Océanographie géologique

Plusieurs chercheurs du département oeuvrent en océanographie géologique, plus spécifiquement sur la biogéochimie des sédiments récents. Les sédiments marins, surtout ceux des estuaires où la capture du matériel en suspension est particulièrement efficace, constituent le réservoir final pour les substances naturelles et anthropogéniques relâchées dans l'environnement marin. Cependant, il est de plus en plus évident que de nombreux échanges se produisent entre le fond des océans et la couche d'eau immédiatement

au-dessus de sorte que ces substances peuvent être recyclées plusieurs fois entre le sédiment et la colonne d'eau avant que le piège se referme définitivement. Nous avons d'abord acquis une certaine connaissance de ce milieu et identifié un certain nombre de problèmes associés à l'étude des processus de la couche limite benthique; puis dans une seconde phase de ces recherches, nous avons voulu améliorer la compréhension des processus de la couche limite benthique dans l'estuaire et le golfe du Saint-Laurent. Ce travail impliquait: 1) la construction et l'utilisation de pièges à sédiment dérivants dans le but de recueillir et de mesurer la quantité, la taille et la nature des particules tombant à l'interface eau-sédiment; 2) la cueillette et l'analyse d'échantillons de la matière particulaire et de l'eau à la fois dans la colonne d'eau immédiatement au-dessus du fond et dans les premiers centimètres de sédiment pour mesurer la distribution et surtout les gradients de concentration d'un très grand nombre d'espèces chimiques, et 3) l'extension de cette approche globale à une variété d'environnements sédimentologiques lors d'une campagne d'échantillonnage d'envergure dans l'estuaire et le golfe du Saint-Laurent à l'été de 1981. Les résultats obtenus nous ont permis: 1) d'estimer les flux de plusieurs espèces à l'interface eau-sédiment; 2) de relier ces flux aux fonctions advectives telles que les taux de sédimentation, les teneurs et la nature de la matière organique et des éléments en trace du matériel sédimentaire, et 3) de déterminer l'effet de la bioturbation sur la composition du sédiment et les flux des substances.

D'autres études portent sur la diagénèse des sédiments. En particulier on étudie la stabilité de divers carbonates et la réactivité des argiles en eau de mer.

(e) Analyse statistique

Dans le cadre général de l'analyse statistique de données océanographiques, nos travaux portent essentiellement sur deux points: 1) l'analyse conjointe de plusieurs tableaux de données, méthode et applications; 2) l'échantillonnage optimal en océanographie. Nous avons abordé l'analyse conjointe sur le plan méthodologique par certains problèmes relatifs à la dualité entre deux représentations possibles de l'ensemble des points, au centrage des représentations graphiques, au choix de différentes métriques, et à l'usage de variables externes de type environnemental afin de faciliter l'interprétation des axes factoriels. Ces divers éléments méthodologiques ont été appliqués au moyen d'un programme de calcul, nommé STATIS, à des tableaux de données évolutives telles que: a) évolution de métaux en trace chez la moule bleue (*Mytilus edulis*) durant 18 mois; b) évolution de l'activité des enzymes digestives chez le zooplancton durant la floraison printanière et durant l'été; c) évaluation du transport de sédiments avec traceur radioactif le long du littoral. La réalisation d'un échantillonnage optimal en océanographie a nécessité d'écrire un programme de calcul sur ordinateur. Une version sur micro-ordinateur est en cours de réalisation afin de pouvoir optimiser une campagne d'échantillonnage en mer par rapport à un effort d'échantillonnage donné.

5. Centre Champlain des Sciences de la Mer, Pêches et Océans, Québec

(a) Océanographie physique

La seconde étape d'une étude de deux ans a été réalisée à Grande-Rivière de la Baleine, au sud-est de la baie d'Hudson. Les résultats de cette étude aideront à prédire l'impact de l'aménagement du Complexe hydro-électrique Grande Baleine sur les conditions physiques et la production de plancton de cette région côtière.

La Division d'océanographie physique a aussi participé à quelques campagnes océanographiques dans le cadre d'une étude sur le zooplancton dans l'estuaire du Saint-Laurent. L'analyse des données physiques a permis d'émettre certaines hypothèses intéressantes sur les mécanismes de distribution des euphausiides, espèce de zooplancton abondante dans l'Estuaire.

(b) Océanographie chimique

Le groupe de recherche en océanographie chimique a poursuivi diverses études sur la moule bleue dans le but d'améliorer son utilisation comme espèce indicatrice de la

pollution marine. Cet organisme se retrouve en quantité sur les côtes de l'estuaire et du golfe du Saint-Laurent et possède une grande capacité de concentrer les polluants.

Depuis 1978, la Division effectue des études sur la distribution et le comportement du mercure. Plusieurs projets ont été réalisés dans le fjord du Saguenay, milieu qui a été contaminé dans le passé par des rejets industriels de mercure. Cette année, les teneurs de mercure ont été mesurées dans les sédiments du fjord et tendent à montrer une perte significative de mercure entre 1978 et 1982. En outre, les résultats publiés sur la distribution du mercure dans l'estuaire moyen du Saint-Laurent indiquent que cette distribution est associée à l'abondance de particules en suspension dans cette partie de l'Estuaire.

Dans les années passées, les fleuves situés dans les régions industrialisées ont vu leurs teneurs en ions majeurs, en particulier en sodium et en chlorure, augmenter sensiblement. Une étude est présentement en cours dans le but de connaître l'état actuel du fleuve Saint-Laurent juste avant son estuaire. Cette étude s'effectue dans le cadre d'un programme international d'études sur les grands fleuves du monde.

Enfin, des travaux sur les métaux en traces et sur certains hydrocarbures contenus dans l'eau et les sédiments se sont poursuivis et une micro-méthode pour le dosage des traces de fer, de manganèse et de cadmium dans l'eau de mer a été mise au point et publiée.

(c) Océanographie biologique

Plusieurs projets de la Division d'océanographie biologique ont porté sur la quantité, la physiologie et la production du phytoplancton, plancton végétal. Entre autres, une campagne océanographique internationale s'est déroulée en septembre 1982, à bord du navire NSC Dawson et réunissait des scientifiques du Québec et de la France. Cette mission avait pour but l'étude de la croissance du phytoplancton dans la zone estuarienne du Saint-Laurent où se mélangent les eaux du fleuve et les eaux salées provenant du golfe du Saint-Laurent.

D'autres études avaient pour objectif de mieux comprendre les mécanismes qui permettent aux micro-organismes de vivre et de se développer dans les glaces. L'estuaire du Saint-Laurent et la baie d'Hudson ont été les régions étudiées. Le groupe de recherche a également accentué ses travaux sur le développement d'un modèle sur la croissance et la distribution des bactéries dans l'Estuaire.

Par ailleurs, les résultats des études sur le zooplancton du fjord du Saguenay, en particulier sur la répartition, ont été publiés. Les travaux exploratoires sur la distribution des euphausiides dans l'Estuaire se sont avérés un succès. Ce projet de recherche sera intensifié dans le futur et une nouvelle instrumentation sera mise à l'essai dans le but de mieux cerner les mécanismes de distribution de ces organismes.

Les données d'une étude sur la population des homards de lagunes des Îles-de-la-Madeleine ont été publiées.

6. GIROQ, Groupe Interuniversitaire de Recherches Océanographiques du Québec

Le GIROQ regroupe des chercheurs des universités McGill, Laval et de Montréal. En 1983 les activités du GIROQ en sciences physiques se sont déroulées dans le cadre des études menées dans l'estuaire et golfe du Saint-Laurent et dans les baies de James et d'Hudson.

(a) Estuaire et golfe du Saint-Laurent: analyse de la variabilité à long terme des caractéristiques des masses d'eau et de la circulation dans l'Estuaire maritime, principalement à la tête du Chenal Laurentien, à proximité de l'embouchure du Saguenay (R.G. Ingram, McGill); étude de la dynamique des fronts à petite échelle (R.G. Ingram, McGill); étude de la variabilité à court terme causé par les vagues dans l'Estuaire et golfe (A. Bah et Y. Ouellet, Laval); étude des mécanismes de transport de sédiment dans la couche suprabenthique dans l'Estuaire moyen (J.P. Savard et B. d'Anglejan, McGill); étude des interactions entre le polychète *Pista maculata* et son substrat sédimentaire dans

l'Estuaire moyen (J. Daignault et B. d'Anglejan, McGill); Formes du phosphore dans la matière particulière et les sédiments (M. Lucotte et B. d'Anglejan, McGill).

(b) Baie d'Hudson: étude des caractéristiques des masses d'eau et de la circulation dans l'Estuaire de la rivière Eastmain et à son embouchure dans la baie de James et effets de la réduction des débits d'eau douce (R.G. Ingram, et S. Lepage, McGill); étude du régime sédimentaire de l'Estuaire de la Rivière (B. d'Anglejan et J. Basmadjian, McGill).

(c) Baie d'Hudson: étude de la circulation et des caractéristiques des masses d'eau du détroit de Manitounuk et de l'embouchure de la Grande-Rivière de la Baleine dans l'hiver (R.G. Ingram et J.C. Deguise, McGill).

7. McGill University, Institute of Oceanography

(a) Current research focuses on modifications occurring in estuarine dynamics as a result of both natural and man-made changes. Amongst the effects considered are the imposition of an ice cover, changing freshwater input both from climatic variability and hydro-electric development and altered sources of suspended matter, nutrients and other properties. The areas selected for this study include Hudson and James Bay as well as the St. Lawrence River.

Hudson Bay: In the past year, current meters were moored at 12 stations over a wide coastal area near Great Whale River. Seven temporary sites were erected for high frequency current meter profiling, echo-sounding and CTD sampling. Although detailed analysis of the results from both 1982 and 1983 is still underway, a data report has been prepared (Ingram and Deguise, 1982), as well as an article published (Ingram, 1983) on the salinity data obtained in the first three weeks of the 1982 experiment. The shape and size of the plume was much different than in previous years. Simultaneous current meter observations in both the brackish and ambient waters showed a variation in the under-ice boundary layer thickness and in the upward salt transport over the fortnightly cycle in Manitounuk Sound. Pycnocline characteristics in Hudson Bay differed as a function of the velocity shear between the expanding plume water and the ambient circulation. The marked changes observed in the plume may result from modification of the coastal current in Hudson Bay because of a major increase in fresh water input from La Grande River.

James Bay: Emphasis over the past three years has focused on the response of the Eastmain River estuary to a permanent cut of over 90% in fresh water discharge. Variability of salt and circulation on both short (weeks) and large (months-years) time scales have been treated and found to differ substantially (Ingram, 1982).

The observed response of the estuary includes modification of the tidal and mean circulation as well as a major upstream salinity intrusion. The tidal height curve has been modified by amplification of the higher frequency components. This resulted in a major change of the tidal current regime and affected both sediments and primary production in the estuary.

Previously reported studies of circulation in the St. Lawrence estuary and the Avalon Channel region were continued this past year. Emphasis was placed on analysis of existing data sets.

b) A study of the chemical partition of phosphorus between the organic and inorganic phases of the seston in the St. Lawrence upper estuary was completed. The monitoring of sedimentological changes in the Eastmain estuary following river cut-off two years ago was continued.

8. Marine Sciences and Information Directorate, Fisheries & Oceans, Ottawa

The Ocean Science Affairs Branch provides a focus for the establishment of national and international policies, programs and priorities for the oceanography program of the Department of Fisheries and Oceans. In 1983, staff participated in such activities as the Energy R&D program, the Canadian Climate program, the Northern Oil and Gas Action Plan, the Environmental Studies Revolving Fund, etc. In addition the branch provided the national coordination for the DFO environmental position statements, inter alia, on the

Beaufort Sea Hydrocarbon Production Proposal and the Venture Development Project (Sable Island). The Canadian input of real-time subsurface temperature and salinity data to the Integrated Global Ocean Services System (IGOSS) was increased from practically zero, in the first half of 1983, to 500 messages in the latter half. The aircraft-deployed Fluorescence Line Imager, which has been developed under contract to monitor chlorophyll a concentrations as a measure of phytoplankton distributions, is now undergoing acceptance trials, and plans are being made for applications in 1984-86. A contract was let for the Adams Island ice deformation study being carried out by the Division of Building Research (NRC) to determine Arctic sea-ice forces against fixed structures. Work was completed on James Bay river plumes and the Bay of Quinte flow exchanges.

The Marine Environmental Data Service (MEDS) archives oceanographic data collected around Canada, including the northeast Pacific, Arctic, and northwest Atlantic oceans. The Canadian Marine Data Inventory continued to expand in 1983 and now contains more than 9800 references to data sets in eleven different scientific categories. In addition to its ongoing wave climate studies, MEDS also contracted for a review of extreme wave conditions and shallow water wave calculations in the Beaufort Sea.

The Scientific Information and Publications Branch (SIPB) provides the national focus for fisheries and oceans scientific and technical information. It produced and distributed about 12,000 printed pages last year including the widely-read monthly Canadian Journal of Fisheries and Aquatic Sciences. SIPB is also the input centre for the Aquatic Sciences and Fisheries Information System sponsored by Food and Agriculture Organization/Intergovernmental Oceanographic Commission.

9. Bayfield Laboratory for Marine Sciences and Surveys, CCIW, Burlington, Ontario

Most of the oceanographic program at the Bayfield Laboratory (Arctic oceanography and ocean technology) has been transferred to other regions. Research continues, however, on the classification of sea-ice by radar (E. Lewis). Development work in hydrographic surveying is also underway and includes testing of a system for continuous sounding through an ice cover (G. Macdonald). The work includes a program for the development and testing of tide gauges (B. White).

10. National Water Research Institute, CCIW, Burlington, Ontario

Physical limnology research at the National Water Research Institute is carried out by two Divisions, the Aquatic Physics and Systems Division, and the Hydraulics Research Division. The former deals with the observations, theory and simulation of water movements in large lakes and the optical properties of lake waters. A program of environmental simulation links physical studies with biological and chemical research carried out at the Institute. The latter deals with riverine problems such as sediment transport and flow in ice-covered rivers, as well as air-sea interaction, shore erosion, design of breakwaters, and scale model studies. An engineering component of the Hydraulic Research Division participates in instrument development.

(a) Physical Limnology

The major study of circulation of the Central Basin of Lake Erie, begun in 1979, and shared with the Great Lakes Environmental Research Laboratory (NOAA, Ann Arbor, Michigan) is being completed with a final report (special issue of the Journal of Great Lakes Research) due in late 1984 (F.M. Boyce). Major circulation patterns in the Central Basin are surprisingly changeable and it is thought that topographic controls operative in the other deeper lakes are ineffective in the relatively featureless Central Basin. Other results of this study include examinations of the heat and momentum balances at a mid-lake site (L. Royer), documentation and simulation of entrainment from the thermocline into a turbulent hypolimnion, combination of deterministic models with statistical techniques to select optimum wind-drag coefficients (P.F. Hamblin, W.P. Budgetell), and a general assessment of the bottom flow with regard to sediment resuspension and hypolimnetic oxygen depletion (F.M. Boyce).

Data from current meters and thermistor chains installed along the north shore of Lake Ontario and on transects across the lake during stratified and unstratified conditions have been used in a study of the large-scale circulation of enclosed basins (T.J. Simons). This study has confirmed the presence of topographic Rossby waves in Lake Ontario. Attempts to simulate the observed circulations using numerical models indicate a degree of ambiguity in the latter; equally good simulations can be obtained with different mixes of parameters. It is suggested that the sea surface slope should be treated as a variable to be observed rather than to be inferred from the wind stress and a version of the tidal equations.

Growing concern that the Niagara River is a major source of toxic contaminants to Lake Ontario has prompted a multidisciplinary study of the river plume as it enters the Lake (C.R. Murthy). Observations from current meters, CTD probes, and drogues have been used to delineate the physical features of the plume and to provide verification data for numerical simulations. Models of the Niagara River plume have been developed from this data base (D.C.L. Lam).

A collection of temperature profiles from Lake Ontario spanning 20 years has proven to be useful to a feasibility study of piping cool deep water from the lake to the downtown Toronto office core for air-conditioning purposes (F.M. Boyce). The same data have been used in support of a study of the coho fishery by the Ontario Ministry of Natural Resources.

An extension of the successful DYRESM family of reservoir models is being developed for lakes with seasonal ice-cover (P.F. Hamblin). This same model is being applied to Kamloops Lake in B.C. and to Lake Laberge in the Yukon Territory. An experimental and theoretical study of thermally induced circulation in lakes near the temperature of maximum density has been carried out.

Tests of five commercially available types of current meters were conducted in order to choose a replacement for the Institute's obsolescent Plessey meters (J. Bull, Valdmanis). Test results will be available on request. Instrumentation development continues with a replacement for the standard NWRI meteorological buoy, preliminary development of a benthic boundary layer system, and field trials of a technique for the direct measurement of sea surface slope.

(b) Environmental Simulation

Numerical hydrodynamical models and the mass balance approach form the backbone of these endeavours to account quantitatively for the distributions of nutrients, toxic substances, etc., in the environment. This work is valuable in assessing trends in water quality parameters and in identifying gaps in our understanding of how lakes behave as integrated physical and biochemical systems.

A report has been published recently on the simulation of water quality variables in Lake Erie (D.C.L. Lam). This work is parallel to the experimental program described above. The report offers convincing evidence that year to year variability of winds and surface heat flux cause a comparable variability in at least one of the important water quality variables, the dissolved oxygen content of the Central Basin hypolimnion. The evaluation of water quality management options thus must include a stochastic component.

A simulation of the effects of acid precipitation on a Canadian Shield watershed is underway (D.C.L. Lam, A.S. Fraser, M.E. Thompson). This study includes both groundwater flows and soil chemistry, and is being operated in parallel with a field program.

Several techniques for the simulation of outfall plumes have been developed and applied to cases such as the dispersion of radioactive material from a nuclear power generating station, and the fate of the Niagara River plume (D.C.L. Lam). These schemes incorporated the observed "acceleration" of diffusion related to the plume or patch size.

Simulation models are being used to explore possible interactions of toxic substances with receiving waters and sediments (E. Halfon).

(c) Environmental Optics

This group makes measurements of the underwater light field and the optical properties of the water itself (J. Jerome). The possibilities of the "remote sensing" of water quality parameters such as chlorophyll are assessed in view of other components affecting optical properties such as fine-grained sediments.

A report has recently been issued relating the colour of lake water to sediment load, chlorophyll, and other organic materials. (R. Bukata).

(d) Shore Processes

The work of the Shore Processes Section is concentrated in the areas of wind-generated waves and shore evolution. In wave research, fundamental questions of air/water interaction are addressed, such as the process of wave amplification and attenuation by wind (M.A. Donelan, M. Skafel). Shore evaluation investigations are undertaken in several disciplines. Field studies include work on nearshore sediment transport and profile changes and on bluff failure (J. Coakley, A. Zeman). Erodibility of soils and the efficiency and design of low-cost shore protection are studied in the laboratory. Shore resources and geological influences are documented and examined by conducting surveys and by interpretation of nearshore sediment, primarily in the Great Lakes (N. Rukavina). In addition, there is active technology transfer; coastal engineering studies are undertaken for clients under the cost recovery policy and site-specific reports on nearshore sediments are prepared in response to requests (C. Bishop).

(e) Environmental Hydraulics

This section conducts research in open-channel hydraulics, river ice engineering and urban water resources. Major efforts were devoted to the study of flow in mobile bed channels. An experimental study of meander formation showed that meanders form even in laminar flows thus challenging the popular hypothesis that turbulence-driven secondary circulation is the cause (B.G. Krishnappan). The effects of ice cover on sediment transport and bedforms in rivers have been investigated by both experiments and numerical models (L. Lau, B.G. Krishnappan). Field observations, laboratory experiments, and theoretical studies were carried out on ice jams in rivers with particular emphasis on conditions at breakup (S. Beltaos). An instrument for measuring concentrations of frazil ice in water has been successfully developed and tested and a commercial version is likely (G. Tsang). The effect of salinity on the formation of frazil ice was studied (G. Tsang).

11. National Water Research Institute, Western and Northern Region

Research is continuing on the physical limnology of large shallow lakes in the prairies where interest is focused on turbulent mixing, resuspension of sediment and nutrients, and the entrainment of transient thermoclines.

Work is also continuing on simulation of nutrient levels in lakes. It has been shown that phosphorus is a dynamic variable and the use of the assumption of static equilibrium is inadequate and/or incorrect. The simulation of time-varying phosphorus concentrations for Lake Washington from 1962 to 1978 provided substantial insight into the effects of the 1972 and 1975 floods. The simulation of phosphorus concentrations in the four Qu'Appelle Lakes required extension of the dynamics concept to account for high prairie evaporation, precipitation and variable lake levels. It was found that three time scales were necessary for dynamic description of this chain of four lakes.

Changes in South Indian Lake following impoundment for hydropower are being studied using water and nutrient budgets from an adjoining bay, Long Bay. Vertical temperature profiles along the bay axis show horizontal gradients in the inverse stratification that suggest the presence of an under-ice circulation. Temperature fluctuations accompanying the two layer flow are intense and show large changes in the thermal structure over a short period. A low velocity current meter was designed to measure the flow in the narrow channel joining Long Bay to South Indian Lake. Currents in excess of 1 cm/s were found. Winter circulation could dominate the water renewal time in the bay with concomitant impact on budget studies.

12. National Water Research Institute, Pacific and Yukon Region

The Pacific and Yukon Regional Branch of NWRI, located in West Vancouver, B.C. conducts applied research related to regional water management problems. The goal is to predict the ecological sensitivity and response of lakes and rivers in the region to changes in environmental stresses such as nutrient loadings, industrial waste discharges, mining wastes, hydroelectric development, and water diversions. An experimental attempt is being made to understand the dynamic processes affecting intra-lake sediment transport and deposition in Lake Laberge and in Kluane Lake (C. Pharo). A study is being undertaken to document and interpret the seasonal ice cycle from the point of view of lake-river interaction. Its objectives are to describe the ice dynamics of an upstream river, the influence of that river on the ice cover and thermal structure of a recipient lake, and the effects of lake outflow on ice conditions in a downstream river (E. Carmack, G. Gray). This study is linked to the ice-cover thermal structure model under development at NWRI, Burlington. The study site is the Yukon River from Whitehorse to Lake Laberge.

13. University of British Columbia, Department of Oceanography (W.J. Emery, M. Ikeda, K. Tomason, L. Royer, A. Thomas, L.A. Mysak, G. Mertz, G. Swaters, P.H. LeBlond, B. Sanderson, J. Cherniawsky, J. Moum, L.C. Wang, R. Ninnis, S. Pond, T. Yao, A.J. Webb, R.W. Burling, D. Dunbar, S.E. Calvert, C.J. Jones, R. François, A. Losher, T.F. Pedersen, K. Perry, E.V. Grill, R.J. Andersen, K. Gustafson, C. Pathirana, S. Ayer, I. van Altena, G. Boyer, K.P. Hamilton).

