Energy, Mines and Resources Canada
Earth Physics Branch

Énergie, Mines et Ressources Canada
Direction de la physique du globe

CANADIAN GEOPHYSICAL BULLETIN

BULLETIN CANADIEN DE GÉOPHYSIQUE

Volume 35

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

Publié par le Comité National Canadien pour l'Union Internationale de Géodésie et de Géophysique du Conseil National de Recherches du 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 reference lists. Since 1974 the Bulletin has been published under the authority of the Canadian National Committee for the International Union of Geodesy and Geophysics.

The coverage of applied geophysics has been strengthened with the return of an expanded chapter on engineering geophysics. Petroleum geophysics will be incorporated beginning next year in a similarly expanded form. Many items in other chapters in the present volume are related to petroleum geophysics.

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. At the meeting of the CNC/IUGG in 1982 the relative lengths of chapters will be reviewed as well as questions regarding the general format and effectiveness of the Bulletin. Readers with views on these matters should write to the editor or to members of the Canadian National Committee. Those who have expressed their views this year are thanked for their interest. It is also a pleasure to acknowledge the assistance of Mrs. S.D. Fay at the University of Manitoba, and Mr. E.B. Manchee and Ms. J. Wagner in the Earth Physics Branch, Department of Energy, Mines and Resources.

The Bulletin is produced and distributed to readers inside and outside Canada by the Earth Physics Branch of the Department of Energy, Mines and Resources, at the request of the Canadian National Committee for the IUGG, and the Canadian Geoscience Council. Anyone wishing individual copies of back issues should request these from:

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There is no charge for the Bulletin, but the Canadian National Committee appreciates receiving similar national or international reports in exchange.

D.H. Hall
Editor

INTRODUCTION

Le Bulletin canadien de géophysique est un rapport annuel des recherches, des développements et des services géophysiques dans l'industrie, le gouvernement 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. Il est fait une brève mention des résultats de ces recherches, 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.

La présente édition traite plus en profondeur de la géophysique appliquée puisqu'un chapitre plus élaboré sur les applications techniques de la géophysique y a été réintégré. À partir de l'année prochaine, un chapitre également plus élaboré sur la géophysique du pétrole sera aussi ajouté au Bulletin. De nombreux articles ayant trait à la géophysique du pétrole apparaissent dans d'autres chapitres de la présente édition.

Le rédacteur en chef désire témoigner 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 n'ait pas plus de 200 pages, limite fixée par des contraintes financières. Lors de la réunion de 1982 du CNC/UGGI, les membres étudieront la question de la longueur des chapitres, de même que les questions relatives à la présentation et à l'efficacité du Bulletin. Les lecteurs qui désirent exprimer leur opinion à cet égard peuvent écrire au rédacteur en chef ou aux membres du Comité national du Canada. Nous remercions ceux qui nous ont fait part de leurs commentaires cette année. C'est avec non moins de reconnaissance que nous mentionnons les noms de Mme S.D. Fay, de l'Université du Manitoba, et de M. E.B. Manchee et de Md. J. Wagner, de la Division des sciences de la Terre du ministère de l'Energie, des Mines et des Ressources, pour l'aide qu'ils ont apportée.

Ce bulletin est publié et distribué aux lecteurs du Canada et de l'étranger par la Direction de la physique du globe du ministère de l'Energie, des Mines et des Ressources, à la demande du Comité national du Canada de l'Union géodésique et géophysique et le Conseil canadien des sciences de la Terre. Les demandes pour obtenir un exemplaire des numéros précédents doivent être adressées à:

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D.H. Hall
Rédacteur en chef

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I (A) GEODESY

Compiled by: D.E. Wells

1. Summary

During 1982 four major long-term projects each continued to attract workers from several organizations in Canada. These were Canadian participation in the NASA Crustal Dynamics Project, with visits of NASA mobile long baseline interferometry (LBI) equipment to Canadian sites scheduled to begin in 1984; the readjustment of the North American horizontal networks (NAD83) scheduled for 1985; the redefinition and readjustment of the North American vertical datum (NAVD) scheduled for 1988; and studies into applications of the Global Positioning System (GPS), which is scheduled to be fully operational by 1990. Canadian work to date on GPS was reported in a special issue of the Canadian Surveyor (Vol. 36, No. 1, March). Major, but somewhat less widespread, research efforts continued into Inertial Survey System (ISS) technology, satellite Doppler techniques, improvements to LORAN-C, local deformation studies, satellite altimetry, and UHF navigation.