(a) Physical Oceanography

A numerical simulation of circulations in Burrard Inlet and Indian Arm is underway. Techniques are based on those developed by P.B. Crean (IOS) for the larger Juan de Fuca - Strait of Georgia system. Present work is on an extension beyond the present stage of tidal simulations to stratified estuarine flows. Studies of topographic control of flow in the mouth of Lancaster Sound and of lateral diffusion from iceberg tracks in the same area are continuing. Lagrangian methods have been applied to the study of non-linear internal waves. Analytical solutions have been developed for semi-geostrophic flow around corners into a channel representing Hudson Strait. A study of dissipation, as measured by a free-falling shear probe, and its relation to stability and shear in the equatorial region, is nearing completion. The spatial transfer function of the airfoil shear probe, utilizing laser doppler anemometry, has been evaluated. A study of seiches in small bays along Juan de Fuca Strait in relation to possible edge wave propagations has started. Long distance correlations of wave groups are being made from wave rider data in the Hibernia area. Analysis of data from long time series of surface salinity in the Strait of Georgia has been extended to demonstrate the agreement between salinity and its prediction by a wind- and discharge-driven model of the Fraser River plume. A study of circulation in the Alaskan Gyre is continuing and satellite-tracked buoys have now been drifting in that area for over two years. A four-layer non-linear model of baroclinic instability in a coastal current has been developed and successfully compared with satellite imagery of the B.C. coast. Satellite data from polar-orbiting weather satellites are now being regularly received and processed. Present projects extend the study of these images to the California coast and the Canadian Arctic. Studies of multiship XBT surveys (with D. Krauel, Royal Roads) are continuing in an effort to document the properties of mesoscale phenomena across the North Atlantic and Pacific. A theory for the generation of annual-period baroclinic Rossby waves in the North Pacific has been developed in which the vorticity source for the waves is generated by the north-south fluctuations in the eastern boundary current off Vancouver Island and Washington. A theory for elliptical topographic waves in a stratified lake has been developed and applied to the Lake of Lugano, Switzerland, where pronounced 3-day temperature oscillations have been observed. A study of topographically-induced baroclinic eddies has been completed in an attempt to explain the frequent occurrence of the Sitka Eddy in the Gulf of Alaska. A comparison of low-frequency current observations off B.C. (Winter 1981-82) with coastal trapped wave theory has been made. Calculations were made of the effect of biennial mean wind variability on the excitation and propagation of the semidiurnal atmospheric tide. The predicted biennial variation in the tidal oscillation was discovered in an analysis of long records of hourly barometric observations at several stations. Cyclesondes (internally-recording profiling current meter/CTD systems) continued to be used to explore the vertical structure of the velocity

and density fields in B.C. waters. Two instruments were deployed in Indian Arm from December 1982 to April 1983 and four instruments were moored in Knight Inlet in July and August 1983. Analyses of the extensive data recovery is continuing. Two instruments will be deployed in Indian Arm from November 1983 to April 1984.

(b) Chemical Oceanography

Studies of the geochemistry of the sediments of oxic and anoxic B.C. coastal inlets are continuing. Methods are being developed for identifying trace metal-organic associations and for partitioning metals between sediment phases. Studies of the geochemistry of molybdenum mine tailings into Alice Arm, B.C. and of copper-molybdenum mine tailings in Rupert Inlet, B.C. are designed to examine the post-depositional mobility of metals in the sediments. A study of the geochemistry of Powell Lake, B.C., a meromictic former fjord lake containing permanently anoxic sulphide-rich relict sea water, has started. Palaeo-geochemical studies of eastern equatorial Pacific sediments are continuing in collaboration with N.J. Shackleton (Cambridge). Investigation of the metals and halogens in sediments and interstitial waters in the Guatemala Basin and at 21°N on the East Pacific Rise continues. Studies of the chemistry and mineralogy of ferromanganese nodules and associated sediments from two DOMES (Deep Ocean Mining Environment Study) sites in the northern equatorial Pacific are continuing (with D.Z. Piper, US Geological Survey and D.J. Huntley, Simon Fraser University). At one site, nodule compositions are clearly related to the patterns of sedimentation and the surface texture of the nodules and a new theory has been developed to explain these relationships. Studies of the composition and age of phosphorite concretions on the Namibian shelf (with J. Thomson, I.O.S. (U.K.)) have been completed. Studies of the geochemistry of modern and ancient sepropels from the eastern Mediterranean have shown that they were most likely formed during increased production rather than anoxia in the basin of deposition. New leaching techniques are being applied to the hydrothermal sediment of the Juan de Fuca Ridge in an attempt to identify particular hydrothermal phases and to study major and trace element associations with these phases. During a cruise to the ridge area with PISCES (with V. Tunnicliffe, U. Victoria, S. Scott, U. Toronto and J. Delaney, U. Washington), a new hydrothermal vent was discovered on a seamount sitting astride the ridge. Further work is planned in the area, using submersibles and surface vessels, in 1984. Studies of marine natural product chemistry are continuing. Compounds isolated from nudibranchs, soft corals and starfish have been identified and, in some cases, synthesized. A siderophone, prorocentrin, has been successfully isolated from the dinoflagellate, *Prorocentrum minimum* and partially characterized.

14. Institute of Ocean Sciences, Sidney, B.C.

(a) Coastal oceanography studies in Observatory Inlet and Alice Arm were continued. Tidal height, CTD and current velocity data were used to examine tidally-driven circulation. A theoretical model and current velocity data show that much of the power from the barotropic tide is being transformed, through interaction with the sill, into a progressive internal tide. Deep-water exchange was shown to be less intense during the 82-83 winter than during 81-82. Density fluctuations, coherent with the low-frequency currents, appear to control the timing of the deep-water renewal events in Alice Arm.

Data acquired between 1979-80 during the Coastal Ocean Dynamics Experiment (CODE) continue to produce results. An analysis of the statistical structure of oceanographic fields on the continental shelf demonstrates how dynamical constraints affect structure. Current and water property measurements collected during CODE reveal the formation of a mesoscale baroclinic eddy off the central coast of Vancouver Island in the fall of 1980. The eddy core was characterized by near-surface currents of 50 cm s^{-1} , a radius of 50 km and mid-depth isopycnal displacements of 59 m.

Current meter observations acquired from several recent discrete experiments have been merged and analyzed. The resulting synthesis describes the general current regime off the west coast of Vancouver Island and in Queen Charlotte Sound.

A detailed study of barotropic and baroclinic continental shelf waves of diurnal period off the west coast of Vancouver Island was completed. Results suggest that the

large amplitude shelf waves consist primarily of first-mode baroclinic oscillations that are significantly modulated by seasonal variations in the prevailing alongshore current over the continental shelf and slope.

A study of the circulation and long-wave propagation along the 300 km west coast of the Queen Charlotte Islands was begun. This will be known as the North Coast Oceanic Dynamics Experiment (NCODE).

A program to measure ocean currents in Hecate Strait was started. This will be part of a multi-year plan to study the circulation in the waters surrounding the Queen Charlotte Islands.

Interpretation of the 1979 early winter hydrographic data from the Beaufort Sea was completed. Principal findings involved haline circulation on the Mackenzie Shelf and Slope driven by wintertime freezing, a systematic modification of Atlantic water temperatures near the continental margin and an improved knowledge of ocean circulation in the area.

Analysis of water level, water structure and current velocity data has provided information on surface current patterns in Prince of Wales Strait and Viscount Melville Sound and an understanding of the upward flux of heat from the Atlantic water in the region. This flux warms the sub-surface water of the Northwest Passage which, when brought to the surface over sills in the central Archipelago, contributes to the formation of polynyas or areas of thin, unstable sea-ice covers.

A program of water height measurement along the Canadian Arctic Continental Shelf was continued in cooperation with the Canadian Hydrographic Service. The analysis of data acquired north and east of Spitsbergen in the spring of 1981 was completed. Preliminary analysis of data acquired in the McMurdo Sound area of Antarctica in the fall of 1982 was completed. CTD surveys were run northward from the coast of Ellesmere and Axel Heiberg Island out to the CESAR camp with an additional section joining them at the CESAR latitude running from the Makarov Basin to the Canada Basin. Of note is the extensive double diffusion indicated by a step structure in the Arctic thermocline which gradually becomes more diffuse near the coast.

Ocean mixing studies continued with the building of a prototype microscale profiler (FLY). Measuring pressure, temperature and dissipation-scale velocity shear, the profiler can be adapted for profiling very close to the bottom. A critical evaluation has been made of various methods used to derive the vertical eddy diffusivity assumed to characterize turbulent transport of mass across isopycnals in a stratified fluid.

Work in acoustics included the study of ambient noise in the ocean at higher frequencies for its potential in the remote sensing of processes at the air-sea interface. Measurements taken in Queen Charlotte Sound have confirmed that wind-noise relationships found in the deep ocean also apply on the continental shelf. They also demonstrated the possibility of separating the noise due to precipitation from the noise due to wind. The forward scatter of sound over short path lengths is being explored for its potential in remote sensing of flow speed and microstructure across tidal channels. Simultaneous velocity and temperature microstructure measurements are being obtained for comparison with the acoustic data.

(b) Ocean climate monitoring studies continued with two cruises along Line P and three other lines between the Canadian west coast and Station P. Observations relating to the 1982-83 El Nino-Southern Oscillation (ENSO) event revealed increased sea-surface temperatures, with a corresponding rise in mean sea level, especially between December and March.

In conjunction with the Australian Institute of Marine Sciences (Townsville), current and temperature data were collected over six months from a Great Barrier Reef location. These data show that tidal motions lead a pronounced upwelling of cold nutrient-rich continental shelf water on to the reef. The seaward eddy heat flux at the outer reef showed correspondence to onshore fluxes of nitrate, phosphate and silicate. Upwelling mechanisms were also studied.

In cooperation with Australian and U.S. agencies, IOS is participating in the Australian Coastal Experiment (ACE) to determine whether the oceanography of the continental shelf is controlled by the physics of shelf waves.

Studies of two-dimensional turbulence included a theoretical investigation of the ability of turbulence to impress its characteristic scales upon phytoplankton concentration, leading to patchiness and the comparative roles of the enstrophy subrange and the large-scale eddies in the relative dispersion of oceanic and atmospheric drifters.

Inverse theory was used in various situations; e.g. to estimate the efficiency of an array of seafloor-mounted pressure gauges and to determine individual interannual variations for which statistical information is available.

(c) Improved barotropic tidal calibration and simulation of tidally induced residual currents has been achieved in joint studies with University of Hamburg. A higher resolution (2 km mesh), vertically-integrated barotropic model (regional) of mixed tides has been developed and work is continuing on the development of a buoyant-spreading upper layer model of the shallow plume formed by the tidally-modulated Fraser River discharge. A storm surge flood delineation study for Tuktoyaktuk and environs and an examination of the influence of ice cover on long gravity waves such as tides and storm surges were undertaken. A regular grid linear finite difference model was used with an inverse model to provide satisfactory M_2 cotidal charts for Hecate Strait. Papers were prepared dealing with storm surges, tides and oil slicks in the Bay of Bengal, Gulf of Oman and Arabian Gulf for U.N. agencies and advice on field programs required to improve storm surge prediction was supplied. Work continued on computer simulation of tidal motion in the Fraser River. The "Current Atlas of Juan de Fuca and the Strait of Georgia" was published.

(d) Work continued on the fluorescence line image sensor being built for IOS to map sea surface phytoplankton concentrations and flight tests were carried out. A collection of visible and thermal imagery of Hecate Strait, Dixon Entrance and the west coast of Vancouver Island is being rectified using new OVAAC-8 software. An airborne water colour survey in the western Arctic was carried out in order to compare the whale distributions with silt and phytoplankton distributions.

15. Bibliography

- Alzieu, C., Bewer, J.M. and Duinker, J.C. 1983. Administrative Summary Report of the ICES Fifth Round Intercalibration for Trace Metals in Seawater (5/TM/SW). ICES Report CM 1983/E:28, 4 pp.
- Anderson, L.G., Dyrssen, D.W., Jones, E.P. and Lowings, M.G. 1983. Inputs and outputs of salt, fresh water, alkalinity, and silica in the Arctic Ocean. *Deep-Sea Res.* 30, 87-94.
- Anderson, N.R., Bewers, J.M. and Palmork, K.H. 1982. Introduction and Executive Summary. In: Scientific Report of the Intercalibration Exercise of the IOC/WMO/UNEP Pilot Project on Monitoring Background Levels of Selected Pollutants in Open Ocean Waters. UNESCO Press, 4-7.
- Ayer, S.W. and Andersen, R.J. 1983. Degraded monoterpenes from the opisthobranch mollusc *Melibe leonina*. *Experimentia*, 39(3), 255-256.
- Barrie, J.V. 1983. Sedimentary processes and the preservation of iceberg scours on the eastern Canadian continental shelf. In: Proceedings of the 7th International Conference on Port and Ocean Engineering under Arctic Conditions (POAC 83) Helsinki, Finland, April 5-9, 1983, Vol III.
- Barron, J.L., Dyrssen, D.W., Jones, E.P. and Wedborg, M. 1983. A comparison of computer methods for seawater alkalinity titrations. *Deep-Sea Res.* 30, 441-448.
- Bell, W.H. 1983. Turbulence vs drag - some further considerations. *Ocean Engineering*, 10(1), 47-63.

- Bennett, A.F. 1983. Predictability and frontogenesis. In: Predictability of Fluid Motions, G. Halloway and B.J. West (Editors), American Institute of Physics, New York.
- Bennett, A.F. 1983. The South Pacific including the East Australian Current. In: Eddies in Marine Science, A.R. Robinson (Editor), Springer-Verlag, 219-344.
- Bennett, A.F. and Haidvogel, D.B. 1983. Low-resolution numerical simulation of decaying two-dimensional turbulence. *J. Atmos. Sci.*, 40, 738-747.
- Bennett, A.F. and Leslie, L.M. 1983. Statistical correction of dynamical prognosis: the decision problem. *Monthly Weather Review*, 111, 344-352.
- Bennett, A.F. and Middleton, K.H.F. 1983. Statistical mechanics of a finite-difference approximation to the barotropic vorticity equation. *Quarterly Journal*, Royal Meteorological Society, 109.
- Benoit, J.R. and Mungall, J.C.H. 1983. Proceedings of the 1982 Grand Banks Current Workshop. Canadian Technical Report of Hydrography and Ocean Sciences, No. 28, iv + 43 pp.
- Berman, S.S., Myktytiuk, A.P., Yeats, P.A. and Bowers, J.M. 1983. ICES Fifth Round Intercalibration for Trace Metals in Seawater. ICES 5/TM/SW (Section 3) Preliminary Report. ICES Report CM 1983/E:24, 33 pp.
- Bowers, J.M. 1982. Cadmium in the marine environment - an overview. In: Report of the Advisory Committee on Marine Pollution. ICES Cooperative Research Report No. 112, 51-56.
- Bowers, J.M. and Duinker, J.C. 1983. Methods of assessing gross riverine discharges of trace metals and organohalogenes into the marine environment. In: Report of the ICES Advisory Committee on Marine Pollution, 1982. ICES Cooperative Research Report No. 120, 60-72.
- Bowers, J.M. and Windom, H.L. 1982. Trace metals. In: Scientific Report of the Intercalibration Exercise of the IOC/WMO/UNEP Pilot Project on Monitoring Background Levels of Selected Pollutants in Open Ocean Waters. UNESCO Press, 8-59.
- Bowers, J.M. and Windom, H.L. 1983. Intercomparison of seawater sampling devices for trace metals. In: Trace Metals in Sea Water, Plenum Publishing Corporation, 143-154.
- Bowers, J.M. and Yeats, P.A. 1983. ICES Fifth Round Intercalibration for Trace Metals in Seawater. ICES 5/TM/SW. Report of Section 1: Comparison of Filtration Procedures. ICES Report CM 1983/E:18, 21 pp.
- Bowers, J.M. and Yeats, P.A. 1983. Transport of metals through the coastal zone. International Council for the Exploration of Sea Cooperative Research Report No. 118, 146-163.
- Bezanson, D. and Kranck, K. 1982. Near-bottom sediment suspensions measured by sediment trap. In: Report on Ocean Dumping Research and Development Atlantic Region 1980-81. Environmental Protection Service and Department of Fisheries and Oceans, Environment Canada Surveillance Report EPS-5-AR-82-1.
- Birch, J.R., Fissell, D.B., Lemon, D.D., Cornford, A.B., Herlinveaux, R.H., Lake, R.A. and Smiley, B.D. 1983. Arctic data compilation and appraisal, Volume 5, Baffin Bay: physical oceanography - temperature, salinity, currents and water levels. *Can. Data Rep. Hydrogr. Oc. Sci.*, No. 5, 372 pp.
- Birch, J.R., Fissell, D.B., Lemon, D.D., Cornford, A.B., Lake, R.A., Smiley, B.D., Macdonald, R.W. and Herlinveaux, R.H. 1983. Arctic data compilation and appraisal, Volume 3, Northwest Passage: physical oceanography - temperature, salinity, currents and water levels. *Can. Data Rep. Hydrogr. Oc. Sci.*, No. 5, 262 pp.

- Bishop, C.T. 1982. Floating tire breakwater design comparison. ASCE Journal of Waterway, Port, Coastal and Ocean Division, 108(WW3), 421-426.
- Bishop, C.T. 1983. Comparison of manual wave prediction models. ASCE Journal of Waterway, Port, Coastal and Ocean Engineering, 109(1), 1-17.
- Bowen, A.J. 1983. Invited summary. Proc. Symposium on the Dynamics of Turbid Coastal Environments. Can. J. Fish. Aqua. Sci., 40, Supplement No. 1, 349-350.
- Boyce, F.M., Robertson, D.G. and Ivey, G.N. 1983. Summer thermal structure of Lake Ontario off Toronto: cooling the big city. Atmosphere-Ocean, 21(4), 397-417.
- Brethes, J.C., Desrosiers, G. and Coulombe, F. 1982. Food of the snow-crab (*Chionoecetes opilio*) from the southwestern part of the Gulf of St. Lawrence. Proceedings of the International Symposium on the Genus *Chionoecetes*, Alaska Sea Grant Report 82-10, 319-335.
- Brinkhurst, R.O. 1983. Coastal ecology: an essay on practical approaches in coastal zone management in British Columbia, B. Sadler (Editor), Cornett Occasional Paper, 3, 53-64.
- Budgell, W.P. and El-Shaarawi, A.H. 1983. Time series modelling of storm surges on a medium-sized lake. In: Predictability and Modelling in Ocean Hydrodynamics, J.C.J. Nihoul (Editor). Elsevier Oceanogr. Ser., 25, 197-218.
- Butt, K.A., Jeans, P.K. and Raymond, R.C. 1983. HF radar technology transfer project - acquisition phase, March 1982. Technical Report, June 1983, 107 pp.
- Calvert, S.E. 1983. Geochemistry of Pleistocene sapropels and associated sediments from the eastern Mediterranean. Oceanologica Acta, 6(3), 255-267.
- Calvert, S.E. 1983. Sedimentary geochemistry of silicon. In: Silicon Geochemistry and Biogeochemistry, S.R. Aston (Editor), Academic Press, 143-186.
- Calvert, S.E. and Price, N.B. 1983. Geochemistry of Namibian Shelf sediments. In: Coastal Upwelling, Pt. A, E. Suess and J. Thiede (Editors), Plenum Press, N.Y., 337-375.
- Carmack, E.C. 1983. Circulation and mixing in ice-covered waters. In: N.J. Untersteiner (Editor), Air-Sea-Ice Interaction, NATO Advanced Studies Institute Series, Plenum Press, N.Y.
- Carnevale, G.F. and Holloway, G. 1982. Information decay and the predictability of turbulent flows. J. Fluid Mechanics, 116, 115-121.
- Chanut, J.P. and Poulet, S.A. 1982. Short-term variability of the size spectra of suspended particles in a rapidly changing environment. Estuarine, Coastal and Shelf Science, 15, 497-513.
- Clarke, R.A. and Gascard, J.-C. 1983. The formation of Labrador sea water. Part I: Large-scale processes. J. Phys. Oceanogr., 13 (10), 1764-1778.
- Clifford, S.F. and Farmer, D.M. 1983. Ocean flow measurements using acoustic scintillation. J. Acoust. Soc. Am., 74(6), 1826-1832.
- Cochrane, N.A. and Dunsiger, A.D. 1983. Remote acoustic classification of marine sediments with application to offshore Newfoundland. Can. J. Earth Sci., 20, 1195-1211.
- Coote, A.R., Mackenzie, F.T., Wollast, R. and Berner, R.A. 1982. The Pallmann effect - an explanation for measured pH decreases in settled oceanic calcite slurries. Amer. J. Sci., 282, 1555.

- Cossa, D., Canuel, G. et Piuze, J. 1983. Rapid micro-method for the simultaneous determination of trace amounts of cadmium, iron and manganese in seawater. *Mar. Chem.*, 12, 224.
- Cossa, D., Picard-Bérubé, M. et Gouygou, J.P. 1983. Polynuclear aromatic hydrocarbons in mussels from the estuary and northwestern Gulf of St. Lawrence, Canada. *Bull. Environ. Contam. Toxicol.*, 31, 41-47.
- Crawford, W.R., Thomson, R.E. and Huggett, W.S. 1983. Continental shelf waves of diurnal period along Vancouver Island. In: *Coastal Oceanography*, H. Grade, A. Edwards and H. Svendsen (Editors), Plenum Press, N.Y., 225-234.
- Crean, P.B. 1983. A numerical approach to simulating the estuarine circulation in a strongly tidal deep coastal sea between Vancouver Island and the mainland. In: *Proceedings of the 3rd International Conference on Applied Mathematical Modelling*, *Mitteilungen des Institutes für Meereskunde der Universität Hamburg*, No. 26.
- Crean, P.B. 1983. The development of rotating non-linear numerical models (GF2, GF3) simulating barotropic mixed tides in a complex coastal system located between Vancouver Island and the mainland. *Can. Tech. Rep. Hydrogr. Oc. Sci.*, No. 31.
- Crean, P.B., Bolton, M. and Huggett, W.S. 1983. *Atlas of Currents: Juan de Fuca Strait and Strait of Georgia*. Canadian Hydrographic Service, Department of Fisheries and Oceans, Ottawa.
- D'Anglejan, B. 1982. Patterns of recent sedimentation in the Eastmain Estuary, prior to river cut-off. *Nat. Canadien, Special Issue on Hudson Bay, James Bay*. *Nat. Can.*, 109, 363-374.
- D'Anglejan, B. and Ingram, R.G. 1982. Investigation of natural sediment and dredge spoil movement in the vicinity of Gros Cacouna harbour (St. Lawrence estuary). *Tech. Rept. for Fisheries and Oceans Canada*.
- Demers, S., Therriault, J.C. et Descolas-Gros, C. 1983. Communautés végétales associées à la couverture de glace saisonnière en milieu estuarien. *Mar. Biol.*, 74.
- Denhartog, G., Smith, S.D., Anderson, R.J., Topham, D.R. and Perkin, R.G. 1983. An investigation of a polynya in the Canadian archipelago. III, Surface heat flux. *J. Geophys. Res.*, 88(C5), 2911-2916.
- Denman, K.L. 1983. Predictability of the marine planktonic ecosystem. In: *Predictability of Fluid Motions*, G. Hallway and B.J. West (Editors). *Am. Inst. Phys.*, New York, 570-572.
- Denman, K.L. and Gargett, A.E. 1983. Time and space scales of vertical mixing and advection of phytoplankton in the upper ocean. *Limnol. Oceanogr.*, 28, 801-815.
- Desrosiers, G., Bellan-Santini, D. et Brethes, J.C. 1982. Evolution spatio-temporelle des peuplements de substrats rocheux superficiels dans un golfe soumis à de multiples pollutions (Golfe de Fos, France), *Tethys*, 10(3), 245-253.
- Desrosiers, G., Brethes, J.C.F. and Coulombe, F. 1982. Edaphic segregation with a population of *C. opilio* in the southwestern part of the Gulf of St. Lawrence. *Proceedings of the International Symposium on the Genus Chionoecetes*. *Alaska Sea Grant Report 82-10*, 353-379.
- Desrosiers, G., Brethes, J.C.F. et Coulombe, F. 1983. Complément à l'étude de l'endofaune benthique des substrats meubles au Chenal de Mingan. *Contrat Hydro-Québec Envr.* 882-120, 64 p.
- Diemand, D. 1983. Measurement of iceberg temperatures. *Iceberg Research*, 5.