Proceedings from three major 1982 meetings reported much of this work: the Third International Geodetic Symposium on Satellite Doppler Positioning, held in Las Cruces, NM, in February; the Centennial Convention of the Canadian Institute of Surveying, held in Ottawa in April; and the Fourth Canadian Symposium on Mining Surveying and Deformation Measurements, held in Banff in June. Canadian geodetic work was also well reported at the General Meeting of the International Association of Geodesy in Tokyo in May, and at the Third International Symposium on the Use of Artificial Satellites for Geodesy and Geodynamics in Ermioni, Greece, in September.

2. Geodetic Survey of Canada

(a) Satellite Doppler observations were made at 49 stations to strengthen and densify the primary framework and to strengthen and integrate lower-order horizontal control networks: 3 primary and 3 secondary stations in Quebec; 2 primary and 3 secondary in Newfoundland (Labrador); and 2 primary and 36 secondary in British Columbia. Triangulation-trilateration measurements were made in the Yukon settlements of Tagish and Teslin (4 new second-order control points), and at the Mactaquac, New Brunswick, hydro-electric site to monitor possible

structural movement (a 10-station trilateration network). Preparations began for visits of NASA mobile LBI equipment to Canada, including precise measurements to monitor local crustal motion at 2 sites (Gold River and Penticton, British Columbia), and preparatory reconnaissance at 2 other sites (northwest of Yellowknife, and at Whitehorse). Calibration baseline measurements were made at 5 locations; London and Burlington, Ontario; Moncton and Fredericton, New Brunswick; and St. John's, Newfoundland. Astronomical observations were made at 3 primary framework stations to provide improved first-order azimuth control, and at 46 additional points to provide local azimuth control, for deflection determination and for geoid studies, in Newfoundland (1), New Brunswick, (2), Quebec (4), Ontario (18), Alberta (1), British Columbia (14), Yukon (2), and Northwest Territories (7). ISS was used to provide mapping control and secondary network densification in Alberta, Saskatchewan, Northwest Territories, and Québec (with assistance from the provinces). Other surveys for mapping and as control for ISS traversing were established by satellite Doppler in the Northwest Territories, Saskatchewan, Manitoba and (with assistance from the Mapping and Charting Establishment of the Department of National Defence) in the arctic islands and Beaufort Sea Region.

(b) In a continuing program to strengthen the basic Canadian net, 3740 km of first-order levelling were completed in British Columbia, Alberta, the Northwest Territories, Manitoba, Ontario and Quebec. In addition, 380 km of special order levelling was completed in 4 areas: Penticton and Bennett Dam in British Columbia, and (for monitoring crustal movement on behalf of the Earth Physics Branch) on Vancouver Island and in the La Malbaie region of Quebec. About 12 000 km of level lines were inspected to help determine where relevelling is necessary and to revise out-of-date bench mark descriptions. New bench marks of various types were installed at 1845 sites.

(c) Preparations for participation in NAD 83 continued. All data, with the exception of data for the 1982 Doppler project, have been automated, evaluated and filed. Exchange of Canadian and United States data along the international network junction line was completed. Formats and procedures for future exchanges related to the continental adjustment were finalized. Development and testing is nearly complete on the Helmert block adjustment software (program GHOST) which will be used for the multi-level NAD83 continental framework adjustment and for the integration of blocks of secondary survey data. Area readjustments were computed for about 1650 stations, including 1100 stations in the arctic islands. About 2300 vertical control stations were readjusted, 1800 in the arctic islands and 500 in Saskatchewan. ISS data for about 1000 stations, and satellite Doppler data for about 300 stations, were processed. Work on NAVD began in 1982, in cooperation with the United States National Geodetic Survey (USNGS). For the continental readjustment, about 55 000 km of first-order level lines in Canada and about 100 000 km in the United States will be used to form the basic network. Additional first-order levelling will be integrated into the network. Modifications were made to the positional component of the National Geodetic Data Base, and some files of data remain to be loaded. Development of the data base component for observed data has been delayed until 1983.