- Dobson, D. and Petrie, B. 1983. Long-term temperature monitoring program 1982, Scotian-Fundy Gulf regions. Can. Data Rep. Hydrogr. Ocean Sci., No. 10, 384 pp.
- Dobson, F.W. 1983. Introductory Physical Oceanography. In: Air-Sea Exchange of Gases and Particles, P.S. Liss and W.G.N. Slinn (Editors), Reidel Publishing Co., 53-119.
- Donelan, M.A. and Pierson, W.J. 1983. The sampling variability of estimates of spectra of wind-generated gravity waves. J. Geophys. Res., 88(67), 4381-4392.
- Dumais, J.F. 1982. On the curl of a vector field. American Mathematical Monthly, 89, 469-473.
- Dworski, J.G. and Holloway, G. 1983. Statistical representations of seafloor topography. Univ. of Washington, Special Report No. 94.
- El Shaarawi, A.H. and Esterby, S.R. (Editors) 1982. Time series methods in hydro-sciences. Elsevier, Developments in Water Science, 17, 614 pp.
- El-Sabh, M.I. 1982. Estuaries and estuarine management. J. Fac. Mar. Sci., 2, 85-89.
- El-Sabh, M.I. and Beltagy, A.I. 1983. Hydrography and Chemistry of the Gulf of Suez during September 1960. In: M.F. Thompson, A.F. Latif and A.R. Bayoumi (Editors), Proceedings of International Conference on Marine Science in the Red Sea, Bull. Inst. Oceanog. Fish., 9, 78-82.
- El-Sabh, M.I. et Cossa, D. 1983. Étude de la dynamique des ressources biologiques de l'estuaire et du Golfe du Saint-Laurent. Rapport soumis au Fond FCAC, Gouvernement du Québec, 99 p.
- El-Sabh, M.I. and Koutitonsky, V.G. 1982. Variability of the near-surface residual currents in the lower St. Lawrence Estuary. J. Geophys. Res., 87(C12), 9589-9600.
- Elouard, B., Desrosiers, G., Brethes, J.C.F. et Vigneault, Y. 1982. Étude des habitats du poisson autour des îlots créés par des dépôts de dragage dans la lagune de Grande-Entrée (Iles-de-la-Madeleine), Rapport technique, Ministère des Pêches et Océans.
- Emery, W.J. 1983. Global summary: review of eddy phenomena as expressed in temperature measurements. In: Eddies in Marine Science, A. Robinson (Editor), Springer-Verlag.
- Emery, W.J. 1983. On the geographical variability of the upper level mean and eddy fields in the North Atlantic and North Pacific. J. Phys. Oceanogr., 13, 269-291.
- Farmer, D.M. 1983. Stratified flow over sills. In: Coastal Oceanography, H. Gade, A. Edwards and H. Svendsen (Editors), Plenum Press, N.Y., 337-362.
- Farmer, D.M. and Crawford, G.B. 1983. Measurements of acoustic correlation in the ocean with a high frequency echo-sounder. Nature, 301(5902), 698-700.
- Farmer, D.M. and Freeland, H.J. 1983. The physical oceanography of fjords. Progress in Oceanography, 12(2), 174-220.
- Fillmore, S. and Sandilands, R.W. 1983. The Chartmakers - A History of Nautical Surveying in Canada, N.C. Press, Toronto, 255 pp.
- Fissell, D.B., Cuypers, L., Lemon, D.D., Birch, J.R., Cornford, A.B., Lake, R.A., Smiley, B.D., Macdonald, R.W. and Herlinveaux, R.H. 1983. Arctic data compilation and appraisal, Volume 6, Queen Elizabeth Islands: Physical oceanography - temperature, salinity, currents and water levels. Can. Tech. Rep. Hydrogr. Oc. Sci., No. 5, 214 pp.

- Foreman, M.G.G. 1983. Analysis of the wave equation model for finite element tidal computations. *J. Comput. Phys.*, 52(1), 290-312.
- Foreman, M.G.G. 1983. An analysis of two-step time discretizations in the solution of the linearized shallow water equations. *J. Comput. Phys.*, 51(3), 454-483.
- Freeland, H.J. 1983. A seasonal upwelling event observed off the west-coast of British Columbia, Canada. In: *Coastal Oceanography*, H. Gade, A. Edwards and H. Svendsen (Editors), Plenum Press, N.Y., 217-223.
- Freeland, H.J. 1983. Low frequency currents observed off southern Vancouver Island, 1979-1981. *Can. Data Rep. Hydrogr. Oc. Sci.*, No. 7, 80 pp.
- Fu, T. and Pocklington, R. 1983. Quantitative adsorption of organic matter from seawater on solid matrices. *Mar. Chem.*, 13, 255-264.
- Garrett, C. 1983. On the initial streakiness of a dispersing tracer in two- and three-dimensional turbulence. *Dynamics of Atmospheres and Oceans*, 7, 265-277.
- Garrett, C. 1983. Variable sea level and strait flows in the Mediterranean: a theoretical study of the response to meteorological forcing. *Oceanologica Acta*, 6(1), 79-87.
- Gascard, J.-C. and Clarke, R.A. 1983. The formation of Labrador sea water. Part II: Mesoscale and smaller-scale processes. *J. Phys. Oceanogr.*, 13(10), 1779-1797.
- Giovando, L.F. 1983. Observations of seawater temperature and salinity at British Columbia shore stations, 1980. *Can. Data Rep. Hydrogr. Oc. Sci.*, No. 9, 133 pp.
- Giovando, L.F. 1983. Observations of seawater temperature and salinity at British Columbia shore stations, 1981. *Can. Data Rep. Hydrogr. Oc. Sci.*, No. 13, 127 pp.
- Gobeil, C., Cossa, D. et Piuze, J. 1983. Distribution des concentrations en mercure dans les eaux de l'estuaire moyen du Saint-Laurent. *Rapp. tech. can. hydrogr. sci. ocean.*, 17, iii + 14pp.
- Gower, J.F.R. 1983. "Layover" in satellite radar images of ocean waves. *J. Geophys. Res.*, 88, 7719-7720.
- Greenberg, D.A. 1983. Modelling the mean barotropic circulation in the Bay of Fundy and Gulf of Maine. *J. Phys. Oceanogr.*, 13, 886-904.
- Greenberg, D.A. 1983. The effect of tidal power development on the physical oceanography of the Bay of Fundy and Gulf of Mexico. In: *The Effects of the Proposed Tidal-Hydroelectric Project in the Bay of Fundy - Proceedings of the Hearing of the U.S. Senate Committee on Environment and Public Works, Augusta, Maine, 25 July 1983*. US Government Printing Office, Washington.
- Greenberg, D.A. and Amos, C.L. 1983. Suspended sediment transport and deposition modelling in the Bay of Fundy, Nova Scotia - a region of potential tidal power development. *Can. J. Fish. and Aquat. Sci.*, 40, Supplement No. 1, 20-34.
- Guérin, J.P., Kerambrun, P. et Rivière, P. 1983. Effets à court terme et à long terme d'un narcotique sur quelques activités enzymatiques chez le copépode harpacticide *Tisbe Holothuriae*. *Mar. Biol.* 66, 217-221.
- Haidvogel, D.B. and Holloway, G. 1983. Predictability: Lagrangian and Eulerian views. In: *Predictability of Fluid Motions*, *Amer. Inst. Phys.*, 67-68.
- Hamilton, K. 1983. Aspects of wave behaviour in the mid and upper troposphere of the southern hemisphere. *Atmosphere-Ocean*, 21, 40-54.

- Hamilton, K. 1983. Diagnostic Study of the momentum balance in the northern hemisphere winter stratosphere. *Monthly Weather Review*, 111(7), 1434-1441.
- Hamilton, K. 1983. The quasi-biennial wind oscillation. *Physics in Canada*, 37-39.
- Harrison, D.E., Emery, W.J., Dugan, J.P. and Bo-cheung Li 1983. Mid-latitude mesoscale temperature variability in six multiship XBT surveys. *J. Phys. Oceanogr.*, 13, 648-662.
- Herman, A.W. 1983. Vertical Patterns of Copepods, Chlorophyll and Production in Northeastern Baffin Bay. *Limnol. Oceanog.*, 28, 709-719.
- Herman, A.W. and Platt, T. 1983. Numerical modelling of diel carbon production and zooplankton grazing on the Scotian Shelf based on observational data. *Ecological Modelling*, 18, 55-72.
- Hill, P.R. and Bowen, A.J. 1983. Modern sediment dynamics at the shelf-slope boundary off Nova Scotia. In: *The Shelfbreak: Critical Interface on Continental Margins*, D.J. Stanley (Editor), S.E.P.M. Special Publication No. 33, Tulsa, Oklahoma, 265-276.
- Hill, S., Denman, K., Mackas, D., Sefton, H. and Forbes, R. 1982. Coastal waters off southwest Vancouver Island: spring and summer 1981. *Can. Data Rep. Hydrogr. Oc. Sci.*, No. 3.
- Hodgins, D.O., LeBlond, P.H. and Huntley, D.A. 1983. Shallow-water wave calculations. Department of Fisheries and Oceans Report.
- Holloway, G. 1982. A comment on streakiness. *Ocean Modelling*, 43.
- Holloway, G. 1982. On interaction time scales for oceanic internal waves. *J. Phys. Oceanogr.* 12, 293-296.
- Holloway, G. 1982. Theories of the oceanic internal wave environment. Technical Report PD-NW-80-244R, Physical Dynamics Inc., Bellevue, Washington, 83 pp.
- Holloway, G. 1983. A conjecture relating oceanic internal waves and small scale processes. *Atmosphere-Ocean*, 21, 107-122.
- Holloway, G. 1983. Contrary roles of planetary wave propagation in atmospheric predictability. In: *Predictability of Fluid Motions*, Amer. Inst. Phys., 593-600.
- Holloway, G. 1983. Effects of planetary wave propagation and finite depth on the predictability of atmospheres. *J. Atmos. Sci.*, 40, 314-327.
- Holloway, G. and West, B.J. (Editors). 1983. *Predictability of Fluid Motions*, Amer. Inst. Phys., 604 pp.
- Hughes, B.A. and Gower, J.F.R. 1983. SAR imagery and surface truth comparisons of internal waves in Georgia Strait, British Columbia, Canada. *J. Geophys. Res.*, 88, 1809-1824.
- Huntley, D.A. 1982. Boundary layer flow and the physics of sediment transport. Short course lecture notes, Shelf Sediment Stability, C-CORE, Memorial University, St. John's, Newfoundland.
- Huntley, D.A. 1983. Contributions to "Oceans from Space: Towards the Management of our Coastal Zone", F.E. Bunn (Editor), Institute for Research on Public Policy, Montreal, P.Q., Canada.
- Huntley, D.A. 1983. In situ sediment monitoring techniques: a survey of the state of the art in the U.S.A. Report No. C²S²-1. Associate Committee for Research on Shoreline Erosion and Sedimentation, NRC, Ottawa.

- Ingram, R.G. 1982. Mean and tidal circulation in Eastmain River (James Bay). *Nat. Can.*, 109, 733-743.
- Ingram, R.G. 1983. Salt entrainment and mixing processes in an under-ice river plume. In: *Coastal Oceanography*, H. Gade, A. Edwards and H. Svendsen (Editors), Plenum Press, N.Y., 551-564.
- Ingram, R.G. 1983. Vertical mixing at the head of the Laurentian Channel. *Estuarine Coastal and Shelf Science*, 16, 333-338.
- Jones, E.P., Coote, A.R. and Levy, E.M. 1983. Effect of sea ice meltwater on the alkalinity of seawater. *J. Mar. Res.*, 41, 43-52.
- Kerambrun, P. et Rivière, D. 1983. Modifications des zymogrammes des estérases d'un copépode planctonique, ACARTIA CLAUSI, dans une aire maritime polluée (zone d'épandage du grand émissaire de Marseille). *CR acad. Sci. Paris*, t294, 229-232.
- Khalil, M.F. and Labbé, J. 1982. Diagenesis of terrigenous and marine organic matter along the St. Lawrence estuary. 2nd International Congress on Analytical Techniques in Environmental Chemistry, Barcelona, Spain, November 1981. J. Albaiges (Editor), Pergamon Press, London, 69-78.
- Khalil, M.F., Horth, A., Labbé, J. and Lantagne, S. 1983. Fatty acids and organochloro compounds in the sediments and herring (*Clupea harengus* L.) of the St. Lawrence estuary, 5th summer session. Ed. Arab school on science and technology Bloudan-Syria, 27-41.
- Krishnappan, B.G. 1983. Suspended sediment profile for ice-covered flows. *J. Hydraul. Eng. Div., ASCE*, 109(3).
- Lam, D.C.L., Shertzer, W.M. and Fraser, A.S. 1983. Simulation of Lake Erie water quality responses to loading and weather variations. *IWD Sci. Series 134*, CCIW. Burlington, Ontario, 310 pp.
- Lau, Y.L. 1983. Suspended sediment effect on flow resistance. *J. Hydraul. Eng. Div., ASCE*, 9(5), 757-763.
- Lawrence, D.J. and Tang, C.L. 1982. Methods and costs of receiving satellite data on BIO ships. *AOL Research Note*, 10 pp.
- Lawrence, D.J. and Trites, R.W. 1983. Surface oil spill trajectory modelling for Georges and Browns Banks. *Can. Tech. Rep. Hydrogr. Oc. Sci.*, No. 29, 30 pp.
- LeBlond, P.H. 1983. The Strait of Georgia: functional anatomy of a coastal sea. *Can. J. Fish. Aquat. Sci.*, 40, 1033-1063.
- LeBlond, P.H., Dyck, K., Perry, K. and Cumming, D. 1982. Runoff and precipitation time series for the coasts of British Columbia and Washington State. Dept. of Oceanography, Univ. of British Columbia Manuscript Report No. 39, May 1983.
- Lebel, J. 1983. Les mystères du Chenal Laurentien. *Réseau*, 14(7), 13-17.
- Lebel, J., Silverberg, N. and Sundby, B. 1982. On gravity core shortening and pore water chemical gradients. *Deep-Sea Res.*, 29, 1365-1372.
- Lebel, J., Pelletier, E., Bergeron, M., Belzile, N. et Marquis, G. 1983. Le panache du Saguenay. *Can. J. Fish. Aquat. Sci.*, 40, 52-60.
- Legendre, L., Ingram, R.G. and Simard, Y. 1982. Aperiodic changes of water column stability and phytoplankton production in an arctic coastal embayment. *Nat. Can.*, 109, 775-786.

- Legendre, L., Demers, S., Yentsch, C.M. et Yentsch, C.S. 1983. The 14C method: Patterns of dark CO₂ fixation and DCMU correction to replace the dark bottle. *Limnol. Oceanogr.*, 28, 996-1003.
- Levasseur, M., Therriault, J.C. et Legendre, L. 1983. Tidal currents, winds and the morphology of phytoplankton spatial structures. *J. Mar. Res.*, 41, 655-672.
- Levy, E.M. 1983. Background levels of volatile hydrocarbons and petroleum residues in the waters and sediments of the Grand Banks. *Can. J. Fish. Aquat. Sci.*, 40, Supplement No. 2, 23-33.
- Levy, E.M. 1983. Commentary: What impact will the oil industry have on seabirds in the Canadian Arctic? *Arctic*, 36(1), 1-4.
- Lewis, E.L. and Perkin, R.G. 1983. Supercooling and energy exchange near the Arctic Ocean surface. *J. Geophys. Res.*, 88(C12), 7681-7685.
- Litherland, J. and Holloway, G. 1983. Statistical theory of the predictability of equivalent barotropic motion on a beta plane. In: *Predictability of Fluid Motions*, Amer. Inst. Phys., 33-348.
- Lively, R.R. 1983. Avalon Channel - Newfoundland temperature, salinity, and sigma-t sections. *Can. Tech. Rep. Hydrogr. Oc. Sci.*, No. 24, 65 pp.
- Loder, J.W., Wright, D.G., Garrett, C. and Juszko, B. 1982. Horizontal exchange on central Georges Bank. *Can. J. Fish. Aqua. Sci.*, 39, 1130-1137.
- Loring, D.H., Rantala, R.T.T., Morris, A.W., Blake, A.J. and Howland, R.J.M. 1983. Chemical composition of suspended particles in an estuarine turbidity maximum zone. *Can. J. Fish. Aquat. Sci.*, 40, Supplement No. 1, 201-206.
- Macdonald, R.W. 1983. The distribution and dynamics of suspended particles in the Kitimat fjord system. *Can. Tech. Rep. Hydrogr. Oc. Sci.*, No. 18, 116-138.
- Macdonald, R.W., Bornhold, B.D. and Webster, I. 1983. The Kitimat fjord system, an introduction. *Can. Tech. Rep. Hydrogr. Oc. Sci.*, No. 18, 2-14.
- Marsden, R.F. and Pond, S. 1983. Synoptic estimates of air-sea fluxes. *J. Mar. Res.*, 41, 349-377.
- Melling, H. 1983. In situ determination of the thermal diffusivity of sea ice. *Can. Tech. Rep. Hydrogr. Oc. Sci.*, No. 27, 24 pp.
- Melling, H. 1983. Oceanographic features of the Beaufort Sea in early winter. *Can. Tech. Rep. Hydrogr. Oc. Sci.*, No. 20, 139 pp.
- Moore, R.M., Lowings, M.G. and Tan, F.C. 1983. Geochemical profiles in the central Arctic Ocean: their relation to freezing and shallow circulation. *J. Geophys. Res.*, 88, 2667-2674.
- Muench, R.D., LeBlond, P.H. and Hachmeister, L.E. 1983. On some possible interactions between internal waves and sea ice in the marginal ice zone. *J. Geophys. Res.*, 88(C5), 2819-2826.
- Multi-year ice thickness distribution in the Beaufort Sea determined by impulse radar. Contract Report, October 1980. In: *Beaufort Environmental Impact Statement 1982*, RW 14. Now available from Pallister Resource Management Ltd., 105, 4116-64 Avenue, S.E., Calgary, Alberta, T2C 2B3.
- Munro, J. et Therriault, J.C. 1983. Migrations saisonnières du homard (*Homarus americanus*) entre la côte et les lagunes des Iles-de-la-Madeleine. *J. Fish. Aquat. Sci.*, 40, 905-918.

- Murty, T.S. 1983. Boundary integral solutions for water wave problems. *J. Hydraul. Eng.*, ASCE, 109(6), 939-940.
- Murty, T.S. 1983. Meteorology and oceanography in the Falkland Islands region. *Lighthouse*, 26, 10-13.
- Murty, T.S. 1983. Sunspot activity and tsunamis in the Pacific Ocean. *Lighthouse*, 27, 31-32.
- Murty, T.S. 1983. Storm surges and tsunamis on the coastlines of Canada. In: *Proceedings of the Canadian Coastal Conference - 83*, Vancouver, B.J. Holden (Editor), Associate Committee for Research on Shoreline Erosion and Sedimentation, NRC, Ottawa, 135-148.
- Murty, T.S. and Henry, R.F. 1983. Tides in the Bay of Bengal. *J. Geophys. Res.*, 88(C10), 6069-6076.
- Murty, T.S., McBean, G.A. and McKee, B. 1983. Explosive cyclogenesis over the northeast Pacific Ocean. *Monthly Weather Review*, 3(5), 1131-1135.
- Mysak, L.A. 1983. Generation of annual Rossby waves in the North Pacific. *J. Phys. Oceanogr.*, 13, 1908-1923.
- Mysak, L.A. and Magaard, L. 1983. Rossby wave driven mean flows along non-zonal barriers, with application to the Hawaiian Ridge. *J. Phys. Oceanogr.*, 13, 1716-1725.
- Mysak, L.A., Salvade, G., Hutter, K. and Scheiwiller, T. 1983. Lake of Lugano and topographic waves. *Nature*, 306, 46-48.
- Needler, G.T. 1983. Subpolar Gyres and the Arctic Ocean. In: *Eddies in Marine Science*. Allan Robinson (Editor), Springer-Verlag, 167-180.
- Needler, G.T., Bowers, J.M. and Hagen, A.A. 1983. Oceanographic model and radiologic basis for control radionuclide releases. IAEA, International Conference on Radioactive Waste Management, Seattle, WA, USA, 16-20 May 1983.
- Pedersen, T.F. 1983. Dissolved heavy metals in a lacustrine mine tailings deposit-Buttle Lake, British Columbia. *Marine Pollution Bulletin*, 14(7), 249-254.
- Pedersen, T.F. 1983. Increased productivity in the eastern equatorial Pacific during the last glacial maximum (19,000 to 14,000 yr. B.P.). *Geology*, 11, 16-19.
- Pereira, C.P.G. 1983. Iceberg scouring off the southeast Baffin Island continental shelf, eastern Canada - Abstract Results. *Iceberg Research*, 3, 7 pp.
- Petrie, B. 1983. Current response at the shelf break to transient wind fording. *J. Geophys. Res.*, 88, 9567-9578.
- Petrie, B. and Anderson, C. 1983. Circulation on the Newfoundland continental shelf. *Atmosphere-Ocean*, 21(2), 207-226.
- Picard-Bérubé, M., Cossa, D. et Piuze, J. 1983. Teneurs en benzo 3, 4 pyrène chez *Mytilus edulis* L. de l'estuarie et du golfe du Saint-Laurent. *Marine Environ. Res.*, 10, 63-71.
- Platt, T. and Herman, A.W. 1983. Remote sensing of phytoplankton in the sea: surface-layer chlorophyll as an estimate of water column chlorophyll and primary production. *Int. J. Remote Sens.*, 4,(2), 343-351.
- Pouliot, D. 1983. Variations naturelles des teneurs en cadmium, cuivre et zinc chez une population de *Mytilus edulis* L.: identification des sources de variabilité et quantification de leurs influences. Mémoire de maîtrise ès sciences (océanographie). Université du Québec à Rimouski, 121 p.

- Quon, C. 1983. Convection induced by insulated boundaries in a square. *Phys. Fluids*, 26, 632-637.
- Quon, C. 1983. Effect of grid distribution on the computation of high Rayleigh number convection in a differentially-heated cavity. In: *Numerical Properties and Methodologies in Heat Transfer*, T.M. Shih (Editor), Hemisphere Publ. Corp., Washington, D.C., 251-281.
- Rodier, L. and Khalil, M.F. 1982. Fatty acids in Recent sediments of the St. Lawrence estuary. *Estuarine, Coastal, Shelf Science*, 15, 474-483.
- Royer, L. and Emery, W.J. 1983. Variations of the Fraser River plume and their relationship to forcing by tide, wind and discharge. *Atmosphere-Ocean*, 20, 357-372.
- Ruddick, B.R. 1983. A practical indicator of the stability of the water column to double-diffusive activity. *Deep-Sea Res.*, 30, 1105-1107.
- Rukavina, N.A. (Editor) 1982. *Proceedings, Third Workshop on Great Lakes Coastal Erosion and Sedimentation*, National Research Council, Burlington, Ontario, November 1982, 177 pp.
- Sandilands, R.W. 1983. Hydrographic surveying in the Great Lakes during the nineteenth century. *International Hydrographic Review*, Monaco, LX(2), July 1983.
- Sandilands, R.W. 1983. Vignettes from hydrography's past. In: *Proceedings Centennial Conf. Canadian Hydrographic Service*, Ottawa, April 5-8, 1983. Special Publication of Fisheries and Aquatic Sciences 67, 36-41.
- Schafer, C.T. and Smith, J.N. 1983. River discharge, sedimentation, and benthic environmental variations in Miramichi Inner Bay, New Brunswick. *Can. J. Earth Sci.*, 20(3), 389-398.
- Schwinghamer, P., Tan, F.C. and Gordon, D.D. 1983. Stable carbon isotope studies on the Pecks Cover mudflat ecosystem in the Cumberland Basin, Bay of Fundy. *Can. J. Fish. Aquat. Sci.*, 40, 262-272.
- Shen, C. and Holloway, G. 1982. Spectral formulation of internal wave interaction. Technical Report No. 392, School of Oceanography, University of Washington, 36 pp.
- Simons, T.J. 1983. Resonant topographic response of nearshore currents to wind forcing. *J. Phys. Oceanogr.*, 13, 512-523.
- Simons, T.J. and Ruddick, B.R. 1983. Dynamic response of conductivity probes. *J. Atm. Oceanic Technology*, 1.
- Smith, J.N., Ellis, K.M. and Bishop, F.J. 1983. Pre-operational environmental monitoring report for the Point Lepreau, N.B. nuclear generating station - 1981. *Can. Tech. Rep. Hydrogr. Oc. Sci. No. 4*.
- Smith, P.C. 1983. Eddies and coastal interactions. In: *Eddies in Marine Science*, Allan Robinson (Editor), Springer-Verlag, 446-480.
- Smith, P.C. 1983. The mean and seasonal circulation off southwest Nova Scotia. *J. Phys. Oceanogr.*, 13(6), 1034-1054.
- Smith, P.C., Chamagne, V.E., Bennett, A.S. and Herman, A.W. 1983. Batfish section near the edge of the Scotian Shelf, 1976-77. *Can. Tech. Rep. Hydrogr. Oc. Sci. No. 1*, 159 pp.
- Smith, S.D. and Banke, E.G. 1983. The influence of winds, currents, and towing force on the drift of icebergs. *Cold Regions Sci. Tech.*, 6, 241-255.