(d) The NAD83 adjustment mathematical model was developed and tested (Steeves, 1982a). Network integration guidelines were produced for use both by federal and provincial agencies responsible for the integration (Steeves, 1982b). Geoid modelling software was further refined and documented (Lachapelle and Mainville, 1982). Refinements to GEODOP software were investigated and procedures for the calibration of Doppler satellite receivers were tested (Boal and Morris, 1982). A motorized levelling system was assembled and tested and a report will be prepared.

Development of the automatic star transit detector continued. The feasibility of developing a two-colour laser EDM instrument was investigated. Progress toward the geodetic application of GPS continued with the development of data analysis software at UNB and detailed equipment specifications at Canadian Marconi.

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

(a) Precise monitoring of the earth's rotation and polar motion by optical astronomical (PZT) and satellite Doppler (TRANET) methods continued from observatories near Ottawa and Calgary. The results are transmitted 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 Monitoring Service in Mizusawa, Japan, to facilitate evaluation of global parameters. PZT and satellite Doppler data from the two observatories for 1979-81 have been reduced to provide direct comparison of variations in station coordinates. Much improved results have been obtained for multiparameter reduction of the satellite Doppler data. Current research concentrates on analysis of systematic effects and improvement of error modelling to increase accuracy of global point positioning necessary for studies of crustal deformation and continental drift.

Research and development of astronomical and satellite LBI techniques continued in cooperation with York University and the University of Toronto. Substantial progress has been made in the development of a new LBI data recording system, and work has started on construction of corresponding playback and correlation facilities. A GPS interferometry experiment was successful and development of a differential pseudorange surveying system is jointly supported by the Branch and the Geodetic Survey.

(b) Strategy has been developed for monitoring of crustal deformations in Canada. Long baseline space techniques (LBI, GPS) will be used in conjunction with precise geodetic measurements (EDM, levelling) to monitor regional strain and local stability at a number of sites within the plate interior and along the plate boundary. Sites for NASA mobile LBI stations have been selected and local stability networks established near Whitehorse, Yellowknife and Penticton. This is a joint effort by the Earth Physics Branch, Geodetic Survey, Pacific Geoscience Centre, York University, and UNB.

4. National Research Council (Division of Physics)

(a) The mathematical theory of the calculation of pure astronomical refraction on the basis of a series of atmospheric integrals in a spherically symmetric model has been completed.

(b) 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 within 0.9 seconds 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 DUT1 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. Bedford Institute of Oceanography (Canadian Hydrographic Service Atlantic Region)

(a) Progress continued with the joint Sheltech Canada/UNB Department of Surveying Engineering/Bedford Institute of Oceanography development of seagoing GPS. Sheltech's STI 5010 receiver was used for on-line navigation onboard CSS HUDSON in June, and GPS accuracy at sea was tested against Mini-Ranger onboard CSS MAXWELL in November. Results are being analysed.

(b) UHF positioning has been used offshore for several years, but may also be useful for coastal surveys, where islands and headlands block off microwave systems, and HF groundwork systems suffer from large phaselag errors. Preliminary results of tests along the Nova Scotia coasts in November indicate UHF propagation velocity is independent of terrain; accuracy is not affected by low lying land (up to about 70 km from the transmitter); range error spikes (30 m) can be expected near (few 100 m) cliffs, bridge abutments, large ships, etc.; occasional locking onto ranges too long by hundreds of metres occurs.

(c) The Tide Section of the Atlantic Region of the Canadian Hydrographic Service is mentioned in the next item.

6. Canadian Hydrographic Service

(a) The Tides, Currents and Water Levels Division sponsors a network of water level gauging stations along the shores of Canada's coastal and inland navigable waters. The accumulation of long and continuous time series of water level data at these stations contributes to studies of sea level variations and vertical crustal movements, as well as to the establishment and control of vertical datums for levelling networks. Offshore tidal information is also being gathered by moored deep-sea pressure gauges. The CHS continues to operate the IHO Tidal Constituent Bank through the facilities of the Marine Environment Data Service.

(b) Continuation of the horizontal control adjustment programme for NAD83 and the computation of LORAN-C lattice parameters for new chart production were the predominant activities during 1982. The horizontal control adjustment for the area from Brockville to Cornwall, Ontario, was successfully completed thereby ensuring identical coordinate values on all National Ocean Survey and CHS charts of common boundary areas.