- Smith, S.D., Katsaros, K.B. and Oost, W.A. 1983. HEXOS - Humidity Exchange over the Sea: Scientific Plan. Can. Tech. Rep. Hydrogr. Oc. Sci., No. 21, v + 47 pp.
- Smith, S.D., Anderson, R.J., Denhartog, G., Topham, D.R. and Perkin, R.G. 1983. An investigation of a polynya in the Canadian Archipelago: 2, structure of turbulence and sensible heat flux. J. Geophys. Res., 88 (C5), 2900-2910.
- Stucchi, D.J. 1983. Shelf-fjord exchange on the west coast of Vancouver Island. In: Coastal Oceanography, H. Gade, A. Edwards and H. Svendsen (Editors), NATO Conf., Ser., Marine Sciences Ser. IV, Plenum Press, N.Y., 439-450.
- Subsea Containment Study: Phase I, Preliminary Feasibility. Contract Report, August 1981. In: Canadian Offshore Oilspill Research Association CS 8V1. Now available from Pallister Resource Management Ltd., 105, 4116-64 Avenue, S.E., Calgary, Alberta, T2C 2B3.
- Symonds, G., Huntley, D.A. and Bowen, A.J. 1982. Two-dimensional surf beat; long wave generation by a time-varying break-point. J. Geophys. Res., 87, 492-498.
- Tabata, S. 1983. Interannual variability in the abiotic environment of the Bering Sea and the Gulf of Alaska. In: From Year to Year, "Interannual Variability of the Environment and Fisheries of the Gulf of Alaska and the Eastern Bering Sea", W.S. Wooster (Editor), A Washington Sea Grant Publication, University of Washington, 139-145.
- Tan, F.C. and Strain, P.M. 1983. Sources, sinks, and distribution of organic carbon in the St. Lawrence Estuary, Canada. Geochimica et Cosmochimica Acta, 47, 125-132.
- Tan, F.C., Dyrssen, D. and Strain, P.M. 1983. Sea ice meltwater and excess alkalinity in the East Greenland Current. Oceanologica Acta, 6(3), 283-288.
- Tang, C.L. 1982. A model for frontal upwelling. In: Hydro-Dynamics of Semi-Enclosed Seas. Elsevier Scientific Publishing Co., Amsterdam. 329-348.
- Thomas, D.J., Macdonald, R.W., Francis, A.G., Wood, V. and Cornford, A.B. 1983. Arctic data compilation and appraisal, Vol. 4, Northwest Passage - chemical oceanography. Can. Data Rep. Hydrogr. Oc. Sci., No. 4, 20 pp.
- Thompson, K.R., Marsden, R.F. and Wright, D.G. 1983. Estimation of low-frequency wind stress fluctuations over the open ocean. J. Phys. Oceanogr., 13(6), 1003-1011.
- Thomson, R.E. 1983. A comparison between computed and measured oceanic winds near the British Columbia Coast. J. Geophys. Res., 88, 2675-2683.
- Thomson, R.E. 1983. Physical Oceanographic aspects of coastal British Columbia. In: Coastal Zone Management in British Columbia, B. Sadler (Editor), Cornett Occasional Papers, 3, 7-27.
- Topham, D.R., Perkin, R.G., Smith, S.D., Anderson, R.J. and Denhartog, G. 1983. An investigation of a polynya in the Canadian Archipelago: 1, introduction and oceanography. J. Geophys. Res., 88 (C5), 2888-2899.
- Trick, C.G., Andersen, R.J., Price, N.M., Gillam, A. and Harrison, P.J. 1983. Examination of hydroxamate-siderophore production by neritic eukaryotic marine phytoplankton. Marine Biology, 75, 9-17.
- Tsang, G. and Pedrosa, A. 1983. Development and Calibration of the NWRI Frazil Instrument. NWRI Contribution Series No. 83-16.
- Warner, J. and Ruddick, B.R. 1982. Internal wave activity at tidal frequency on the Labrador Shelf. Offshore Labrador Biological Studies Program Report, Martec Ltd.

- Wiegand, R.C., Carmack, E.C., Daley, R.J., Gray, C.B.J., Jasper, S. and Pharo, C.H. 1982. Seasonal aspects of the surface and advective heat fluxes of Kootenay Lake, B.C. Water Res., 18, 1493-1502.
- Windsor, W.D. and Klein, K. 1983. A feasibility study of using HF groundwave radar for sea ice and iceberg detection: evaluation of an HF antenna and data collection of ocean spectra. Contract Report, March 1983, prepared for Fisheries and Oceans Canada. C-CORE Technical Report, October 1983, 76 pp.
- Wolanski, E. and Pickard, G.L. 1983. Upwelling by internal tides and Kelvin waves at the continental shelf break on the Great Barrier Reef. Aust. J. Mar. Freshw. Res., 34, 65-80.
- Wolanski, E. and Bennett, A.F. 1983. Continental shelf waves and their influence on the circulation around the Great Barrier Reef. Aust. Mar. Freshw. Res., 34, 23-47.
- Woodworth-Lynas, C.M.T. 1983. A possible submarine mud volcano from the southeast Baffin Island shelf. Technical Report, March 1983, 38 pp.
- Woodworth-Lynas, C.M.T. 1983. The relative age of ice scours using cross-cutting relationships. Technical Report, March 1983, 54 pp.
- Wright, D.G. and Thomson, K.R. 1983. Time-averaged forms of the non-linear stress law. J. Phys. Oceanogr., 13(2), 341-345.
- Yao, T., Pond, S. and Mysak, L.A. 1982. Low-frequency subsurface current and density fluctuations in the Strait of Georgia. Atmosphere-Ocean, 20, 340-365.
- Yeats, P.A. and Bewers, J.M. 1983. Potential anthropogenic influences on trace metal distributions in the North Atlantic. Can. J. Fish. Aquat. Sci., 40, Supplement No. 2, 124-131.
- Yeats, P.A. and Campbell, J.A., 1983. Nickel, copper, cadmium, and zinc in the northwest Atlantic Ocean. Mar. Chem., 12, 43-58.
- Zeman, A.J. 1982. Erosion resistance of cohesive sediments. Proceedings, Third Workshop on Great Lakes Coastal Erosion and Sedimentation, Burlington, Ontario, November 1982, 93-96.

VIII GLACIER STUDIES

Compiled by: R.M. Koerner

1. Summary
2. Polar Continental Shelf Project, EMR, Canada
3. National Hydrology Research Institute,
Environment Canada
4. Karl E. Ricker Ltd., Vancouver
5. University of British Columbia
6. Memorial University of Newfoundland
7. University of Calgary
8. University of Ottawa
9. McMaster University
10. Trent University
11. University of Minnesota
12. University of Massachusetts
13. Bibliography

1. Summary

Glacier work in Canada in 1983 varied from the routine measurement of mass balance in the Rockies, northern Newfoundland, and the Arctic Islands, through continuing the inventory of Canadian ice bodies, monitoring of glacier fluctuations and surging, ice thickness mapping by airborne radar to use of Landsat imagery as a glaciological tool and the contribution and mode of glacier melt to stream flow. Climate change is appearing as an even more important ingredient of some glacier studies and adds further justification to monitoring Canadian ice bodies. Modelling of glaciers is an expanding field and last year encompassed flow and temperature models as well as reconstruction of the Laurentide Ice Sheet. Progress was made in relating synoptic climatology to glacier mass balance and history.

2. Polar Continental Shelf Project, Energy, Mines and Resources, Canada (R.M. Koerner, D. Fisher, B. Alt, M. Parnandi, J. Bourgeois, K. Langley)

A three-dimensional model of the 18 000 B.P. Laurentide Ice Sheet was computed in collaboration with N. Reeh of the University of Copenhagen; the work has been submitted for publication. A model of vapour transport and its relationship to oxygen isotope ratios in ice cores was developed. Work on the Northern Ellesmere pre-Holocene ice is almost completed. The study of regional variations of pollen rain in the High Arctic continues and the analysis of pollen concentration in the northern Ellesmere core has been completed. Using a synoptic approach certain sections of the ice-core time series were studied to assess the effect of variations in the ratio of warm to cold season snow accumulation on oxygen isotope values.

The mass balance of four Arctic ice caps was remeasured. On Agassiz ice cap on Northern Ellesmere Island bulk snow samples for pollen analysis were collected, borehole tilt and diameter remeasured and samples for graphite particle analysis by University of California were taken.

3. National Hydrology Research Institute (NRHI), Glaciology Division, Environment Canada (D.H. Lennox, C.S.L. Ommanney, A. Champoux, J.W. Clarkson, G. Holdsworth, O. Mokievsky-Zubok, J. Power)

Six of the eight index maps covering 5373 glaciers in the Iskut and Stikine River basins have been drafted. Compilation work continues in the other two map areas where 2286 glaciers have been identified to date. Interpretation of ice features in Glacier National Park is virtually complete. Other work continues on the inventory of glaciers contributing to the headwaters of the Yukon River. It is anticipated that the basic

compilation of all Yukon glaciers will be finished shortly. Procedures for digitizing inventory data and reducing them to the standard format have been developed.

Mass balance and related studies were continued on a number of glaciers in B.C. Observations on flood hazards from Natavas and Flood Lakes, in the Iskut and Stikine River watersheds, showed no impounded water in Natavas Lake during the summer, though Flood Lake was filled to capacity (approx. $200 \times 10^6 \text{ m}^3$) and discharged two-thirds in August. Studies to determine mass balance and to assess glacier melt contribution to the Homathko River, for a hydro feasibility investigation, continued. A Data Collection Platform (DCP) provided meteorological data and river flow level. Measurements of winter and summer balances and meltwater flow continued on Sentinel and Place Glaciers. Mass balance only was measured on Helm Glacier.

Collection of mass balance data continued under contract to P.G. Johnson (GEOG/Ottawa). A portable monopulse radar system was used to measure the thickness of the glacier tongue at various locations. Work continues on incorporating glacier melt runoff into conceptual hydrologic forecasting models such as the UBC model. For core-related work in the future an area at the head of the Donjek Glacier (Yukon Territory) was radar-sounded and reflections obtained from a 1500 B.P. White River volcanic eruption at 450 m depth. A reconnaissance of Cathedral Glacier (Yoho National Park) was made to follow up previous jokulhlaups that disrupted CP rail transport. Mount Logan core work proceeds with the assembly of data pertinent to the 1908 Tunguska meteorite event and spectral analysis of 100-year oxygen isotope time series.

4. Karl E. Ricker Ltd., West Vancouver, B.C.

(a) Wedgemount Lake and Glacier, Northern Garibaldi Park, Coast Mountains, B.C. (K. Ricker, B. Tupper and British Columbia Institute of Technology).

The glacier was visited in early autumn at the close of the melt season. Phototheodolite stations were occupied to monitor surface ice velocities across the snout and at the equilibrium line. Dendrochronologic studies were extended beyond the historic climax position of the glacier. At present all data are in the early analysis stage. Permanent Service for the Fluctuation of Glaciers data forms have been completed and ice frontal data from 1900 to 1980 will appear in their next quadrennial report.

(b) "New Moon Glacier", Buckley Ranges, Hazelton Mountains, B.C. (K. Ricker, Private Consultant, St. Joe Canada Inc.)

The historical rate of retreat as well as morainal trends were studied to pinpoint a potential ore source under the glacier. Methods used included dendrochronology and a series of aerial photos. Increments of ice withdrawal have been submitted to the PSFG file for inclusion in their quadrennial report. To the south of this glacier another informally named "UTEM" glacier was visited for purposes of morainal examination and the establishment of a base line across its snout. In addition to the ice work, a facies examination of the morainal forefield on both glaciers was undertaken. A historic turn-of-the-century major rockfall onto New Moon Glacier, and changes in drainage channel patterns during deglaciation were mapped from the evidence. Further investigations on all facets will likely continue.

(c) PSFG Reports - Coastal Mountains (K. Ricker et al.)

Glacier snout fluctuation data were filed on 17 glaciers in the Coast Mountains. These included not only Wedgemount and New Moon Glaciers (see individual reports on each) but also two glaciers in the Tchaikazan area, four in the Snow cap Icefield area, six in the Clendenning-Toba area, two in the Tatlow Range and one very small glacier on the Stein River divide, leeward of the wet axis, in the Lillooet Ranges.

(d) East Arm Glacier, Alsek Ranges, St. Elias Mountains, B.C. (St. Joe Canada Inc. and K. Ricker)

St. Joe Canada Inc. continued the field surveys conducted previously by Swiss Aluminum Co. to find the source of sulphide boulders now found in the end moraines of this glacier. They established an ice surface velocity profile so that basal velocities can be approximated to aid any contemplated through-ice drilling program in the future.

(e) "Caltha Lake" Moraines, Stern River Divide, Lillooet Ranges, B.C. (K. Ricker)

A two-fold pair of moraines were dated by lichenometry at 1898 (± 7) A.D. and 1914 (± 9) A.D.

5. University of British Columbia, Department of Geophysics and Astronomy (G.K.C. Clarke, G.M. Cross, M.G. Maxwell, B.B. Narod, B.T. Prager, J. Schmok, R.D. Russell, E.D. Waddington)

(a) Laboratory Investigations.

A project involving flow and temperature modelling of the Agassiz Ice Cap, Arctic Canada using finite-difference and finite-element methods has now been completed. The results will assist in the interpretation by Polar Continental Shelf Project of ice core records in the area. Maxwell is studying the application of isotopic methods to the problem of identifying regelation ice in glaciers. Oxygen isotope analyses are being performed on the automated system at UBC and hydrogen analyses are being done at the University of Alberta.

(b) Field Work.

Trapridge Glacier last surged around 1945 and its next surge is expected to occur within several years. In 1983 12 new holes were drilled to the glacier bed to monitor basal temperature changes. Schmok is attempting to trace the subglacial water flow from the warm-based region by releasing dye in drill holes connected to the subglacial system. Glacier flow measurements were taken at 1-min intervals over a period of 36 h using a computer-controlled survey system devised at UBC. Prager has completed an M.Sc. thesis on the computer processing of digital radar data taken with the UBC 840 MHz radar over Northern Ellesmere ice shelves and glaciers in 1981. In April 1982, Clarke and Benson carried out an airborne radio echo sounding survey of the ice-filled caldera of Mt. Wrangell. The soundings will be used to guide the selection of ice-core drilling sites. The sounding data are now being computer processed and plotted by Prager and Cross. The most remarkable feature of the results is the discovery of several continuous reflecting horizons, presumed to be caused by impurities from past eruptions of the volcano.

6. Memorial University of Newfoundland, Department of Geography (R.J. Rogerson)

Mass balance, ice movement and snout measurements were continued in July and August 1983 on four cirque glaciers south of Nachvak Fiord.

7. University of Calgary, Department of Geography (M.O. Jeffries, H.V. Serson)

In April and May a total of 52 m of 7.6 cm diameter ice core was obtained from nine different locations on Ward Hunt and Milne Ice Shelves. Ice density, crystallographic, chemical and isotopic determinations on these cores will complement those undertaken on cores obtained in 1982 in order to improve the understanding of Arctic Ice Shelf evolution. Mass balance measurements were completed on the stake networks installed in the early 1960's.

8. University of Ottawa, Department of Geography (P.G. Johnson and G. Binda)

The extreme variability of glacier discharge suspended sediment regimes continues to be studied at Peyto Glacier. Sediment pulses are apparent in both short time frame (mins.) and longer time frame (daily). Results for 1983 were destroyed by continuation of flood and landslide events at the glacier terminus as a result of very heavy precipitation events between July 11 and 14 after a prolonged period of wet weather in early July. The suspended sediment regime of the Slims River in south west Yukon was monitored at the Alaska Highway bridge. The river is fed from the Kaskawulsh Glacier and although the variability of suspended sediment load is damped downstream the characteristics of the regime are still glacier controlled. Analysis is proceeding.

An investigation is being conducted of the temporal variations in suspended sediment concentration and hydrochemistry in glacier-fed Peyto Creek, Alberta. Daily samples were collected throughout the ablation season and hourly samples were taken during specific periods of the summer to determine the seasonal and diurnal fluctuations. The hourly suspended-sediment samples were also analysed for their attached cationic load.

9. McMaster University, Department of Geography (P.J. Howarth, D.C. Ford, C.C. Smart)

P.J. Howarth of McMaster University, with the support of NHRI, Ottawa, is undertaking a study to determine the usefulness of Landsat digital data for the study of Canadian glaciers, particularly for the purpose of glacier inventory. The work is now complete and one report and one paper have so far been produced. The areas studied were the Steacie Ice Cap on Axel Heiberg Island, the Kaskawulsh and Tweedsmuir Glaciers in the St. Elias Mountains and the Athabasca and Saskatchewan Glaciers of the Columbia Icefield. Using the data for the Tweedsmuir Glacier, G. Holdsworth of NHRI, Calgary is analysing changes in moraine patterns between 1973 and 1978 to determine displacement and hence velocity and strain rate information. Applying the analysis methodology developed for the Tweedsmuir Glacier, it is hoped to study changes in the Lowell Glacier which is currently surging.

McMaster University karst groundwater researchers and associates have completed a series of hydrological and other studies of Castleguard Cave and underlying karst spring systems. The Cave extends beneath parts of the Columbia Icefield, Alberta-B.C., and the springs are draining portions of the icefield, the Saskatchewan Glacier and smaller glaciers via sink points at the ice base.

10. Trent University, Geography Department (W.P. Adams, J.R. Glew, D.C. Pierson)

Mass balance measurements were made on the White Glacier, Axel Heiberg Island and stakes were redrilled in the ablation area.

11. University of Minnesota, Barnes Ice Cap Project (R. LeB. Hooke)

The Barnes Ice Cap program has been reduced to one of monitoring velocity and mass balance every second year. Measurements are to be made along a 10 km flowline that has been studied for over 10 years. The first survey under this new program was done in 1982 and yielded average movement rates and mass balance values for the period since 1980.

During the past year these last measurements and those of previous years were systematically analysed to study changes in ice thickness from year to year, and corresponding changes in horizontal velocity. This work is continuing using 1970 as the base year.

12. University of Massachusetts, Department of Geology and Geography
(R.S. Bradley)

Two small plateau ice caps (which were first studied by G. Hattersley-Smith & H. Serson in 1972) were revisited in 1982 and 1983 to carry out detailed topoclimatic and energy balance measurements. Using the original stake network, net mass balance of the larger (E) ice cap was remeasured.

Detailed mass balance measurements on the main 'Hazen' Ice Cap indicate 1981-82 and 1982-83 balance years were quite different (-144 kg m^{-2} in 1981-82 and $+137 \text{ kg m}^{-2}$ in 1982-83). They thus provide an interesting range of conditions for energy balance and topoclimatic measurements on and around the ice caps. Meteorological measurements were made at 3 main stations along a transect from the ice cap center to the unglacierized plateau about 5 km away. The following parameters were measured at hourly intervals: barometric pressure, incoming short- and long-wave radiation, net radiation, reflected short-wave radiation (albedo), air temperature, relative humidity and wind speed at 15 cm, 150 cm and 300 cm and at various depths in the snow and ice. In addition, hourly synoptic observations were maintained and a low-level tethered balloon system was used at irregular intervals to record vertical profiles of temperature, humidity, wind speed and direction above the ice cap.

13. Bibliography

- Andreas, E.L. and Ackley, S.F. 1982. On the differences in ablation seasons of Arctic and Antarctic sea ice. *Journal of the Atmospheric Sciences*, 39 (2), 440-447.
- Bailey, R.H. 1982. *Planet Earth: Glacier*. Time-Life Books, Alexandria, Virginia, 176 pp.
- Binda, G. 1983. Sediment load and hydrochemical variations at the discharge of Peyto Glacier. M.A. Thesis, Department of Geography, University of Ottawa, Ottawa, Ontario.
- Canada, Environment Canada, 1982. The Canadian glacier inventory project. Internal report, National Hydrology Research Institute, Environment Canada, Ottawa, Ontario, September, 45 pp.
- Canadian Arctic Resources Committee, 1982. Northern Ellesmere. *Northern Perspectives*, 10 (4), 1-9.
- Chorlton, W. 1983. *Planet Earth: Ice ages*. Time-Life Books, Alexandria, Virginia, 176 pp.
- Christie, R.L. 1982. Lithological suites as glacial 'tracers', eastern Ellesmere Island, Arctic Archipelago. In: *Current Research, Part A, Geological Survey of Canada Paper 83-1A*, 399-402.
- Clague, J., Jozsa, L.A. and Parker, M.L. 1982. Dendrochronological dating of glacier dammed lakes: an example from Yukon Territory, Canada. *Arctic Alpine Research*, 14 (4), 301-310.
- Driscoll, F.G. 1983. Reply to comments by John Pickard regarding "Wastage of the Klutlan ice-cored moraines, Yukon Territory, Canada". *Quaternary Research*, 20 (2), 251-257.
- Fisher, D.A. 1982. Carbon-14 production compared to oxygen isotope records from Camp Century, Greenland and Devon Island, Canada. *Climatic Change*, 4 (4), 419-426.
- Fisher, D.A., Koerner, R.M., Paterson, W.S.B., Dansgaard, W., Gundestrup, N. and Reeh, N. 1983. Effect of wind scouring on climatic records from ice-core oxygen-isotope profiles. *Nature*, 301 (5897), 205-209.
- Ford, D.C. 1982. Exploration of ice caves in the Canadian Cordillera. *Research Reports No. 14*, National Geographic Society, Washington, D.C., 235-242.
- Gammon, P., Gagnon, R., Bobby, W. and Russell, W.E. 1983. Physical and mechanical properties of icebergs. OTC Paper No. 4459, Offshore Technology Conference, 2-6 May 1983, Houston, Texas.
- Holdsworth, G. 1983. Meeting report - advances in core drilling technology. *EOS, Transactions, American Geophysical Union*, 64 (6), 58.

- Hotzel, I.S. and Miller J.D. 1983. Icebergs: their physical dimensions and the presentation and application of measured data. Proceedings of the Second Symposium on Applied Glaciology, 23-27 August 1982, New Hampshire, USA, *Annals of Glaciology*, 4, 116-123.
- Howarth, P.J. and Ommanney, C.S.L. 1983. LANDSAT digital data for updating glaciological information on topographic and glacier inventory maps. In: *Automated Cartography: International Perspectives on Achievements and Challenges*, Vol. II, Proceedings of the Sixth International Symposium on Automated Cartography, B.S. Wellar (Editor), 16-21 October 1983, National Capital Region of Canada, 504-513.
- Jeffries, M. 1982. The Ward Hunt Ice Shelf, Spring 1982. *Arctic*, 35 (4), 542-544.
- Jeffries, M.O. and Serson, H. 1983. Recent changes at the front of Ward Hunt Ice Shelf, Ellesmere Island, N.W.T. *Arctic*, 36 (3), 289-290.
- Johnson, P.G. 1983. Rock glaciers. A case for a change in nomenclature. *Geografiska Annaler*, 65A (1-2), 27-34.
- Jones, S.J. 1982. The confined compressive strength of polycrystalline ice. *Journal of Glaciology*, 28 (98), 171-177.
- Jones, S.J. and Chew, H.A.M. 1983. Effect of sample and grain size on the compressive strength of ice. Proceedings of the Second Symposium on Applied Glaciology, 23-27 August 1982, New Hampshire, USA, *Annals of Glaciology*, 4, 129-132.
- LeDrew, E.F. 1983. Arctic weather: numerical models reveal the dynamic components. *GEOS, Energy, Mines and Resources Canada*, 12 (2), 6-9.
- Lixvar, J. 1983. Glacier retreat in the Tchaikazan Valley. *Canadian Alpine Journal*, 66, 67.
- Meier, M.F. and Roots, E.F. 1982. Glaciers as a water resource. *Nature and Resources*, 18 (3), 7-14.
- Mokievsky-Zubok, O. 1983. Glaciological studies in Homathko River basin in 1982: annual report. Internal report, National Hydrology Research Institute, Environment Canada, Ottawa, Ontario, 18 pp.
- Mokievsky-Zubok, O. 1983. Glaciological studies in Iskut River basin in 1982: annual report. Internal report, National Hydrology Research Institute, Environment Canada, Ottawa, Ontario, 25 pp.
- Narod, B.B. and Clarke, G.K.C. 1983. UHF radar system for airborne ice thickness surveys. *Canadian Journal of Earth Sciences*, 20, 1073-1086.
- Paterson, W.S.B. and Budd, W.F. 1982. Flow parameters for ice sheet modeling. *Cold Regions Science and Technology*, 6 (2), 141-148.
- Prager, B.T. 1983. Digital signal processing of UHF radio echo sounding data. M.Sc. Thesis, Dept. of Geophysics and Astronomy, University of British Columbia, Vancouver, B.C.
- Punning, J.M. 1983. The development of late Ice Age and early Holocene glaciation in the Arctic. *Polar Geography and Geology*, 7 (2), 159-168.
- Ricker, K.E. 1983. Preliminary observations on a multiple morainal sequence and associated periglacial features on the Mt. Tatlow Area, Chilcotin Ranges, Coast Mountains. *Canadian Alpine Journal*, 66, 61-67.
- Ricker, K.E., Tupper, W.A. et al. 1983. Wedgemount Lake and glacier studies, Northern Garibaldi Park: 1982 Progress Report. *Canadian Alpine Journal*, 66, 58-61.

IX HYDROLOGY

Compiled by: G.J. Young

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1. Introduction

This report is a compilation of activities on hydrology for the period July 31, 1982 to July 31, 1983. It covers both the research and operational aspects but does not include the hydrologic aspects of glacier studies - this being the subject of a separate chapter in this Bulletin. Hydrometeorological activities are also addressed separately.

During the year the Associate Committee on Hydrology had its mandate within NRC renewed for another 5 year period (1983-1988). To facilitate committee functioning, three new administrative sub-committees were formed on International Affairs, Research Priorities and Dissemination of Knowledge. The major project of writing a Design Flood Guide for Canada is well under way.

2. Environmental Conservation Service, Environment Canada

(a) Inland Waters Directorate (IWD)

The Inland Waters Directorate (IWD) of the Environmental Conservation Service conducts its day to day programs under the Canada Water Act and the International River Improvements Act. It has a headquarters office at Ottawa and regional offices at Vancouver, Regina, Burlington, Quebec and Halifax. IWD's role involves the development of, planning for, and participation in national and international river basin programs, including a national flood damage reduction program. It conducts special water quality investigations, research on water quality, quantity and the socio-economic aspects of freshwater resources, and maintains inventories relating to the quantity and quality of surface and ground waters. Much of IWD's hydrologic work is carried out at its two national research institutes - the National Hydrology Research Institute (NHRI) and the National Water Research Institute (NWRI) - and in its Water Resources Branch (WRB).

(i) National Hydrology Research Institute (NHRI)

The NHRI is a national research facility specializing in research related to rivers and streams, snow and ice, and underground water. It is based in Ottawa with subsidiary offices in Calgary and Vancouver. The Institute is scheduled to be relocated to Saskatoon, Saskatchewan in 1985 where it will be the principal tenant in the new National Hydrology Research Centre (NHRC). Most of the research conducted by NHRI forms part of Environment Canada's Water Management Research Program. NHRI is made up of 3 water divisions.

The Surface Water Division investigates watershed processes, in particular those that characterize elements of the hydrologic cycle other than the ground water and the snow and ice regimes, and develops and tests precipitation-runoff models. Hydrologic processes in alpine, prairie and permafrost environments are of particular interest. Studies of these processes include those on the interaction between Arctic streams and permafrost, on lake dynamics and flooding in the Mackenzie Delta and an interrelated group of studies on freeze-up, break-up, ice jamming, and other fluvial processes in the Liard and Mackenzie Rivers and the Mackenzie River delta. This group also is conducting hydrologic studies of four watersheds along the proposed route of the Inuvik-Tuktoyaktuk Highway. Modelling activities include the design of statistical streamflow forecasting models with and without climatic forecasting ability, the Monte Carlo analysis of the sampling, time-dependent and distribution properties of rainfall-runoff models, the design of a model to relate runoff volumes to antecedent values of tension storage, gravity storage and snow cover in a basin, the development of a physically based model of water flow in snow-covered terrain, the development of a new methodology for determining baseflow recession curves, the sensitivity analysis of a passive microwave snow cover model to a range of snow cover and soil moisture conditions, and the operational testing of a modified UBC precipitation-runoff model that accounts for contributions of meltwater from glacierized areas. Remote sensing studies include the application of gamma ray and passive microwave to the measurement and observation of snow pack water equivalent, the use of aerial photography for surface water velocity measurements in rivers with moving ice, and the application of conductivity and time domain reflectometry to ice thickness measurement. The Division is responsible for the Agricultural Land Drainage Research Project which should be fully underway in 1983-84 with the selection of two or more field areas for intensive investigation. The major long-term objective is to gain an understanding of the hydrologic effects of both surface and subsurface modifications to drainage in agricultural areas.

The Ground Water Division carries out investigations of ground water in permafrost areas, the interactions between northern mining activity and ground water systems, the application of geophysical techniques to the solution of hydrogeological problems, and the modelling of ground water flow systems. It is heavily involved in studies of contaminant transport in subsurface waters and the geochemical controls that influence this transport. Contaminant transport studies have been conducted at a number of sites and include tracer investigations at Chalk River, Ontario; arsenic contamination at various locations in Nova Scotia, New Brunswick and Ontario; and pesticide contamination near Osoyoos, British Columbia. A major research project sponsored by Atomic Energy of Canada Limited is studying the ground water aspects of the underground disposal of nuclear wastes in crystalline rocks. The effect of the ground water/aquifer system in mitigating the adverse effects of acid rain is under investigation, principally at a field site near Sault Ste. Marie. In the North, research is directed toward ground water discharge and recharge under permafrost conditions; studies of the effect on the ground water regime of engineering structures and developments such as pipelines and roads, and vice versa; and investigations of the relationships between ground water flow systems and mining excavations. An investigation is under way into the deep water-bearing formations of the western Canada sedimentary basin in the vicinity of the International Boundary. This is in response to concerns regarding the potential transboundary effects on ground water which might be created by the proposed deep aquifer developments for water supply for coal development in the United States.

The Snow and Ice Division conducts investigations of the movement of water through a mountain snowpack and continuing evaluations of the mass, energy and water balances for selected glaciers in the Coast Mountains. The Division is responsible for the long-term undertaking to prepare a complete inventory of Canadian glaciers. Other studies include the measurement of the liquid water content of wet snow and an examination of the metamorphism of dry snow. Glacier ice coring near Mount Logan, Canada's highest mountain, is yielding information on past climatic changes and on levels of atmospheric contamination. Field studies in central and northern British Columbia are furnishing knowledge that will be essential in assessing the contribution of glacier melt to stream runoff in basins proposed for hydroelectric power development.

(ii) National Water Research Institute (NWRI)

The NWRI is located at the Canada Centre for Inland Waters at Burlington with regional offices at Vancouver and Winnipeg. The Institute conducted research, development, engineering or scientific activities in the following areas during 1983: eutrophication; Thompson River algal ecology; northern hydrology limnology (Yukon); habitat studies; lacustrine sediments; WHO Collaborating Centre on surface and groundwater quality; pathways, fate & biological impact of toxics in prairie lakes & rivers; origin & pathways of mercury in Manitoba reservoirs & Qu'Appelle River; prairie lakes physics; the Tobin Lake project; cultural impact on benthic communities of the Qu'Appelle River lakes; nutrient and contaminant pathways in prairie drainage systems; sources, speciation and concentration of organotin and organolead; hydrogeochemical responses of Turkey Lakes to acid rain; availability, transport and removal of trace elements in lakes and streams; fate of organotins in aquatic systems; availability of trace metals in suspended and bottom sediments; geochemical controls of aquatic system response to acid rain; particle size and composition effect on toxics concentration in sediment; historical contamination of Lake Ontario by organics from Niagara River; fate and impact of effluents on an ecosystem; utilization of chemicals by protozoa; accumulation and effects of contaminants in aquatic biota; evaluation of environmental distribution of toxics in model ecosystems; accumulation and degradation of organic contaminants in fluvial systems; correlation and prediction of contaminant hazards; the bioavailability of organic contaminants in sediment; organic contaminant sources in the Great Lakes basin; chlorinated hydrocarbons in sediments and biota of the Great Lakes; microbial transformations of PCB; degradation rates and products of organic contaminants by bacteria; chemistry of chlorinated hydrocarbons at the air and water interface; toxicity and biodegradability of organic contaminants by eukaryots; trends in radioactive contaminants in the Great Lakes; radium-226 pathways - Port Granby waste management site to Lake Ontario; radionuclide pathways in the Niagara River and Lake Ontario; aquatic pathways of radionuclides released by uranium mining; persistent toxic substances in urban runoff; Toronto area watershed management study; comparisons of flow models; ice jams and floods; frazil ice; oil spills in lakes and seas; sediment transport under ice cover; friction factor for mobile boundary channel flows; sediment load measurement; updating of users manual for mobed; ice problems in Millbrook at Kentville, N.S.; design of diversions and conveyance channels; modelling of solid and liquid transport in storm water system; transverse mixing in ice-covered rivers; flood forecasting; ice thickness measuring; energy - artificial islands; economic development - marinas; air-water interaction; turbulent mixing beneath wind-generated waves; wind-wave flume operation; shoreline evolution, Lake Erie; shore recession, nearshore baseline data, nearshore sediment data service, economic shore management; national calibration service; lake acidification and sediment trace metal release in macrophytes lakes; contaminant content of aquatic macrophytes in a contaminated stream; control of eurasian water milfoil; aquatic macrophytes and acid rain; cladophora in the Great Lakes; taste and odour problem in drinking water from Lake Ontario; effects of climatic change on water quality; effects of acidification on organic matter cycling in shield lakes; metal cycles in softwater lakes in relation to lake acidification; sulfur and selenium pollution of softwater lakes in Northern Ontario; atmospheric deposition from coal-fired power plants; impact of peat as an energy source upon northern aquatic ecosystems; paleolimnology of acid susceptible lakes; biogeochemical processes in Great Lakes sediments-paleoenvironment; arsenic and selenium pollution of the Great Lakes; sediment bank-Great Lakes; sediment phosphorus regeneration in Lake Erie; nutrient processes at different thermal stratas in Lake Ontario (1982); aquatic invertebrates as indicators of environmental change; Great Lakes water chemistry atlases, vol. 2, Lake Erie; nutrient and contaminant transport and sediment movement in Lake Ontario; bioavailability of phosphorus; productivity and phosphorus limitation in Lake Superior phytoplankton; Lake Erie surveillance continuity; cladophora abundance in Lake Ontario and nearshore aesthetics; dynamics of nutrients and organic substances in polluted systems; assessment of microbial activities in freshwater ecosystems; binding capacity of lake water polysaccharides; physiological impact of organic colloidal fibrils in lake water; regulating phytoplankton by coprecipitation of phosphate with calcite; nutrient transformations in lakes; biosynthesis-contaminant inhibition; lake restoration by hypolimnetic aeration; calcite precipitation effect on phosphate in Lake Ontario thermal bar; Lake Ontario nutrient assessment study; applications of optical measurements to lake research; operational water quality and contaminant transport models; stratification and air-sea interaction; coastal exchange dynamics; fate of organic contaminants in the

aquatic environment; environmental simulation-statistical analysis; aquatic regime acidification models and monitoring; coastal transport models; vertically profiling and bottom mounted current meters; water movements in the central basin of Lake Erie; Lake Ontario physical limnology studies; Great Lakes climatic atlas (volume 2); physical limnology study of a Yukon Basin Lake; analysis and interpretation of Lagrangian Drogue Data; pollutant transport through porous-media and surface-water interfaces; exploration of narrow-bore WCOT columns for faster analyses of toxics; determination of elements and organometals by ICAP & microwave plasma; electroanalytical techniques in water analysis; high pressure liquid chromatography for trace organics; toxaphene methodology; radioimmunoassay techniques for dioxins; benzofurans and dioxin methodology; legionella; mesoecosystems and microbial nitrogen cycle methodology; bacterial toxicity workshop; bacterial surveillance and microbial response to acid stress; methods development for herbicides; quality assurance programs; development of methods and certified reference materials (inorganics); preservation studies for inorganics; organics standard reference materials and quality control studies.

(iii) The Water Resources Branch

The newly-created Hydrology Division of the WRB implements and co-ordinates data interpretation and network evaluation activities in the eight regional offices of the Water Resources Branch at Dartmouth, Longueuil, Guelph, Winnipeg, Regina, Calgary, Yellowknife and Vancouver. The primary objective of the Division is to improve the effectiveness and efficiency of hydrometric data collection activities through the use of analytical techniques for transferring information from gauged sites to ungauged sites. These analytical techniques are used to determine the number, type, location and operation schedule of stations for economically meeting prescribed coverage and accuracy requirements. The Headquarters Division develops manuals of procedures, guidelines and standards in hydrological analyses for operational use across the country. It provides consultation services and carries out joint studies with the regions on hydrological problems. It operates the Canadian HOMS National Reference Centre which is part of the program of the World Meteorological Organization for the transfer of hydrological technology among more than 50 countries of the world. It also co-ordinates hydrological training in Canada for candidates from developing nations with fellowships funded by the United Nations Development Programme.

The Water Survey of Canada Division is the agency responsible for the collection of information on water quantity from over 2600 sites in Canada. To oversee such a large network, the Water Resources Branch employs more than 300 engineers and technicians to maintain the gauging stations and assemble the data. The eight regional offices of the Branch collect the field data in accordance with national standards, carry out the computations necessary to transform raw field data into a format suitable for dissemination and then pass the data to the central computer storage and retrieval facilities in the Hull-Ottawa area known as HYDAT. To ensure uniformity in the measurement and recording of water data (streamflows, water levels and sediment data) the Water Survey conducts the Canada-wide program under co-operative federal-provincial cost-sharing agreements. The stations operated by Quebec are linked to the federal network through the Water Survey's regional office in Longueuil. Other provinces conduct some field surveys, usually on a short-term basis, for preliminary feasibility studies and for water quality purposes. Companies and commissions operating hydroelectric stations also collect water data related to the operation of their facilities.

In a continuing effort to provide data to meet federal, provincial and user needs, the Water Survey is continually reviewing and updating its data collection, computation and dissemination procedures to make use of the latest technology. For example satellite data collection platforms (DCP) and data acquisition and telemetry systems (DATS) are being installed at selected stations to improve monitoring and to provide timely data.

Implementation of the national FLOOD DAMAGE REDUCTION (FDR) PROGRAM in co-operation with the provinces continued. The aim of the program is to discourage future flood-vulnerable developments in designated areas by having the senior levels of government withhold support for such developments. By July 1983 maps prepared and

designations made covered almost 200 communities in New Brunswick, Quebec, Ontario, Manitoba and Saskatchewan. All maps produced are referenced in DOE's WATDOC system.

(b) The Canadian Wildlife Service

The Canadian Wildlife Service of the Environmental Conservation Service carried on activities to preserve endangered waterfowl habitats, research into effects of waterborne and other pollutants on wildlife, and research on aquatic ecology and limnology in national parks.

3. Canadian Forestry Service, Environment Canada

The Canadian Forestry Service conducts hydrologic research at four of its regional research centres, i.e., Maritimes in Fredericton, Great Lakes in Sault Ste. Marie, Northern in Edmonton and Pacific in Victoria. The group at the Maritimes centre reported no activity in 1982-1983.

(a) Great Lakes Forest Research Centre

Twenty small catchments, each 4 to 7 ha in area, in the Algoma district of Ontario, are being monitored for precipitation, throughfall, stemflow, forest floor percolate, soil percolate at four levels and for total output of the small feeder streams. This is part of a multi-agency multi-disciplinary study whose purpose is to look at terrestrial, aquatic and fisheries parameters with respect to acid rain. Eight small catchments are being monitored for flow and water chemistry east of Lake Nipigon where black spruce is being harvested by both clearcut and strip-cut methods. This is a continuation of work conducted from 1972 to 1976 in the jack pine type area at the Experimental Lakes Area near Kenora where clearcutting was the only harvesting system in use.

(b) Northern Forest Research Centre

Three forested watersheds greater than 125 square kilometres in area have been found suitable to host a watershed management project. These will be presented to the Alberta Departments of Environment, Energy and Natural Resources as candidates for a project to ascertain the scaled-up effects of forest harvesting practices designed specifically to increase the annual water yield by 15% or more. It is hoped that one of the watersheds will be designated during 1983 so that preharvest streamflow evaluations can start in the fall and a detailed forest management plan covering harvesting activities during the next 15 years can be prepared. The Alberta Government has been informed that the Marmot research program should continue through the 1988 water year in order to achieve any statistical level of confidence on the data from the streamflow changes resulting from the harvest treatment on the Twin Creek subbasin of Marmot that was installed during 1978-1979.

(c) Pacific Forest Research Centre

Carnation Creek project - primary work continues to involve a slope hydrology study of soil water or groundwater behavior processes and logging-induced changes. Much of the field work is completed, including case studies of two small land slides. Detailed studies of subsurface water movement pathways and rates are being undertaken from July 1983 to June 1984. Plot studies to determine the fate of urea fertilizer applied on snow have been conducted at Spillimacheen (near Golden) and Green Mountain (near Nanaimo). Meteorological stations are being maintained at these sites to facilitate extrapolation of climatic data. Rain-on-snow studies continue to be of high priority in B.C. in relation to rate-of-harvest, and potential impacts on rain/snow peak flows, aquatic habitat and fisheries values. For coastal areas, hydrologists have concluded that forest harvesting has a significant potential for increasing peak flows resulting from rain-on-snow events. Concern over this possibility is being expressed in terms of limitations on the rate at which companies are being allowed to harvest timber. This past winter detailed plot studies were conducted to investigate and measure differences in rain-on-snow runoff between open and adjacent forested areas in the Jamieson Creek watershed and in the Queen Charlottes. A computer program is being developed to evaluate or integrate effects of rain-on-snow runoff on a watershed basis. These research activities are expected to

increase in the near future because of the importance of this runoff process in British Columbia.

4. Atmospheric Environment Service, Environment Canada

In support of national needs in operational hydrology, intensity-duration-frequency statistics for over 500 stations across Canada were updated to 1981 with data in both hardcopy and microfiche. Preparation of a new rainfall atlas for Canada was initiated with 106 maps completed. A study on the time distribution of storm rainfall recommending specific rain storm time distributions for various Canadian climate regions was completed. Significant improvements to the Storm Analysis Program were implemented. A complete storm analysis can now be processed within two weeks, once the input data are available in computer-compatible form. Fifteen major storms were processed and published in the "Storm Rainfall in Canada" series. A re-evaluation of the critical meteorological conditions leading to the maximum flood on the Stikine River in northern British Columbia was completed.

An assessment of the climate network needed to monitor monthly temperature and precipitation for evaluating the water resources of the Mackenzie River Basin was completed and recommendations were submitted to the Inland Waters Directorate/Atmospheric Environment Service Task Force on Hydrometeorology Network Expansion - Mackenzie River Basin. The final report on the Lake Okanagan Evaporation Study was completed.

Weekly monitoring of hydrometeorological impacts continued with the regular production of national maps of water budget parameters. The mapping of water budget output was improved significantly and plotted time series of the water-budget components updated each week are now available.

A large Nipher-type shield, designed to reduce precipitation undercatch on recording precipitation gauges, has been field tested during the last three winters. Modifications were completed in 1982 and prototypes have been redeployed at eight stations across Canada. Meteorological sensors were installed and tested successfully on a Bristol data collection platform operated by Inland Waters Directorate on the Ottawa River. This prototype station has provided experience in determining the advantages and problems of operating a joint data collection platform station, and in assessing data from data collection platforms compared to those from standard synoptic or climate stations.

The application of remotely-sensed meteorological parameters to water resource management problems continued to be an active area of development. The Image Transformation and Analysis System software package supported many specialized hydrometeorological analyses of remotely-sensed satellite and radar data. These included the monitoring of surface water temperatures and snow cover from satellite data and the analysis of precipitation from digital radar data. A hybrid analogue-digital image analysis procedure was developed on a microcomputer system to map snow cover using standard satellite photo imagery. Staff also participated in the multi-agency Canada/U.S. Joint Prairie Snow Cover Runoff Study. The 1982 experiment was to develop the capability of mapping a real snow cover on the Canadian Prairies, integrating ground based, airborne and satellite data. Data were collected along 1100 km of flightlines over Saskatchewan.

The hydrometeorological network of observing stations around the Great Lakes was assessed for the International Great Lakes Technical Information Network Board established by the International Joint Commission. Water temperature maps of the Great Lakes and Scotian Shelf/Fundy area were prepared on a bi-weekly basis from digital infrared satellite data and on an opportunity basis for the Grand Banks.

As a complement to a climatological statistics package developed to serve marine interests (MAST), computer software was also devised for coastal and land station data (LAST) to provide graphic and statistical summaries from the climate archive for inland areas.

During the year, the Canadian Air and Precipitation Monitoring Network (CAPMON) was formed by amalgamating smaller environmental networks. Under the Long Range Transport of Air Pollutants Program (LRTAP) a joint working group with the U.S.A. reported on the

present state of knowledge of atmospheric processes and numerical modelling. Scientists in the Air Quality and Inter-Environmental Research Branch are participating with Ontario and the Federal Republic of Germany in studying long-range transport models which include both wet and dry deposition processes.