7. University of New Brunswick (Department of Surveying Engineering)

A generalized approach to the analysis of deformation surveys has been developed (Chrzanowski et al., 1982a), and applied to the analysis of crustal movements in Peru, and in the area covered by a microgeodetic network. A microprocessor-based radio telemetry system which uses tilt meters for continuous monitoring of ground movements in a mining area in British Columbia continued in operation (Chrzanowski and Kurz, 1982; Chrzanowski et al., 1982b; Fisekci and Chrzanowski, 1982). The appraisal of photogrammetry as a tool for monitoring subsidence continued (Chrzanowski and Faig, 1982; Armenakis and Faig, 1982; Faig and Armenakis, 1982). A modified form of trigonometric levelling has been tested as a possible replacement for second or even first-order geodetic levelling in hilly or mountainous areas. The method employs "leap-frog" traversing with vertical angle and electromagnetic distance measurements to three elevated targets. Preliminary results indicate the new method increases the speed of geodetic levelling by a factor of 2 to 3, or more.

Measurement and study of the rotation of the earth, in collaboration with colleagues at the Massachusetts Institute of Technology, continued (Langley et al., 1981a; Langley et al., 1981b; Langley et al., 1982a; Counselman et al.,

1981; Herring et al., 1981). It is known that at certain frequencies there is a high degree of correlation between changes in the angular momentum of the global atmosphere and changes in the length of day. This correlation is being investigated (Langley et al., 1981c; Langley et al., 1982b). Improvements to GEOAIM, an LBI analysis software package were made, including better modelling of earth rotation and accounting for ocean tidal loading. An interactive plotting package for the analysis of LBI residuals is being developed (Slipp, 1982). A model to describe the behaviour of ocean tidal loading on three-dimensional positioning has been developed and tested with gravity and LBI data (Pagiatakis, 1982).

A new technique has been developed for analysing horizontal strain as observed through monitoring networks (Schneider, 1982). The technique is capable of modelling strain and creep variation continuous or discontinuous in space and/or time. Application of the technique to the triple fault junction area near Hollister, California, revealed hitherto undetected features.

The fit obtained between a new geoid model based on a set of satellite-derived potential coefficients and Doppler-derived geoidal heights, and a gravimetric geoid, ranged from 0.5 m to 1.5 m for different regions in Canada, depending on gravity data distribution.

Studies continued into applications of GPS to marine navigation (Delikaraoglou and Wells, 1982; Mertikas and Wells, 1982; Wells et al., 1982; Wells and Delikaraoglou, 1982a; 1982b), and to geodetic positioning (Davidson et al., 1982; Langley et al., 1982c), including development of DIGAP, a differential GPS data analysis and reduction software package.

Work began on LORAN-C phaselag data analysis and modelling and use of differential LORAN-C for buoy position checking. A model for the behaviour of gyrocompasses at high latitudes was developed and tested under simulations (Christou, 1982). Results indicate real time software compensation of gyrocompass errors is useful and feasible. Investigation of local variations of sea surface topography continued.

Current studies in Transit satellite positioning include the development and application of a new multidimensional cubic spline smoothing technique to the sequence of Transit positions from the Lomonosov Ridge Experiment (LOREX); the development of microcomputer software for field data storage, verification and processing (Lord, 1982); and development and testing of a model for multipath effects on apparent antenna phase centre.

8. Université Laval (Département de Géodésie et de Cartographie)

Un projet sur l'évaluation des déviations de la verticale et des ondulations du géoide à l'aide de données hétérogènes dans les régions montagneuses a été complété (Mainville, 1982). J.-G. Leclerc poursuit des travaux sur le nivellement géométrique: analyse du modèle mathématique et de la réfraction atmosphérique en terrain montagneux. Des travaux ont également été entrepris par J.-G. Leclerc sur l'étude des applications des méthodes interférométriques en géodésie.

J. Jobin a poursuivi des travaux sur l'automatisation de la cueillette des données et des calculs de nivellement de premier ordre (Jobin et al, 1982a). Des travaux sont également en cours sur l'utilisation des micro-ordinateurs en géodésie (Jobin et al, 1982b). Le projet sur le développement d'un instrument pour l'étude de la stabilité des repères se poursuit.

Le programme de mesure de nivellement de précision s'est poursuivi à l'observatoire géophysique de Charlevoix. Une analyse des données des cinq dernières années est en cours.