5. Energy, Mines and Resources

(a) Geological Survey of Canada (GSC)

The GSC is working on a wide range of subjects more or less closely related to hydrology. These include: development of seismic reflection techniques for the mapping of buried valleys and the delineation of potential aquifers; study of the relationship between vegetation and snow patches in arctic Canada; compilation of a new map of permafrost in Canada, to include information on ground ice distribution; evaluation of the relationship of the chemistry of tree rings (the heavy metal content) and flood frequency; observation of the occurrence of permafrost in arctic beaches; study of the nature of recent sedimentary fill in various types of lake basins in Canada, and of recent tectonic disturbances of the fill; research into the relationship between hydrological parameters and changes in grain size distribution of stream beds; a groundwater geochemistry program for mineral and hydrocarbon exploration; several studies of the properties and distribution of permafrost in various parts of Canada; airborne gamma ray snow surveys during the late fall and winter in cooperation with the National Hydrology Research Institute; lake sediment geochemistry surveys as part of the National Geochemical Reconnaissance Program; detailed geological and geophysical studies of geothermal energy resources in southwestern British Columbia in cooperation with B.C. Hydro and Earth Physics Branch, EMR; and the investigation of the relationship between metal content of surface waters and the geological environment.

In addition, the Geological Survey provides background information and geological support to the nuclear waste management research program and the acid rain research program.

(b) Earth Physics Branch (EPB)

Work related to hydrology is undertaken by the EPB in two main areas: geothermics and permafrost studies. The movement of groundwater can have a profound effect on the thermal regime of the upper part of the earth's crust. Almost all aspects of the geothermics program involve this effect in one way or another. They include: hydrological studies of sedimentary basins for their low grade geothermal energy potential; hydrological studies of areas of high grade geothermal energy potential (e.g. young volcanic centres); and hydrological analysis of different types of rock fractures for their thermal structures (e.g. in support of the nuclear waste management research program).

Geothermal studies at the EPB also seek to improve the knowledge of permafrost processes and the distribution of onshore and subsea permafrost. Research on the dynamic behaviour of permafrost and its significance to frontier hydrocarbon exploration, production and transportation is conducted primarily through contracts. Moisture migration phenomena in frozen soils are a focus of research. Field observations and laboratory experiments include: investigation of stresses and water movements during secondary frost heaving; laboratory frost heave testing; studies of the phase composition of submarine permafrost; investigation of soil freezing in association with a buried chilled pipeline in a large scale test facility; joint operation of the Calgary test loop; investigation of frost heave in association with buried refrigerated pipelines in a large scale outdoor facility; and investigation of processes of water and ice redistribution through studies of stable isotopes.

Research on the distribution of permafrost include: ground ice and permafrost investigation in the Yukon; investigation of the impact of climatic change on the thermal regime of permafrost; distribution of permafrost in the Mackenzie Delta-Beaufort Sea; and research on state of the art permafrost analysis capabilities of geophysical tools, e.g., radar and electromagnetics.

(c) Surveys and Mapping Branch (SMB)

The Geographical Research Division, SMB, is compiling a new map of drainage basins in Canada, at a scale of 1:7,500,000 for inclusion in the National Atlas of Canada.

6. Agriculture Canada

Agriculture Canada's Research Branch has undertaken research in hydrology at various locations. Agricultural meteorology research on modelling of water flow in the soil-plant-atmosphere system was done at Ottawa. The measurement of crop water use efficiency was conducted at Beaverlodge, Alberta, and at Swift Current and Ottawa. Each of the seven soil survey units in the provinces/regions have undertaken hydrological activities to relate soil properties and geohydrological features to the water and climate regime of each region. Research programs on irrigation requirements are on-going in the Okanagan valley, southern Alberta and southern Ontario. The hydrological impact of agricultural land drainage and manure management on both water quantity and quality is a component of drainage research at Agassiz, B.C. and at Lethbridge, Winnipeg, Ottawa and Harrow, Ontario. Hydrologically related land quality problems such as soil erosion and soil salinization received research attention in the Peace River district, and at Lethbridge, Swift Current, Guelph and Ottawa.

7. Newfoundland

Memorial University: A study of orographic rainfall enhancement over the N.E. Avalon Peninsula, using radar and autographic raingauge observations, commenced in summer 1982. The relationship between the radar-derived rainfall estimates and the corresponding gauge data from eleven sites, together with the orographic effects, is being examined for selected cases of frontal rainfall. Meanwhile further observations are continuing during summer and fall 1983. Graduate student research in the Department of Geography includes the environmental and social impacts of urban development on watersheds in the vicinity of St. John's and the effect of peat mining in Central Newfoundland. Field and laboratory studies of the pathways of herbicides in Newfoundland soils have been initiated. In addition to research in the open Atlantic Ocean and Southern fjords of the island, the Newfoundland Institute for Cold Ocean Science conducts estuarine and land/water studies as follows: a) Analyses of trophic structure according to size in a series of lakes on the Avalon Peninsula. These data are being gathered for comparison with size structure phenomena observed in other experimental lake regions; b) Primary fish production in the waters of Cat Arm reservoir being constructed in western Newfoundland. This work is part of a study examining the effects of large impoundments on fish populations, and is being done in cooperation with Newfoundland Hydro; c) Studies of insect production and pike predation in the Minipi Lakes region of south-central Labrador. This work attempts to elucidate the factors responsible for the growth of brook trout; d) The response of aquatic insects and periphyton to spruce budworm spraying.

The faculty of Engineering has initiated experimental work to study the frictional properties of sea ice. Also within the Faculty's Ocean Engineering Research Group, studies of environmental loadings of offshore marine structures by sea ice and icebergs is undertaken. Studies are listed in "Work in Progress" reports, and reported in "ICE" and other publications. The Centre for Cold Oceans Resources Engineering (C-CORE) is continuing with the measurement of stress in pack ice, and of predicting failure strengths based on stress history. Indirect methods of measuring stress by acoustic propagation, anisotropy and conductivity are being evaluated. Remote sensing work is concentrating on high-frequency systems for measuring surface currents and winds and the detection of pack ice and icebergs.

8. New Brunswick

The Water Resources Branch of the Department of the Environment is active in assessing the Province's water resources, in flow and flood forecasting and in encouraging applied research on ice mechanics and ice jam problems. Considerable experience has been gained in the application of remote sensing techniques to snow distribution estimation for use in flood forecasting. Assessment of water availabilities in five of the seven regions of the Province have been published. Draft reports of the last two regions have been completed.

A study was also published recently on wells that dried up in northeastern N.B. following the 1982 earthquake events. Hydrological analyses have been carried out for various watersheds in the Province in connection with hydrotechnical studies under the Canada-New Brunswick Flood Damage Reduction Program. The long-term Nashwaak Experimental Watershed Project located in central New Brunswick is continuing. Impact and recovery are monitored. Water and energy balance, streamflow regime, snow cover, water chemistry (including acidity of precipitation), throughfall and soil moisture are being studied. A number of research papers and project reports are available. The project began in 1970 and was designed to determine the impact of certain forest management practices on environmental quality and on the hydrology of the watershed. The management of the project is provided by a Technical Committee which is comprised of university researchers (UNB) and government representatives.

The New Brunswick Subcommittee on River Ice has been established with members from Environment N.B., Environment Canada and the N.B. Electric Power Commission under the Flood Forecasting Technical Committee. The main goals of the subcommittee are related to the collection of data on river ice and the promotion of ice related research. An Ice Workshop is planned to be held in Fredericton in June, 1984 and is being organized by Environment New Brunswick and the University of New Brunswick.

The University of New Brunswick's department of Civil Engineering has been involved in the evaluation of sediment production from stream banks, sediment yield from watersheds as a result of rain storm events, changes in channelized river reach with time and the investigation of flow through bends in laboratory and natural channels. Work is continuing on the project on flow under ice covered rivers and on the effects of drainage in an agricultural area near Maugerville, N.B.

9. Nova Scotia

Technical University of Nova Scotia, Centre for Water Resources Studies: The Halifax Urban Watersheds Program continued with monetary support from NSERC and the University. Considerable support in terms of expertise has been contributed by Environment Canada and the City of Halifax. One full year of water quality data has been collected. Quantitative runoff models have been adapted for use on local computing equipment and are being calibrated. In addition, a water quality model is being developed for the research lakes. Advisory panels on stormwater quality and quantity, on-site disposal, and the use of roofwater for domestic supply have been active.

10. Quebec

University of Quebec in Chicoutimi (UQAC) During the past year, research at UQAC was mainly centred on space and time characterization of rainfall for urban drainage applications. Studies are being conducted on real-time operation of a hydroelectric system using a conceptual hydrological model. Research has continued with Ecole Polytechnique de Montréal to study the rainfall-runoff phenomena in the Montreal region and to investigate the design of a rainfall-runoff measurement network. The question of how to select the most appropriate plotting position formula in hydrologic frequency analyses is being investigated thoroughly in cooperation with L'Institut national de la recherche scientifique - eau.

INRS-Eau, un des centres de recherche de l'INRS (Institut national de la recherche scientifique): Les méthodes traditionnelles d'évaluation des quantités d'eau disponibles sont insuffisantes et souvent mal adaptées face à la complexité des problèmes suscités par les usages conflictuels de la ressource eau. L'amélioration de ces méthodes, et le développement de méthodes tenant mieux compte des divers aspects de la gestion intégrée, nécessitent une meilleure connaissance des phénomènes hydrologiques pour améliorer la représentation des processus impliqués.

Dans ce cadre, les activités de recherche portent sur les sujets prioritaires suivants: la modélisation déterministe permettant d'effectuer la simulation et la prévision des écoulements en tout point d'un bassin versant en tenant compte des éléments du bilan hydrologique et des caractéristiques du bassin; la comparaison par simulation des lois statistiques adaptées aux crues des rivières du Québec afin d'en déterminer la

distribution la plus adéquate; le développement et l'application de techniques statistiques de rationalisation des réseaux hydrologiques (données météorologiques, hydrométriques et de qualité de l'eau), afin d'optimiser l'acquisition de l'information en fonction des objectifs visés; l'analyse rationnelle des informations fournies par la télédétection en vue d'améliorer la connaissance de la variation spatiale de phénomènes hydrométéorologiques et hydrologiques.

Les activités de recherche à l'Université Laval couvrent: modélisation mathématique de l'écoulement en rivières; comparaisons des modèles existants et adaptation aux conditions canadiennes; analyse hydrologique de petits bassins versants; crues et étiages; modèles de génération régionale de débits; modèles de prévision de déficits et de surplus en eau; étude du comportement hydrologique d'un petit bassin au moment de la fonte; étude des caractéristiques physiques et hydrologiques d'un couvert de neige; modèles mathématiques des eaux souterraines.

En collaboration avec l'Institut de Recherche d'Hydro-Québec, Hydro-Québec Montréal développe une série d'outils mathématiques basée sur la programmation dynamique afin d'optimiser la gestion des systèmes hydriques. Le défi particulier est la prise en compte dans le mécanisme décisionnel, du degré d'incertitude inhérent à toute prévision des apports naturels.

11. Ontario

McMaster University: Hydrological research at McMaster University is carried out in the departments of Geography, Civil Engineering, Geology and Chemistry. One major emphasis is northern hydrology, with research projects on: (1) snow hydrology, involving the metamorphism of very cold snowpacks and the effects of Arctic towns on snowmelt rates; (2) lake ice freeze-up and break-up processes; (3) permafrost hydrology involving the surface and subsurface flow of Arctic slopes, and the water balance of northern basins; (4) hydrometeorology including evaporation in a subarctic environment and the distribution of snow precipitation in drainage basins; (5) wetland hydrology, including a comparison of hydrological processes in Arctic and subarctic wetlands, and modelling the effects of uranium mining tailings on wetlands underlain by permafrost. Another major research direction is in water quality. This includes a study of acid rain, a study on the quality of snow as influenced by a northern settlement, and the water chemistry of carbonate rock terrains. The groundwater dynamics and the flow velocities in underground pipe networks in several karst regions of Canada are also being investigated. In terms of hydrological modelling, research continues in urban storm water modelling, and the stochastic analysis of floods on a regional scale.

Studies at the University of Ottawa concerned flood frequency, space-time hydrologic modelling and stochastic hydrology.

Queen's University was involved in real-time flood forecasting using stochastic models, simulation of quality and quantity of urban runoff, the development of urban design storms and the assessment of the impact of agricultural drainage on flooding. Most hydrological research at Trent University is undertaken in conjunction with the Watershed Ecosystems graduate program offered jointly by the Geography and Biology Departments. Research over the past year has focussed on the hydrology and water chemistry of small wetland, agricultural and urbanizing catchments, and on hydrological and biological aspects of snow and lake ice cover in the Peterborough region, in Labrador, and on Axel Heiberg Island, N.W.T.

Great Lakes Institute, University of Windsor: The current hydrologic research of the Great Lakes Institute involves the study of four toxic contaminants: lead, cadmium, pcb's and octachlorostyrene in the St. Clair River, Lake Saint Clair and the Detroit River; their origin, transport, surface deposition and effects on aquatic life. This research is part of a large three year interdisciplinary study of toxic contaminants in the Essex Region.

York University, Department of Geography: The main area of interest concerns the biogeochemistry of stream ecosystems. Current research focuses on processes of nitrogen

transport and transformation in rivers, and the influence of nutrient dynamics in hydrologic source areas on stream water chemistry.

Kilborn Limited, Consulting Engineers: Studies carried out include: Flood plain mapping - Colborne Creek, for the Lower Trent Region Conservation Authority; brief on the Welland River flood plain studies, Ministry of Natural Resources; flood plain mapping and water management study - Delisle River for the Raisin Region Conservation Authority; Crowe River water management study - flood forecast manual and dam operational manual for the Crowe Valley Conservation Authority; a) Moira River water management study - flood plain mapping and preliminary engineering assessments, b) preliminary engineering - Corbyville to Foxboro, c) Ice Management Study, all three for the Moira River Conservation Authority; Flood Plain Mapping - Forwell Creek for the Grand River Conservation Authority; Flood Damage Reduction Study - Landry Creek for the Nickel District Conservation Authority.

MacLaren Plansearch Inc., a member of the Lavalin Group, has carried out a variety of hydrological studies in 1982-83. These include: performance evaluation of various snowmelt models for six test watersheds in Ontario; the assessment of the potential water supply from the proposed multi-purpose Rafferty Reservoir on the Souris River (Saskatchewan) involving estimates of long term evaporation rates and multi-reservoir model simulations; the modification of the widely used HYMO model for real time flood forecasting and continuous flow simulations with applications to the tidal power project in the Annapolis River basin, Nova Scotia, and the decommissioning of the Beaverlodge mine and mill complex in Northern Saskatchewan; the development of a flood warning system for the Sudbury area including an automated data collection network and computerized flood forecasting model; long-term hydrologic and water quality simulations of the South Nation River watershed with HSPF and field scale models to assess the effect of agricultural drainage on flood peaks and water supply; a water balance analysis of the East Bull Lake watershed in Northern Ontario with the installation and collection of data from ground water monitoring and hydrometeorological stations; and the continuation of stream flow gauging at Dawn and McClean Lakes in Northern Saskatchewan. While many of the studies concentrated on surface water hydrology, a number looked at the complete hydrological cycle with emphasis on surface water-groundwater interaction.

Marshall Macklin Monaghan Limited (Ontario) has undertaken hydrological flood damage and low flow augmentation studies for the Glengowan Dam, ice control study for the Credit Valley Conservation Authority, flood damage reduction study for the town of St. Mary's and a flood control and policy study for the town of Walkerton.

12. Prairies

Prairie Farm Rehabilitation Administration (PFRA) has been involved in providing water supply and flood studies for the design of proposed water development projects, collecting basic hydrometric data for future studies (e.g. Spring Runoff Monitoring Program), providing flood potential analyses for existing projects under the PFRA Dam Safety Program, providing hydrologic and hydraulic analyses for the Federal-Provincial Flood Damage Reduction Program, and providing hydrologic assistance for various components of the Federal-Provincial Drought Proofing Studies.

13. Manitoba

Manitoba, Department of Natural Resources: Phase One of the five-year Agreement Respecting Flood Forecasting is near completion. Work under this agreement between Canada and Manitoba commenced in 1981. The object of the study is to improve forecasting procedures for the Red, Souris and Assiniboine River Basins in Manitoba. Under Phase One three runoff simulation models have been calibrated on the Boyne River Basin. The results will be compared to the accuracy of the current forecasting procedure. If the results show significant improvement, Phase Two will proceed wherein the selected model will be applied to the Red, Assiniboine and Souris Rivers.

The Domain Drain Area Crop Demonstration Project was initiated under the terms of the Canada-Manitoba Subsidiary Agreement on Value-Added Crops Production. The Domain Drain and the Mannes Drain watersheds, located adjacent to each other, have been instrumented

with seven standard rain gauges, a recording rain gauge, two temperature accumulators, two humidicells and two stream gauges. The objective is to determine the effects of drainage improvement and land use changes in the Domain Drain watershed on the runoff regime. The Mannes Drain watershed is being monitored as a "control" watershed.

The Water Resources Branch is continuing to study the feasibility of enhancing both the quantity and quality of groundwater by injecting high quality surface runoff water into both surficial sand and gravel aquifers and confined bedrock aquifers. A water transfer mechanism and an aquifer monitoring system have been completed to assess the feasibility of transferring water from the La Salle River near Elie, Manitoba during the spring runoff period to a sand and gravel aquifer which is the source of the municipal water supply. Undesirable water quality characteristics during the runoff period in 1983 prevented the testing of the transfer system.

A study to define the capacity of major aquifer units in the province is concentrating primarily on the Assiniboine Delta Aquifer, a large surficial sand deposit located along the Assiniboine River east of Brandon, Manitoba. Field activities are being carried out to establish a data base that will be compatible for aquifer modelling analyses. Both groundwater studies are being carried out under terms of the Canada-Manitoba Interim Subsidiary Agreement on Water Development for Regional Economic Expansion and Drought Proofing.

University of Manitoba, Department of Civil Engineering, has been involved in: the analysis of width-depth relationships in rivers; a re-evaluation of flood frequency for the Red River to incorporate historical data using a technique based on the Hurst statistic; the analysis of hydrometric networks through the use of simple statistics (this work is being performed on the Pembina River Basin, and it is hoped that these statistics may be related to physiographic conditions within the basin); and review of the variation in localized rainfall patterns in the Wilson Creek experimental watershed on the Manitoba escarpment.

University of Winnipeg, Department of Geography, is looking at 19th century hydrology of the Red River through archival sources to consider the nature of the hydrology in inter-flood years; and studying Paleo-channels of the Assiniboine River and the effect of rerouting the Assiniboine on the Red River.

14. Saskatchewan

Saskatchewan Environment reports that Phase I of the Drought Proofing studies under the Canada-Saskatchewan Interim Subsidiary Agreement on Water (SAW) was completed by March 1983. Phase II, the drought sensitivity analysis, which is aimed at an assessment of the cost of droughts in Saskatchewan, has now been started. Phase III will define drought proofing strategies. Phases II and III are expected to be completed during the next year and a half.

Ground water investigations have led to the preparation of the following reports (Subject/Consultant/Status of Report): Estevan Valley Aquifer System Re-evaluation - Part 1/Beckie Hydrogeologist Ltd./Final; Groundwater Resources of the Judith River Formation in Southwestern Saskatchewan/Silverspoon Research Cons. Ltd.(S.H. Whitaker)/1st Draft; Hatfield Valley Aquifer System - Melville Region/Sask. Research Council/Final; Hatfield Valley Aquifer System - Waterhen River Area/Sask. Research Council/Final; Hatfield Valley Aquifer System - Wynyard Region/Sask. Research Council/Final.

Potentiometric maps have been published by the Water Rights Branch for 19 National Topographic Map areas in Saskatchewan showing the approximate elevation of the groundwater level at 15 metre contour intervals. The maps also show ground water drainage basins, direction of lateral ground water flow and flowing artesian well areas.

The Hydrology Branch undertook hydrologic investigations associated with basin planning studies and watershed development proposals and provided hydrologic services for provincial agencies including water supply, flood peak potential, safe building elevation, drainage control assessment and environmental impact assessment studies. The Hydrology Branch also carried out reservoir and river system operation planning and provided

provincial streamflow forecasting services. The department represented the province and provided support in administering interjurisdictional water resources.

The University of Regina, Faculty of Engineering, has undertaken research in the generation of streamflow data.

15. Alberta

The Hydrogeology Branch of Alberta Environment's Earth Sciences Division is continuing its geophysical and drilling activities to enhance the ability to predict groundwater behavior in Central Alberta. The Branch is involved in the detailed evaluation of groundwater potential and delineation of the glacial hydrostratigraphy in the vicinity of Bonnyville, Grand Centre and the Cold Lake Air Weapons Range. A modelling of subsurface contaminant transport is currently in progress. To demonstrate its use in a practical situation, the model will be applied to simulate leachate migration from a sanitary landfill. The model will further be used in designing an effective groundwater monitoring network and a suitable remedial scheme for aquifer restoration.

The University of Calgary, Department of Geography: a study of the impact of surface coal mining on surface and subsurface flow in the Corbin Creek basin of the Elk-Crowsnest Watershed, B.C. was begun in 1978. Two hydrometric station networks were installed in two sub basins: one in the actively mined area and the other in an adjacent control basin with characteristics similar to the mined basin. The major result of the investigation to date is a confirmation of the dominant role played by unsaturated flow in stream discharge in the mined basin.

Marshall Macklin Monaghan Limited (Calgary) has been involved in urban stormwater simulation and master drainage planning for the City of Edmonton; floodplain mapping and low flow augmentation studies for Alberta Environment; hydrological and hydraulic assessment related to flood damage reduction strategies for Saskatchewan Environment; the analysis of water quality in a water supply reservoir and of potential sources of contamination for the City of Calgary; and the development of a flood damage reduction program for a municipality subject to flooding from tsunamis for the City of Port Alberni and B.C. Environment.

16. British Columbia

The B.C. Ministry of Environment continued development on regionalization of peak flows in order to provide a simple procedure for estimating extreme peak flows from ungauged watersheds. Hydrologic input to Provincial Strategic Plans continued; this consists of review and analysis of hydrometric, meteorologic and snow course data and providing estimates of hydrologic characteristics for ungauged watersheds. Estimates of dependable water supply for various drought durations and return periods were provided for irrigation projects. Development and expansion of the Province's snow pillow network continued with application of remote sensing and data transmission.

The University of British Columbia, Department of Civil Engineering, has undertaken studies into the migration of constituents in groundwater resulting from waste disposal or spills, the effects of subsaturated flow, and horizontal flow on septic tank and aerobically treated effluent; and water balance analysis for leachate flow through and from sanitary landfills. Work was also undertaken on the development of methods for computing hydrologic design parameters such as mean flows and floods using both local and regional data and taking into account the uncertainty in both.

The Department of Geological Sciences has carried out research into multiple seepage faces on heterogeneous hillslopes, the role of groundwater in genesis of ore deposits, the relative importance of hydrogeologic conditions and economic constraints in siting and design of waste-management facilities, rainfall-runoff modelling, effects of groundwater flow on the near-surface thermal regime, nonisothermal groundwater flow in fractured mountainous terrain and its impact on geothermal exploration in the Coast Mountains of British Columbia, pore pressures on the dynamics of faulting (thermal pressurization), and the development of a continuum model for flow and transport in fractured porous media.

The Department of Soil Science has been involved in measuring and modelling the effect of understory removal on tree water use, growth and evapotranspiration in a thinned, 30-year old Douglas-fir stand; determining the water use efficiency of a 20-year old Douglas-fir stand by making energy balance/Bowen ratio measurements of water vapour and carbon dioxide flux above the stand; and determining the variation in growing season water deficits on a forested slope using water balance analysis. Studies have been carried out on the hydrology of ponding on Lower Fraser Valley agricultural lowland soils within the context of soil structure degradation and timeliness of farming operations. Investigations have included the causes of ponding, the mechanisms of formation of low infiltrability layers and the physical and hydrologic characterization of low infiltrability layers.

The Department of Geography has been studying evapotranspiration comparisons between rural and suburban sites in Greater Vancouver, parameterization of suburban evapotranspiration, the water budget of a suburban area in Vancouver, runoff and sediment sources in B.C. Coast Mountains, evolution of water quality and denudation in alpine watersheds, and land use water quality interactions in the Okanagan Valley.

The Faculty of Forestry has been conducting research into snowmelt rates in forest and clearcuts in coastal B.C. during rain-on-snow, the separation of groundwater-surface water using oxygen isotopes to estimate the effect of logging on water supplies, and has continued work on the Jamieson Creek experimental watershed to determine the effects of logging on hydrology in Vancouver catchments.

The Bio-Resource Engineering Department has been studying the impact of drainage water on water quality under a specific climate regime; specifically, the effect of agricultural drainage on the quality of water, and the relationships between the precipitation, drainage discharge and nutrient leaving from an agricultural drainage basin. Studies were also carried out into the effects of precipitation and evapotranspiration on groundwater table fluctuations in agricultural lands with and without drainage systems. Field data obtained in 1982 are being used to verify the predicted water table positions generated from a hydrologic water balance model. Conclusive results will be reported after the completion of 1983 field observations (December, 1983).

Other work undertaken at the University of British Columbia includes the development of simple but physically based models of evaporation from bare soils, the development, purchase, and construction of equipment to rapidly and routinely determine the hydraulic conductivity characteristics of undisturbed soil samples (one-step method), and the calculation of rainfall erosivities for selected sites in the Lower Fraser Valley from hourly rainfall values.

Peter Ward & Associates, Vancouver, have adapted a numerical model of physical and water chemistry parameters in reservoirs (U.S. Army Corps of Engineering's CEQUAL R1 Model) to Canadian conditions. The project was conducted on behalf of B.C. Hydro to determine the impacts of proposed reservoirs on the Stikine and Iskut Rivers on release water quality, particularly water temperatures. The model simulates the reservoir physics with a one-dimensional Lagrangian approach and carefully inputs the meteorological and other heat inputs. The hydrology of the inflowing streams including seasonal changes in discharges, suspended and dissolved solids and water temperatures were measured in the field over a 2-year period and were included in the model.

17. Northwest Territories

In the Northwest Territories, Indian and Northern Affairs Canada (INAC) continued the operation of the small stream network along southern NWT Highways, the collection of basic climate data at eleven remote Water Survey/INAC hydrometric stations across the N.W.T., and the collection of snow survey results from about thirty INAC operated stations and another thirty-seven operated by Environment Canada and Transport Canada.

18. Bibliography

A cross referenced guide to 478 Canadian hydrology and water resource publications and documents issued during the period July 31, 1982 to July 31, 1983, is available from: Secretariat, Associate Committee on Hydrology, c/o Environment Canada, Inland Waters Directorate, Ottawa, Ontario, K1A 0E7.

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X MINING GEOPHYSICS

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27. Bibliography

1. Introduction

Twenty-five organizations reported research in mining geophysics in 1983 - roughly the same number as in 1982. Despite a more complete reporting by those responding, the apparent level of effort is distorted by a lack of information from several organizations in both the private and government/university sectors.

Total expenditure reported in 1983 was \$5.5 million, comprising \$4.2 million from industry, \$0.9 million from government and \$0.4 million from universities. A corresponding 1,554 person-months of research employment was divided between industry with 1,225 months, government with 264 months and university with 65 months. Within industry, \$3.2 million was spent by three companies: Scintrex, Kenting and Phoenix Geophysics. Since no information was provided by either Hunttec or Geoterrex, both big spenders in 1982, it is likely that the total industrial effort probably did not decrease substantially from the \$7.9 million reported in 1982. The industrial effort continues to

be supported by approximately \$1.0 million from the ETDF (Exploration Technology Development Fund) program of the Ontario Ministry of Natural Resources.

Level of effort in the government and university sectors is also understated, no figures being available from the Ontario Geological Survey or several of the major universities. However, the available information suggests that there has been a drop of about 20-30% in the level of effort from 1982 to 1983.

Research is underway in all areas of instrumentation, survey methods and interpretation. There was continued emphasis on the use of microprocessors, both in data acquisition and processing/interpretation. A highly successful symposium was held on this subject in Toronto in January 1984.

The reporter wishes to acknowledge the help of his colleague Stephen Reford in the compilation of this report.

INDUSTRY

2. A-Cubed Inc., Mississauga, Ontario (P. Annan, G. Black, D. Leggatt, J. Lobach)

During the past year, systematic progress was made in the development of the PROSPECT series of airborne electromagnetic survey systems. The PROSPECT series of AEM systems is based on the use of real-time, high speed digital processing. They are designed to provide greater depth of penetration, better target discrimination and higher spatial resolution than previously available in airborne electromagnetic systems. They are designed with the geophysical end user in mind and will be applicable to discrete anomaly mapping projects, as well as resistivity mapping.

3. Androtex Limited, Mississauga, Ontario (A. Rogozinski)

Development commenced on a new version of the frequency-scanning, large fixed source (Turam) electromagnetic method. It differs from the conventional method in that it utilizes a single (rather than double) receiving coil, which leads to high sensitivity and programmable frequency scanning capability. Expected improvements from the new approach will be increased survey production, measuring accuracy and exploration depth. Eighteen person-months and \$75,000 in R&D are being devoted annually to this project. This work is supported by an Ontario Ministry of Natural Resources (ETDF) grant.

4. Barringer Research Limited, Rexdale, Ontario (L.R. Daubner, R. Lett, D. Gladwell, A. Loveless)

Development is underway on the application of reflectance radiometry to alteration mineral description. This technique provides for the rapid, semi-quantitative determination of alteration minerals in geological materials by examination of features visible as reflectance spectra in the 2.0 to 2.85 micron range. Tests on standard minerals and rock sample suites from uranium and gold deposits show that discrimination and semi-quantitative analysis to 2 moded % is feasible.

Work commenced on comparative tests of the COTRAN and INPUT airborne electromagnetic (AEM) prospecting systems. Modifications were made to the COTRAN AEM installation so as to allow the COTRAN and INPUT receivers to operate in parallel from the same aircraft. Test flights with the INPUT transmitter and bird over local conductors clearly demonstrated the greater S/N ratio and time constant resolving power of the COTRAN receiver, even with a single receiver coil. Similar tests with the COTRAN bird are in progress. This company is devoting ten person-months and \$50,000 to these projects annually.

5. Dighem Limited, Toronto, Ontario (D.C. Fraser, S. Kilty)

Research has been focussed on extending the capabilities of airborne helicopter exploration and mapping. The objective of this project is to expand the dynamic range of present HEM technology in order to measure apparent resistivity values from .1 ohm-m to 50,000 ohm-m. Resistivity values will be calculated utilizing a new inversion technique

that is both rapid and economical. The hardware consists of a high frequency (50 KHZ) active EM system. To date the hardware has been assembled and ground tested. The inversion techniques have been developed and are presently undergoing feasibility tests. Twenty-four person-months are being devoted annually to this project.

6. Geonics Limited, Mississauga, Ontario (J.D. McNeill)

Research and development continue to be carried out into the use of electromagnetic techniques for both geological mapping and the direct detection of conductive orebodies at the rate of about sixty person-months per year. The work includes research using both transient and multispectral techniques employing both local (dipolar or large loop) and remote (plane wave) sources. Some of this research is supported by the IRAP (Industrial Research Assistance Program) of the National Research Council.

7. GEM Systems, Incorporated, Don Mills, Ontario (I. Hrvoic, J. Myzyk)

Activities include the miniaturization of the Overhauser airborne magnetometer and the development of both Overhauser and proton portable/base station magnetometers with memory. Eighteen person-months and \$85,000 in R&D are being devoted annually to these projects. Support has been provided by the Ontario Ministry of Natural Resources through an ETDF grant.

8. Instrumentation GDD Inc., Ste. Foy, Quebec (R. Desbiens, E. Gaucher)

Development continued on the electronic chain level capable of measuring the difference in elevation and the slope distance between two points not necessarily in visual contact. The results are stored in memory for processing during field use, improving the precision to 0.2%.

The Beep Mat, an automated and miniaturized EM mineral detector, was designed to detect hidden, near-surface conductive or radioactive boulders. Research has resulted in improved penetration while maintaining lightness of the instrument. Detection capabilities are now, for example, a 12-inch diameter boulder containing 0.2% copper at a depth of two to three feet and near-surface high grade mineralized bodies at five or six feet. Twelve person-months and \$100,000 in R&D are being devoted annually to these projects.

9. Kenting Earth Sciences Limited, Ottawa, Ontario (J. Irvine, R. Stemp, O. Cepella, T. Payne, R. Moore, J. Wilson, I. MacDonald, D. Wensorra)

Installation of the Commercial Airborne Gradiometer System (CAGS) was completed and the systems fully tested. The rate of four samples per second doubled the required rate yet still fell within the noise requirements. The system was tested and passed by the CAGS Committee and the required 16,000 line km of flying were completed. The program was carried out with financial assistance and technical cooperation from the Ministry of Natural Resources, Ontario and the Federal Government.

Development is ongoing for video applications to replace the 35 mm flight-path camera. An ARINC interface is being developed to retrieve all navigational information for digital recording. To date, it has been used with Loran-C, doppler and inertial systems. Latitude and longitude information is retrieved and recorded.

The development and field testing of a high-powered, fixed wing airborne EM system is underway. The system is being installed in a Canso aircraft for evaluation by extensive flight testing.

A total of fifty-eight person-months and \$755,000 in R&D are being devoted annually to these projects.

10. Lamontagne Geophysics Limited, Toronto, Ontario (Y. Lamontagne, A.E. Wieckowski, R. Cockburn, I. Hrvoic, J.C. Macnae, R. Huxter, N. Vallean)

A borehole measurement system that includes a winch, automatic controller and fibre optic link is under development. A one-component system measuring the axial magnetic field component for use with the UTEM system is completed. Development of multi-component sensors and a pole-dipole IP tool is in progress. Support for this project is provided by the Ontario Ministry of Natural Resources (ETDF funding) and by mining companies.

In conjunction with GEM Systems, Inc., development of the GSM-18 proton precession magnetometer system with memory storage has been completed. Research continues into the GSM-10 portable, high-resolution, fast cycling Overhauser effect magnetometer system as well as computer interfaces for both systems.

A high-power (15 KW), high-voltage regulated transient EM transmitter is under development. It will include novel switchmode regulation and packaging techniques. Support for this project is provided by the Ontario Ministry of Natural Resources (ETDF funding).

In the field of model studies and theories for electromagnetic interpretation, model curves for 1200 scale models, as well as numerical studies, are available for interpretation. A new depth sounding processing technique was developed and is being refined.

A total of forty-eight person-months and \$125,000 in R&D are being devoted annually to these projects.

11. McPhar Geophysics Limited, Willowdale, Ontario (A. Stevens, M. Yamashita, P. Bhattacharyya, J. Liber, B. Stovehaus)

Development was successfully completed on a user-friendly, five-frequency ground electromagnetic system based on the measurement of tilt-angle and ellipticity and providing digital data storage. Forty-eight person-months and \$190,000 are being devoted annually to the development of this system. This work is supported by the Ontario Ministry of Natural Resources with an ETDF grant.

12. Paterson, Grant and Watson Limited, Toronto, Ontario (N.R. Paterson, D.J. Misener, S.W. Reford, I.N. MacLeod, P. Walker)

With the assistance of an ETDF grant of the Ontario Ministry of Natural Resources, the company continued with a program to develop a comprehensive computer software library for both internal and public geophysical interpretation applications. In conjunction with R.C. Bailey (University of Toronto) and with the assistance of Dataplotting Services Inc., a method of ternary colour mapping of three-channel (U, K, Th) radiometric data has been developed. This facilitates radiometric zoning by plotting both the relative distribution of the radioelements (as colour) and the overall response (as intensity) on a single map. This technique is now being used on a production basis.

In conjunction with R.N. Edwards (University of Toronto), a technique has been developed to invert multi-channel, frequency-domain ground EM data to an n-layered model earth. The technique is, in many ways, similar to the method for inversion of airborne EM data developed in 1982 (see 1982 Bulletin).

Refinements continued on a technique for the calculation of susceptibility at a variable depth surface from magnetic data. This was principally in the area of continuation from one specified surface to another.

A significant amount of effort in the past year has been directed toward the development of an extensive library of applications software for personal computers. Programs for the data reduction, forward modelling and filtering for such methods as magnetics, gravity, IP and Turam EM have been written. Applications software for graphics, plotting, splining and mainframe communications has also been developed.

A total of 30 person-months and \$105,000 in R&D are being devoted annually to these projects.

13. Phoenix Geophysics Limited, Willowdale, Ontario (P. Hallof, W. Pelton, J. Klein, G. Graham, B. Anderson, J. Sevenhuysen, L. Fox)

The uses of spectral I.P. in exploration were studied. Parameters were measured over base metal deposits such as volcanogenic massive sulfides, gold-bearing sulfides, copper-nickel and porphyry copper deposits. Spectral I.P. properties of hydrocarbon deposits and I.P. effects of alteration chimneys over possible sulfide-bearing deposits were also studied.

Remote sensing to improve the quality of magnetotelluric data was studied. Cross-correlation of data from two simultaneous MT soundings improves data quality by reducing correlated noise. A very satisfactory system was developed for both linked (by wire) and unlinked (synchronized clocks) modes.

Development has been initialized for a new high-frequency geophysical current source (3 KW/10 KHZ/10A) for use in I.P., EM. and applied field AMT. A prototype is expected by mid-1984.

Two hundred and forty person-months and \$700,000 in R&D are being devoted to these projects.

14. Questor Surveys Limited, Mississauga, Ontario (P.G. Lazenby, A. Becker)

Fundamental research continued on airborne EM principle and practice, using experimental equipment installed in a DC-3 aircraft. The system was upgraded by the addition of a microprocessor-controlled digital detector that automatically rejects atmospheric spikes, compensates for receiver motion effects, filters the acquired data and provides a monitor analog record. Several successful test flights were carried out over the Cavendish test range. Support for the project has been provided by the Ontario Ministry of Natural Resources through an ETDF grant.

15. Sander Geophysics Limited, Kanata, Ontario (G.W. Sander, N. McGowan, S. Ferguson, L. Archer)

An airborne Overhauser magnetometer is under development. The prototype gives sufficient signal to measure two readings per second with an accuracy and resolution of approximately 20 milligammas.

An 8 KHZ helicopter-borne electromagnetic instrument has been developed to measure the response due to fairly resistive sediments in an environment of very resistive rocks. The system consists of two horizontal coils mounted on the standard Sander Geophysics EM bird. Software was developed to produce maps of apparent conductivity. The system has been successfully implemented to map bands of siltstone in a Proterozoic basin environment.

Fifty-five person-months and \$213,000 in R&D are being devoted to these projects annually.

16. Scintrex Limited, Concord, Ontario (H.O. Seigel)

Investigations into mineral luminescence continue on a number of approaches simultaneously. A six-week field program has been conducted utilizing an airborne remote sensing system mounted in a vehicle, to study the photoluminescent response of Precambrian rocks and minerals. This program was conducted in collaboration with the Geological Survey of Canada. Further development of both the airborne system and hand-held portable luminex analysers continues. A new ingredient is a luminex borehole probe, being undertaken with assistance from the Ontario ETDF program. Laboratory studies of the mineralogy, geochemistry and spectral characteristics of photoluminescent minerals are also being carried out. Support for this project has been provided by the Federal Government.

A microprocessor-based ground geophysical system has been developed that integrates magnetometer/gradiometer and VLF (H and E field) measurements into a single portable unit. A common CPU, peripheral hardware and operating software are utilized. Support for this project has been provided by the Federal Government.

Through the use of a microcomputer and appropriate software, refined and tested over the past year, the commonly accepted Cole-Cole model spectral I.P. parameters may be determined from time domain transient curve information.

A program was started during the year to provide a better understanding of the factors affecting the performance of cesium vapour magnetometers with the objective of improving production technology and operating characteristics. Support for this project has been provided by the Federal Government.

A total of six hundred person-months and \$1,800,000 in R&D are being devoted annually to these projects.

17. Sonotek Limited, Mississauga, Ontario (J. Soltys)

Testing of the Automatic Aeromagnetic Digital Compensator (ADC) has been completed and the system is now available for commercial use. The system was developed in conjunction with the National Aeronautical Establishment of Canada (NAE) and the National Research Council (NRC). All design parameters were exceeded, resulting in a standard deviation of the compensated signal of less than 0.05 gamma for total field and less than 0.09 gamma for gradient. Important features of the ADC are: the instrument can be easily retrofitted into existing installations, aircraft compensation calibration is fully automatic and no active fields are produced.

GOVERNMENT

18. Geophysics/Geochemistry Section, Ontario Geological Survey, Ministry of Natural Resources, Ontario (R.B. Barlow, D.H. Pitcher, V. Gupta and J.A.C. Fortescue)

During the 1983 summer field season, survey activity and experimentation continued on the Night Hawk geophysical test range near Timmins, Ontario. Several new techniques were applied specifically to help resolve conductors in close proximity, with encouraging results. The Night Hawk grid was extended 300 m east for the purpose of acquiring survey coverage over the eastern extension of the conductive zones outlined to date. A line traversing the midpoint of the conductive zones was widened to permit accurate navigation by airborne systems. In addition, an alternative test range in Sheraton Township has been prepared for survey work in the future. At least 3 known conductors in this area are covered by the new grid system.

Both the development and data acquisition stages of a contract to test-fly a commercial aeromagnetic gradiometer have been completed by Kenting Earth Sciences Limited of Ottawa. Approximately 19,000 line km of aeromagnetic data were acquired in September and October of 1983 in southeastern Ontario. Several system tests were conducted in August for the purpose of benchmarking the signal-to-noise characteristics and the effectiveness of the compensation system. The results were impressive and demonstrated that the aeromagnetic gradiometer is now ready for commercial service.

An interpretation of the gravity data over the Sudbury area was completed over the summer season. The results are scheduled to be published in the "Ontario Geological Survey Special Volume on Sudbury". Eight profiles have been interpreted using two hypotheses with regard to the near-surface effects of the Sudbury structure. Modelling results have predicted the presence of a basic intrusion of larger areal extent at depth than the boundaries of equivalent surface rocks; this accounts for most of the 30 mgal gravity high in the area.

19. Resource Geophysics and Geochemistry Division, Geological Survey of Canada, Department of Energy, Mines and Resources (K.A. Richardson, P.G. Killeen, A.V. Dyck, C.J. Mwenifumbo, A.K. Sinha, Q. Bristow, R.L. Grasty, B.W. Charbonneau, K.L. Ford, V.R. Slaney)

A variety of borehole geophysical methods (nuclear, thermal, magnetic, electrical and electromagnetic) are being studied to contribute to the development of subsurface mining geophysics technology. This is accomplished by improving and quantifying these methods, establishing standards, developing calibration facilities for quantitative measurements, extending theoretical and physical modelling studies, and developing new interpretation techniques.

An electrochemical probe for borehole measurement of temperature, hydrostatic pressure, S.P., pH and fluid conductivity will soon be completed. Trial borehole logs corresponded closely with susceptibility measurements made on drill cores from test holes.

Development and application of airborne and ground gamma-ray spectrometric methods continued. A number of airborne gamma-ray surveys were flown. Ground investigations and interpretation of a 1982 airborne survey and other airborne test strips were carried out. Variations of radioactivity with soil moisture in various soil types were studied. An image analysis system was used to integrate airborne gamma-ray and aeromagnetic data with satellite imagery. Under contract, satellite imagery was used to produce fracture maps covering most of Ontario.

A total of 264 person-months and \$900,000 in R&D are being devoted annually to these projects.

UNIVERSITIES

20. Department of Geology and Geophysics, University of Calgary (K. Duckworth, A.R. Bays, C. Cummins, R.J. Brown)

Development commenced on a low frequency (0.01 Hz to 200 Hz) EM prospecting system using a fixed loop source and SQUID magnetometer detector. Hardware for this system has been assembled and field trials should begin in 1984.

The Turam prospecting system has been studied by means of physical scale modelling. Initial studies of conductive overburden and conductive environments have been conducted and extensions to multiple target cases are in hand.

An electromagnetic scale modelling laboratory is under development in association with the previously mentioned projects. The system records all signals as a digital time sequence and can operate in broad band on discrete frequency modes.

A study of the effect of permafrost on the I.P. effects associated with metallic minerals is being extended to a wider range of metallic minerals and synthetic rock specimens. To date, it has been found that the Cole-Cole parameters M, T and C are all strongly affected by low temperatures, the predominant effect being an increase of M and T.

A simplified theoretical formulation for inductive coupling effects in multifrequency induced polarization is under development. A generalization of the Cole-Cole impedance model has been developed which provides for improved representation of amplitude and phase spectra while retaining a parametric simplicity comparable to that of the Cole-Cole model with consequent ease of computation. The present model treats the homogeneous earth but extensions to a layered earth are in progress.

21. Department of Geological Sciences, University of Saskatchewan (Z. Hajnal, M.R. Stauffer, B. Pandit, B.L. Reilkoff, D. Gendzwill)

The petrophysical characteristics of the Athabasca Basin rocks are being studied on a regional scale. Laboratory measurements determine the density, resistivity, velocity, porosity, permeability, magnetic susceptibility and geological properties of a suite of core samples. Results show that the physical properties of the sandstone change with

depth. The regolith properties vary in accordance with level of oxidation. Four sets of samples have been analyzed to date.

High resolution reflection studies in the Athabasca Basin are underway. Data processing techniques were developed for the analysis of poor signal to noise level data, which appear to be characteristic of the known seismic experiments in the basin. A static correction technique, using Hilbert transforms and a two-dimensional wave number filtering method were developed and applied to some experimental data sets with very encouraging results.

Graphical interpretation techniques for the Geonics EM 34-3 are being developed for electromagnetic sounding over a two-, three- or four-layered earth, to be applied in potash mines.

A total of twelve person-months and \$40,000 in R&D are being devoted annually to these projects.

22. Department of Geophysics, University of Western Ontario (A.E. Beck, W. Ravenhurst, R.B. Hearst)

A comprehensive study of time-domain EM responses from conductive environments has been started as interpretation techniques have not kept pace with the advances in instrumentation. Problems under study include the lack of availability to the field geophysicist of thin sheet and sphere model solutions, and response distortion due to ring currents in conductive overburden.

The bipole-dipole differential method of resistivity depth sounding has been evaluated by computer modelling. This new technique is thought to possess greater resolving power and depth of investigation than conventional arrays.

23. Geophysics Division, Department of Physics and Department of Geology, University of Toronto (G.F. West, J.S. Holladay, D.E. Boerner, P. Walker, M. Bloore, A. Wieckowski, D. Pai, R.N. Edwards, B. Lo, S. Cheesman, M.N. Nabighian, G. Oppliger, J. Yeoh, J.D. McNeill, G.M. Levy, R.C. Bailey, T. Urbancic)

A controlled source method has been devised for sounding/profiling of stratified terrain which synthesizes the chief advantages of various existing direct current and electromagnetic methods and takes account of anisotropy. It has been designed to exploit the modern capability to perform forward and inverse modelling computations for complicated stratified earth models and arbitrary source configurations. A broad-band, high accuracy, computer-assisted measurement system is currently being field tested. The envisaged field procedure employs a long grounded wire source and broad-band measurement of electric and magnetic fields at a small number of sites about the wire.

Use of the EM analogue scale modelling facility continued in the past year with particular emphasis on the response of free-air models to various kinds of time-domain EM equipment.