Les travaux reliés au positionnement Doppler se sont poursuivis (Gélinas, 1982; Usandivaras, 1982; Usandivaras et al, 1982a; 1982b).

R. Sanchez a poursuivi les travaux suivants: analyse de la méthode de Black en astronomie; analyse de la méthode de Bomford pour le calcul des perturbations lunaires de champ de la pesanteur terrestre; création d'une projection de l'ellipsoide et son application aux calculs de Mercator transverse.

9. University of Toronto/Erindale College (Department of Survey Science)

A technique using strain for the strength analysis of horizontal geodetic networks was developed (Dare, 1982; Dare and Vanicek, 1982), which shows promise of becoming an operational tool alongside the standard variance-covariance analysis. Research continues on other possible applications to horizontal networks of this approach. Reference ellipsoid misalignment and its effect on geodetic azimuths and the deflections of the vertical was investigated, including development of a new approach for dealing with differential rotation matrices. Work on a covariance analysis of levelling data continued, with the goal of detecting systematic errors in levelling. A comprehensive approach to height determination in regions plagued with vertical crustal movements was formulated. A study of density distribution within the earth, and its relation to external gravitational potential was completed. Development of the diagrammatical approach to least-squares estimation continued.

Software to compute the sun's astronomical coordinates from Newcomb's theory of the motion of the earth around the sun was developed, which allows users to compute the sun's right ascension and declination independently of the fundamental ephemerides.

10. York University (Department of Physics)

Work proceeded (jointly with colleagues at the University of Toronto Department of Electrical Engineering, Herzberg Institute for Astrophysics, and the Earth Physics Branch) on the development of a new 12 Megabit/sec LBI digital recording and correlation system, for use in geodynamical and geodetic applications in Canada. Software for the reduction of LBI data based on the new IAU/IUGG J2000 ephemeris and earth motion model is in preparation.

11. University of Manitoba (Department of Earth Sciences)

Development was completed of an interactive numerical method for the transient sea surface height calculation from the satellite wind field. The result is being correlated with SEASAT data. Objectives are correction of SEASAT-ALT data reduction, and study of the ocean-earth tide coupling mechanism. The test area is Hudson Bay.

12. University of Calgary (Surveying Engineering Division)

Research on the use of inertial technology in geodesy and surveying continued. Rueger (1982) discusses construction principles of gyroscopes and systematises the error sources with the view to a unified model for inertial surveying. An efficient Kalman filter and optimal smoother for the FILS system was developed, and data from an L-shaped test course analysed in detail (Wong, 1982). Design of smoothing and adjustment software for filtered inertial data continued. Simulation studies on the use of an integrated GPS/ISS for offshore applications (Wong and Schwarz, 1982) (in cooperation with Sheltech Canada), led to development of a real-time filter which was tested at sea in November. Influence of the anomalous gravity field on inertial positioning has been investigated for the airborne case (Schwarz, 1981), and real-time models for Kalman filtering are under development.

Research on the comparison of both various gravity field approximation techniques and efficient three-dimensional representations continue (Schwarz, 1982b), including gravimetric terrain corrections in mountainous areas.

A software package (CANDESN) for the design of survey networks using interactive computer graphics is nearing completion (Mepham et al., 1982).

A study of optimization techniques applied to surveying and mapping, concentrating on problems of field logistics and cost optimization, was completed (Anderson et al., 1982; Anderson, 1982a). Experimental work on the systematic effects of vertical motion of the level and rods in precise geodetic levelling was conducted (Anderson, 1982b) and results obtained for a variety of soil conditions, and for a series of levelling runs on the Kananaskis Multi-purpose Experimental Levelling Line (KAMELL), in conjunction with the Geodetic Survey of Canada.

Investigation of survey and photogrammetry methods for remote monitoring of the fracture system on Turtle Mountain, Alberta (site of the 1903 Frank slide), has been initiated (Fraser, 1982; Teskey and Anderson, 1982). Substantial progress was made on research into basic theoretical problems concerning the precision, reliability, and sensitivity of monitoring surveys; modelling; statistical testing; and the sources and control of systematic errors (Niemeier et al., 1982; Teskey, 1982). Problems in the design of surveys for a 15 km long railway tunnel near Rodger's Pass are being investigated (Anderson), 1982c). Work continued on the establishment and observation of local and regional three-dimensional deformation networks near Priddis, Alberta.