Alternative numerical approaches to computer modelling of EM data are under investigation. Interpretation of EM survey data will become simpler and more robust for target conductor models such as a plate situated in a conductive host medium under an overburden.

A 2-D numerical modelling program for the magnetometric resistivity method (MMR) has been prepared. MMR responses are calculated for an arbitrary 2-D conductivity distribution and arbitrary source-receiver locations. An exact theoretical derivation has been carried out for the MMR response of a half-plane plate conductor buried in a full space for arbitrary source-receiver locations.

Instrumentation and interpretation aids have been developed for the crosshole MMR method, which requires two boreholes in the vicinity of the target. The receiving coil in one hole measures, as a function of depth, the component of the magnetic field of the transmitter current (source in the other hole) parallel to the hole. Interpretation of

the MMR anomaly will indicate the position, orientation, relative conductance and type of mineralization of the conductor. Support for this project has been provided by Newmont Exploration Ltd.

Approximate calculations of the electromagnetic response of buried lamellar conductors in a conductive medium have been made. The problem is solved in the frequency domain, for an airborne frequency domain prospecting system, and directly in the time-domain, for a large-loop, transient (TEM) system. Using borehole geophysical logging techniques, a study is underway as to whether or not statistical correlations can be used to delineate lithologic units favourable for gold mineralization. To study certain associations, a number of boreholes in Archean rocks of the Larder Lake, Ontario area have been logged with gamma, I.P., resistivity, S.P. and temperature methods.

These projects have been supported by the Natural Sciences and Engineering Research Council of Canada, the Ontario Geoscience Research Fund and the Department of Energy, Mines and Resources.

24. Department of Geological Sciences, Queen's University (D.V. Woods, S. Taylor, J.W. MacGaughey, D.H. Krentz, R.G. Barlow)

A means of resolving multiple, small conductive bodies from complex borehole TEM response curves for detailed interpretation, is being investigated. The method consists of continuation of late-time TEM fields outward from the borehole, and will be tested using a numerical and analogue forward modelling. The basic theoretical framework of the technique is presently being formulated.

Research is being carried out to improve the field methodology and data processing techniques of small-scale reflection surveys in order to obtain high-resolution reflections from shallow bedrock interfaces. The unconformity between Paleozoic limestones and shales, and Precambrian crystalline basement at depths of 50-250 m in the Kingston vicinity, is being used as a test case for the technique. Preliminary seismic property investigations have been completed and results are being used to design optimal field procedures for the next phase of the project.

A study of transient electromagnetic soundings in southern Ontario is underway. This research project will initially be concerned with shallow TEM soundings in the southeastern and south-central Ontario Paleozoic formations for the purpose of optimizing field procedures and interpretational techniques. The electrical targets will be the conductive, basal clastic units of Ordovician-Cambrian ages, and the resistive oil shales of the Silurian shale sequence.

Ten person-months and \$23,000 in R&D are being devoted annually to these projects.

25. École Polytechnique/IREM MERI, Montréal, Québec (R. Bazinet, G. Pouliot, M. Chouteau, D. Couture, M. Vallée, P. Trudel)

A magnetotelluric study of the Abitibi Belt is underway. Forty-four MT soundings were completed last summer in order to gain an understanding of the deep structure of the Abitibi Belt. The data are now being processed and a final report is in preparation.

Computer programs and interpretation charts were developed for VLF borehole logging. The model used was a thin conductive rectangular plate represented by a set of concentric filaments.

Instruments and techniques are being developed for high-frequency (up to 1 MHz) MT surveys. These will be useful in high resistivity shield environments and for civil engineering applications. The sensors have been developed, field strengths evaluated and receiver design is now in progress.

A variety of prospecting tools are being evaluated for locating orebodies in long "structural" conductors delineated by INPUT surveys. A test site was selected and gravity, EM-17, magnetics, UTEM, I.P., geochemical and geological surveys were performed. Drilling is underway at this time. Results are now being evaluated.

A magnetotelluric scale modelling facility for the study of 3-D structures is in the first stages of construction.

A total of forty person-months and \$350,000 in R&D is being devoted annually to these projects.

26. Department of Geology, Université Laval (M.K. Seguin, D. Chénard, L. Samson, E. Gaucher, R. Desbiens, R. Fortier)

The operation principle, calibration and mode of utilization of a portable conductivity/susceptibility meter for use in the study of rocks and ore minerals has been completed. The apparatus has the advantages of measuring samples of varying shapes, being simple to use and carry, and is inexpensive. The magnetic susceptibility and electrical conductivity may be measured from samples in the laboratory or in the field through the construction of master curves.

This project has been undertaken in conjunction with Instrumentation GDD Inc. Three and one half person-months and \$6,000 in R&D are being devoted annually to this project.

27. Bibliography

- Bristow, Q. 1983. Airborne gamma-ray spectrometry in uranium exploration. Principles and current practice. *Int. J. Appl. Radiat. Isot.*, 34, 199-229.
- Collett, L.S., Barringer, A.R. and Loveless, A.J. 1982. COTRAN electromagnetic survey of the NEA/IAEA Athabasca Test area. In: *Uranium Exploration in Athabasca Basin*, Geological Survey of Canada, Paper 82-11, 179-190.
- Couture, D. 1983. *Interprétation de diagraphies électromagnétiques TBF*. M.Sc. Thesis. École Polytechnique.
- Dyck, A.V., Scott, W.J. and Lobach, J. 1982. Waterborne resistivity/induced polarization survey of Collins Bay, Wollaston Lake. In: *Uranium Exploration in Athabasca Basin*, Geological Survey of Canada, Paper 82-11, 281-290.
- Dyck, W., Cameron, E.M., Richardson, K.A., Brameld, P., Bell, K., Card, J.W., Chowdhury, M.I., Gingrich, J.E., Roze, V., Shah, S.R.A. and daSilva, F.G. 1982. Radon, gamma-ray spectrometer, and trace element investigations of soils at the Midwest and McClean uranium deposits. In: *Uranium Exploration in Athabasca Basin*, Geological Survey of Canada, Paper 82-11, 215-242.
- Ford, K.L. and Ballantyne, S.B. 1983. Uranium and thorium distribution patterns and lithogeochemistry of Devonian granites in the Chedabucto Bay area, Nova Scotia. In: *Current Research, Part A*, Geological Survey of Canada, Paper 83-1A, 109-119.
- Hajnal, Z., Stauffer, M.R. and King, M.S. 1982. Petrophysics of the Athabasca Basin near the Midwest uranium deposit. In: *Uranium Exploration in Athabasca Basin*, Geological Survey of Canada, Paper 82-11, 303-310.
- Killeen, P.G. 1983. Borehole logging for uranium by measurement of natural gamma radiation. In: *Nuclear Geophysics*, C.G. Clayton (Editor), Pergamon Press, 231-260.
- Killeen, P.G., Bristow, Q. and Mwenifumbo, C.J. 1983. Gamma-ray logging for uranium; status of international efforts to resolve discrepancies in calibration models. In: *Transactions of the SPWLA (Society of Professional Well Log Analysts) 24th Annual Logging Symposium*, Calgary, Paper AA, 1-16.
- Lazenby, P.G. and Becker, A. 1983. Redefinition of the INPUT system. *ETDF/BILD summary of research 1981-1983*. E.G. Pye and R.B. Barlow (Editors), Ontario Geological Survey Misc. Paper 115, 1-9.
- Mansinha, L. and Mwenifumbo, C.J. 1983. A mise-à-la-masse study of the Cavendish Geophysical Test Site. *Geophysics*, 48, 1252-1257.

- Maurice, Y.T. and Charbonneau, B.W. 1983. Recognition of uranium concentration processes in granites and related rocks using airborne measurements. In: Current Research, Part A, Geological Survey of Canada, Paper 83-1A, 277-284.
- Mwenifumbo, C.J., Urbancic, T.I. and Killeen, P.G. 1983. Preliminary studies on gamma-ray spectral logging in exploration for gold. In: Current Research, Part A, Geological Survey of Canada, Paper 83-1A, 391-397.
- Paterson, N.R. 1983. New Geophysical Guides to Ore Exploration. In: Bender, F., New Paths to Mineral Exploration, Proceedings of Third International Symposium, Hannover, Fed. Rep. of Germany, Oct. 27-29, 1982, Fed. Inst. for Geosciences and Mineral Resources, Hannover, 155-168.
- Paterson, N.R. 1983. Exploration Geophysics: Airborne. In: AGID Guide to Mineral Resources Development; M. Woakes and J.S. Carman (Editors), Report Series; No. 10, 121-152. Association of Geoscientists for International Development, Bangkok, Thailand, 1983.
- Paterson, N.R. 1983. Airborne Geophysics Industry. In: The Geosciences in Canada 1980, Part 1: Marine Geoscience in Canada; A Status Report; Prepared and Edited by the Marine Geoscience Committee of the Can. Geoscience Council; Geological Survey of Canada, Paper 81-6, Part 1, 82-85.
- Paterson, N.R., Grant, F.S. and Misener, D.J. 1983. Development of Computer Software for Geophysical Interpretation. In: Exploration Technology Development Program of the Board of Industrial Leadership and Development: Summary of Research 1981-1983; Ontario Geological Survey, Misc. Paper 115, 53-62.
- Richardson, K.A. 1982. Airborne gamma-ray spectrometric survey of the NEA/IAEA Athabasca Test Area. In: Uranium Exploration in Athabasca Basin, Geological Survey of Canada, Paper 82-11, 167-170.
- Sinha, A.K. 1982. Deep transient electromagnetic soundings over the McClean uranium deposits. In: Uranium Exploration in Athabasca Basin, Geological Survey of Canada, Paper 82-11, 273-280.
- Sinha, A.K. 1983. Deep multifrequency E.M. sounding at a site near Bowmanville, Ontario. In: Current Research, Part A, Geological Survey of Canada, Paper 83-1A, 133-137.
- Sinha, A.K. 1983. Airborne resistivity mapping using a multifrequency electromagnetic system. Geophysical Prospecting, 31, 627-648.

XI ENGINEERING GEOPHYSICS

Compiled by: J.A. Hunter

1. Université Laval
2. Queen's University
3. Nova Scotia Research Foundation Corporation
4. Gartner Lee Associates
5. Paterson, Grant and Watson Ltd.
6. Ontario Geological Survey
7. Geological Survey of Canada
8. Atlantic Geoscience Centre
9. Bibliography

1. Université Laval (M.K. Séguin)

Au cours de l'année 1983, M.K. Séguin, M. Allard et un groupe de chercheurs-étudiants du Centre d'études nordiques, Université Laval, ont poursuivi les études du pergélisol sur le versant est de la mer d'Hudson. Les travaux de terrain ont été concentrés dans la région des rivières Nastapoka et Sheldrake. Cette étude du pergélisol a été effectuée dans des sables et argiles marins ainsi que dans des dépôts littoraux grossiers de la mer de Tyrrell, des dépôts sablo-graveleux fluvioglaciaires et quelques tills. Les palses et buttes minérales cryogènes abondent dans les argiles et sables de fond de vallées. Le complexe de palses de toundra forestière se caractérise par de grands plateaux palsiques en érosion avec de gros coins de glace, des mares de thermokarst, des palses (sur argile et sur sable) très dégradées et de petites palses en croissance dans les espaces ouverts. L'épaisseur du pergélisol dans les dépôts grossiers varie de 0 à 22 m (généralement 10 à 19 m). Le mollisol atteint 1,7 m de profondeur. Les sondages de résistivité électrique et les profils de gradient géothermique indiquent des épaisseurs de pergélisol variables de 5 à 18 m dans les palses et buttes cryogènes argileuses.

2. Queen's University (D.V. Woods)

With funding from Ontario Hydro, a three-station array of vertical, short-period seismometers has been set up in the vicinity of Kingston, Ontario, to monitor local microseismicity. Stations were established at the Lennox Generating Station (LNX) near Bath, Ontario (44°08'42.1"N, 76°51'44.9"W), at the Hinchinbrooke Test Site (HBK) north of Verona, Ontario (44°34'38.4"N, 76°44'44.2"W) and near Gananoque (GNQ), Ontario (44°19'27.8"N, 76°11'09.6"W). The stations were connected via Bell Canada telephone line telemetry to the Geophysics Lab at the Department of Geological Sciences in May 1982. Signals from the three stations are multiplexed and then recorded in FM form on stereo tape recorders along with a time signal from WWV. An analogue record is also made from the Kingston (KGN) seismometer station located in the Geological Sciences building of Queen's University (44°13'38.0"N, 76°29'36.4"W). This analogue record is visually checked for seismic activity and recognized events are played back from the tape recorders to a four-pen chart recorder (one channel for each remote station plus the time signal). To date, no confirmed microseismic activity has occurred in the Kingston vicinity. Small seismic events occur frequently during normal weekday working hours and infrequently during evening and on weekends; however, they can all be attributed to local quarry or construction blasts because of their repetitive, near-surface locations. More remote earthquakes of magnitude 2.0 or greater have been observed in Ontario and northern New York State. These events have been more accurately located by the Eastern Canada Telemetry Network and the Lamont-Doherty Telemetry Network.

3. Nova Scotia Research Foundation Corporation (K. Howells)

Preliminary seismic experiments were carried out in November, 1983, near the Prince Mine, Cape Breton Island, Nova Scotia, to detect underground coal mine workings. Members of the Geophysics Division and the Geological Survey of Canada operated a multi-channel, digital, engineering seismograph in the constant offset reflection mode along a paved road passing over the main mine tunnels and abandoned workings at depths of 45-55 metres in a

2-metre thick seam within a Pennsylvanian shale-sandstone sequence. The seam dips gently to the east. The bedrock is overlain by 4-5 metres of surficial deposits. Step-out profiles were initially measured to determine seismic velocities and optimum offsets. The 275 metre-long constant offset seismic reflection traverse was measured using a seismic shot-gun source and 100 Hz geophones. Seismic equipment was provided by the Geological Survey of Canada. Initial results appear promising with enhanced reflections over the main tunnels and confused seismic reflections correlating with collapsed areas in the old, abandoned workings.

4. Gartner Lee Associates (D. Slaine)

Gartner Lee Associates have been actively involved in studies of the application of electromagnetic methods to mapping groundwater contaminants (see bibliography).

5. Paterson, Grant and Watson Ltd. (R.K. Watson)

In 1983 the company continued as prime consultants and managers of the AECL Master Contract for geophysical research in the Canadian Nuclear Fuel Waste Management Program. Electromagnetic (VLF) and magnetic gradiometer studies were carried out at two research sites, Atikokan and East Bull Lake. The magnetic gradiometer studies appear to have demonstrated a relationship between magnetic activity and fracture density in exposed rock. Gravity studies at East Bull Lake were carried out to provide additional data from which calculations of the size and shape of the gabbro-anorthosite intrusion were made. Rock densities were calculated from density profiles using Nettleton's method.

At East Bull Lake an interpretation of all geophysical data was done on an integrated data base to provide geological surface maps and cross sections which are as complete and thorough as can be made from geophysical data. The data base included aeromagnetic total field and gradiometer data, magnetic property measurements, gravity, density and helicopter EM and VLF data. Interpretation methods included susceptibility mapping, magnetic and gravity inversion to both simple geometric models and a matrix of vertical prisms.

6. Ontario Geological Survey (D. Russell)

An extensive deep drilling programme carried out by Ontario Geological Survey in the last two years has provided a wealth of information in the form of continuous cores to Precambrian basement and full suites of geophysical logs from nine boreholes across southern Ontario. In one of these boreholes, at Pickering, a sonic waveform log was used to confirm the exact depth of fractured zones, where core recovery was poor. Subsequently, a multi-level piezometer was installed in this borehole by John Cherry of the University of Waterloo with zones defined by this waveform log isolated for groundwater monitoring and permeability testing. Results from this work will emerge slowly as groundwater data are collected and correlated with log results.

As noted above, the Ontario Geological Survey has a wide range of geophysical logs and corresponding core through all types of lithologies. This resource appears to be a useful one for setting up correlations between log parameters and physical properties, especially for lithologies not usually cored. The Ontario Geological Survey would welcome any approach to do some work along these or any other lines using the data.

7. Geological Survey of Canada (J.A. Hunter)

Shallow seismic reflection studies were carried out over a number of sites across Canada to obtain reflections from the overburden bedrock contact in order to refine the "optimum window" technique. This technique has been designed for use with a 12 channel engineering seismograph with microcomputer assistance for seismogram analysis. Software has been written for an Apple II computer and is available on G.S.C. Open File.

A 13 channel marine seismic refraction eel has been tested in the Beaufort Sea and in the Atlantic shelf near Newfoundland. The eel is designed to be towed approximately 5 m above sea-bottom and to measure compressional wave velocities of the immediate sub-bottom. The eel was initially designed for the detection of shallow ice-bearing

permafrost in the Beaufort Sea floor but may also have applications in other sea-bottom engineering problems as well as defence research.

8. Atlantic Geoscience Centre (R. Parrot)

The Atlantic Geoscience Centre has continued its regional mapping program with multidisciplinary geophysical surveys to determine the distribution, character and genesis of seafloor sediments and features on the eastern Canadian continental shelf and in the Beaufort Sea. These regional programs provide the framework for more site and problem oriented surveys and allow information from these surveys to be extrapolated over a larger area. Projects were performed: to determine the regional distribution of sediments and features on the seafloor in the Beaufort Sea, Jones Sound, Davis Strait, Labrador Shelf and Sable Island Bank; to study the time and method of formation of various morphological features such as sand waves, ripples and iceberg scours seen on the continental shelves; to study the type and distribution of permafrost and its relationship to observed stratigraphy. Borehole and temperature probe data were related to regional seismic coverage to allow extrapolation of borehole results; to study the nature and occurrence of submarine slumps and turbidity currents on the continental slope using a wide swath sidescan sonar system; to study the mobility of modern sediments and the current and wave conditions required for remobilization of the sediments; to relate seismic data to information obtained from geotechnical tests and geological logging of boreholes and other samples; to map the occurrence and location of engineering hazards on the seafloor.

A.G.C. has also become more involved in joint research projects with industry through application of PILP, OERD and ESRF programs. These research programs are generally focussed on development of new techniques for the extraction of engineering properties from geophysical data, and also to provide better access to data held in the government laboratories. Projects were initiated: to provide support for the development of an 'acoustic drill' which will provide information on the properties of the sediments on the seafloor; to consolidate available data for sediment transport and iceberg scouring.

Further details of the activities and publications of the 100 scientists and support staff at the Atlantic Geoscience Centre can be found in the Geological Survey of Canada Report of Activities.

9. Bibliography

- Greenhouse, J.P. and Slaine, D.D. 1983. The use of reconnaissance electromagnetic methods to map contaminant migration. *Ground Water Monitoring Review*, 3(2), 47-59.
- Slaine, D.D. 1983. Predicting the response of mapping subsurface contamination with inductive conductivity techniques. In: *The Proceedings of the National Water Well Association 1983 Technical Education Session*, Ground Water Technology Division, St. Louis, Missouri, September, 1983, 33 p.
- Slaine, D.D. 1983. Geophysical mapping of subsurface contaminants. M.Sc. Thesis, University of Waterloo, Waterloo, Ontario, 192 pp.
- Woods, D.V. 1983. Region Seismic Monitoring: Annual Report of the Queen's Seismometer Array, 1981-82. Rept. No. 83226, Ontario Hydro, Toronto.

GUIDELINES FOR THE EDITOR AND REPORTERS
CANADIAN GEOPHYSICAL BULLETIN

1. The Canadian Geophysical Bulletin is an annual report of geophysical research and development activities in industry, government and universities in Canada. Its main purpose is to inform geophysicists in Canada and abroad of current projects, developments and publications in their own and related areas. At the same time, it provides an overview for those outside the earth science disciplines of the extent and directions of scientific research activity in this subject in Canada.
2. The Bulletin shall be made up of a collection of chapters authored by reporters named by the Editor, after consultation with the National Correspondents.
3. The Editor will review the chapter titles on an annual basis to ensure that together they continue to cover the full range of geophysical activities in Canada. He will then set a maximum length for each chapter after consideration of the following:
(i) the total length of the Bulletin, cover to cover shall not exceed 200 pages;
(ii) the importance of the chapter topic in both the national and international community; (iii) the number and productivity of Canadian workers in the field.
4. Each chapter shall begin with an index, include a one-page summary written by the appropriate reporter, followed by a succinct account of current activities and conclude with a list of reports and papers that have appeared in print during the previous calendar year. Abstracts, current year material and material in press or preparation will not be listed. Scientific publications in a recognized government series and appearing in the year under review may be included in the list of references. Theses accepted as part of a recognized graduate degree program during the year under review should also be included in the list of references.
5. The accounts of current activities are listed in each chapter under headings for each reporting research group. Each of these items should include a brief statement of current activities. Lengthy statements of results obtained will not be allowed. The latter should be abbreviated to not more than two or three typewritten lines.
6. Copy-ready material will be prepared by the Earth Physics Branch of EMR from clearly presented text supplied by the Editor not later than March of the year following that covered by the Bulletin. Reporters should supply the Editor with final, complete chapters that have been proof read. The layout, headings, sub-headings, references, etc. should follow the style of CGB Volume 36. If possible, chapters should be prepared on a Wang word processing unit and a diskette of each chapter provided to the Editor.
7. The Bulletin will be published by the Earth Physics Branch of Energy, Mines and Resources Canada as early as possible in the year following that which the material covers.

DIRECTIVES POUR LE RÉDACTEUR EN CHEF ET LES RAPPORTEURS
BULLETIN CANADIEN DE GÉOPHYSIQUE

1. Le Bulletin canadien de géophysique est un rapport annuel des activités de recherche et de développement géophysiques de l'industrie, du gouvernement et des universités au Canada. Son but principal est d'informer les géophysiciens au Canada et à l'étranger des recherches, des développements et des publications en cours dans leur propre domaine ou dans des domaines connexes. De plus, il fournit à ceux oeuvrant en dehors des disciplines des Sciences de la Terre une vue d'ensemble sur l'étendue et les directions de la recherche scientifique dans ce domaine au Canada.
2. Le Bulletin consistera en un ensemble de chapitres rédigés par des rapporteurs nommés par le rédacteur en chef après consultation avec les correspondants nationaux.
3. Le rédacteur en chef révisera les titres des chapitres sur une base annuelle afin de s'assurer que ceux-ci couvrent bien la totalité des activités géophysiques au Canada. Il fixera ensuite une longueur maximale pour chaque chapitre en tenant compte des considérations suivantes: (i) la longueur totale du Bulletin ne doit pas excéder 200 pages d'une couverture à l'autre; (ii) l'importance du contenu du chapitre tant sur le plan national que sur le plan international; (iii) le nombre et la productivité des travailleurs canadiens dans ce domaine.
4. Chaque chapitre commencera par un index, suivi d'un résumé d'une page écrit par le rapporteur approprié; résumé suivi des comptes rendus concis des activités en cours. Le chapitre se terminera par une liste des rapports et des articles qui ont été publiés l'année précédente. Les résumés, les références de l'année courante et les publications sous-presse ou en préparation ne devront pas être mentionnés. Les publications scientifiques apparaissant au cours de l'année considérée dans une série reconnue du gouvernement pourront être incluses dans la liste de références. Thèses acceptées pendant la période considérée comme partie d'un programme de diplôme reconnu pourront également être incluses.
5. Les comptes rendus des activités en cours pour chaque chapitre seront accompagnés de titres se référant aux groupes de recherches rapporteurs. Chacune de ces rubriques devra inclure un bref paragraphe sur les activités en cours. Les longs exposés des résultats obtenus ne seront pas autorisés. Ceux-ci devront être abrégés afin de ne pas excéder une ou deux lignes dactylographiées.
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