The Kananaskis test network project continues, with 30 gravity stations being established. Aerial photography is being measured and the corresponding photogrammetric block will be adjusted using the SPACE-M software to analyse reduced ISS auxiliary data. SPACE-M is currently being extended to accept auxiliary airborne sensor data from statoscope, ISS, GPS, and other sensors.

The use of Givens transformations in least-squares estimation (which allow for recursive least-squares computations without forming normal equations) has been investigated, especially for photogrammetric and geodetic applications (Blais, 1982a). An investigation of Kriging estimation methods has been extended to study generalized covariance functions and their use in solving prediction problems. Geodetic and photogrammetric applications are being considered. A study of duality principles in linear least-squares estimation has resulted in a better insight and understanding of estimation in the Hilbert space context.

13. Sheltech Canada

Research into the use of GPS for land and marine positioning was pursued. Sequential least-squares expressions for the processing of ranging data have been developed and applied on data obtained with Sheltech's Stanford Telecommunications Inc. 5010 GPS geodetic receiver (Lachapelle and Beck, 1982). A comparison of instantaneous positions derived using either P- or C/A-codes has shown that both codes provide the same order of accuracy, i.e., 10 to 25 m (Lachapelle and Wade, 1982). The consistency of positions derived from sequences of 10 to 15 hours of continuous observation was found to be of the order of 10 m at the present time using either range, Doppler, or a combination of both types of data (Lachapelle et al., 1982; Lachapelle, 1982). The development of methodologies and software for GPS marine navigation was continued (in cooperation with CHS and UNB), and two ocean trials were conducted (Wells et al., 1982). Research into the combination of GPS and ISS for enhanced navigation has been initiated (in cooperation with the U of C), and several land dynamic and one ocean test were carried out. The combination of detailed surface gravity data and high degree (up to 180) geopotential coefficient solutions for the estimation of geoid undulations

using different methods was carried out and results were compared using satellite Doppler derived undulations located in North America (Lachapelle and Rapp, 1982). On 1 January 1983 Sheltech Canada became Nortech Surveys Canada.

14. Huntec (70) Limited

Under the Seabed 2 project (see Engineering Geophysics section), Huntec is developing a multi-sensor track recovery system for use in all underwater towed body. Using a Kalman filter, the system will generate real-time position, velocity, attitude and angular rate data, for both absolute positioning and to compensate for towed-body dynamics.

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I (B) GRAVITY

Compiled by: R.A. Gibb

1. Summary

In 1982 the National Gravity Mapping Program included extensive reconnaissance sea-gravimeter surveys of the Scotian Shelf and Pacific Margin; on land, the reconnaissance gravity survey of British Columbia was extended; on ice, gravity surveys of Prince of Wales Strait and the East Arm of Great Slave Lake were completed. This level of activity compares favourably with recent years. The trend toward local investigations by both universities and government agencies continued with an underwater gravity survey in Newfoundland and land-based surveys in Nova Scotia, New Brunswick, Quebec, Ontario and the Northwest Territories.

Gravity surveys and interpretations have contributed to many multidisciplinary investigations including: motions of the Juan de Fuca Plate; the structure and tectonics of the Arctic Ocean, the Arctic Islands, the Labrador Sea and the Canadian Shield; the geological zonation of Newfoundland and Ireland; and the structure of earthquake regions such as Vancouver Island, La Malbaie and Miramichi, Nova Scotia.

Several maps of general interest were released in 1982. They include gravity and magnetic maps (1:2,000,000) of the Appalachians, a gravity map (1:2,000,000) in the Juan de Fuca Plate map series, and a set of manuscript maps (1:1,000,000) covering all of Canada.

Highlights in software development in 1982 include data processing systems for production of line contour maps, Applicon colour maps and terrain corrections; interpretation software for regional/residual separation by a finite element integration approach, interactive and/or automated 2-D modelling, and computation of the position and dip of a faulted structure by direct methods.

2. Earth Physics Branch (EPB)

(R.K. McConnell, D.B. Hearty, L.A. Warren, J.B. Boyd, D.W. Halliday, R.A. Gibb, R.P. Riddihough, J.R. Weber, J.F. Sweeney, L.W. Sobczak, A.K. Goodacre, M.D. Thomas, D. Nagy, H.D. Valliant, A. Lambert, D.R. Bower, J.O. Laird, L. Jeudy)

(a) A one week workshop on the processing and adjustment of gravity traverse and control network data was held in Ottawa for Latin American geophysicists. The data base associated with the Latin American Gravity Standardization Net 1977 was transferred to the University of Chile in Santiago.

A network of gravity control stations along the east coast of Greenland was established in collaboration with the Geodetic Institute,

Copenhagen. These stations will provide control for future marine gravity surveys in the Baffin Bay/Davis Strait area.

(b) A software system was developed to routinely compute regional terrain corrections using a digital terrain model (DTM) of some 1.5 million elevation picks at 1 km spacing over southern British Columbia. An integral component of this system is the facility to systematically generate 10 km x 10 km templates for selecting inner zone data consistent with the DTM.

(c) Four new open files comprising Bouguer and free air gravity maps of Hudson Bay, B.C. Coast and B.C. Interior were released during the year. Details concerning the maps, scales and locations can be found in the bibliography. A fifth open file comprising a compilation of all bathymetric data obtained to date during Natural Resource Charting cruises on the west coast has also been released. This map (scale 1:1,000,000) shows contours at 100 m intervals with 20 m intervals on the shelf.

The complete set of manuscript maps (95 maps) used to compile the Gravity Map of Canada 1980 was released during the year. These maps are black and white ozalid prints showing station position and 5 mGal contours at a scale of 1:1,000,000.

A gravity map in the Juan de Fuca Plate map series was produced at a scale of 1:2,000,000. This shows free-air values at sea and Bouguer values on land and is contoured at 10 mGal intervals. The area covered is 39°-53°N, 116°-133°W.

(d) In 1982 more than 1500 new static gravity stations were occupied over the Canadian mainland and ice-covered offshore areas and about 23,000 line kilometres of dynamic gravimeter profiling were logged off the east and west coasts.

About 9000 line km of dynamic gravimeter profiling were observed to the southwest of the Queen Charlotte Islands between 100 and 200 nautical miles from the coast. Line spacing was 10 km and the survey was undertaken jointly with the Geological Survey of Canada (GSC) and the Canadian Hydrographic Service (CHS).

In the second and final year of a contract survey of the Rocky Mountains about 250 static gravity measurements were made at a regional spacing (10-15 km) in the area defined by 52°-54° N, 118°-121°W. Positioning by inertial navigation was obtained at approximately 120 of these stations.

The project to establish gravity observations at Geodetic Bench Marks was continued during the year. About 640 measurements along roads in the eastern interior of British Columbia were observed by contractor personnel. Station spacing averaged 3 km.

A helicopter-supported field party completed the final phase of a contracted survey of the East Arm of Great Slave Lake. About 120 stations were observed on the frozen surface of the lake with a station separation of 4 km.

A helicopter-supported field party, sponsored by the Polar Continental Shelf Project and working in cooperation with CHS completed a survey of Prince of Wales Strait between Banks Island and Victoria Island by observing more than 280 gravity stations spaced 6 km apart.

(e) The detailed motion of the system suggests that there is an important tectonic distinction, evident across Vancouver Island, between

over-riding without subduction in the north and over-riding with subduction in the south. A change in trench 'roll-back' velocity near 4 Ma may account for the bend in the subducting plate and relate to Cascade volcanic history.

Two large sheets (posters) at a scale of 1:500,000 showing strip maps of geology, bathymetry, topography, Bouguer and Free-air anomalies, seismicity, aeromagnetic anomalies, structural sections to a depth of 48 km, and gravity interpretation along a north-south transect from the North American craton to the Canada Basin were compiled for the North American Continent-Ocean Transects Program.

Two new ideas about Arctic tectonic history have been published. The first suggests that the mid-Paleozoic Ellesmerian orogeny in the Arctic Islands was produced when a continental terrane that included northern Alaska was displaced southwestwards by as much as 2000 km from its initial orogenic site to the north and east of Ellesmere Island. The second idea is that the Lomonosov Ridge was sheared from the polar margin of western Eurasia, probably in Late Cretaceous time, along a trans-Arctic left-lateral offset that may have been related to the opening of Baffin Bay. The Eurasia Basin was opened later, in early Tertiary time, when the North Atlantic rift extended into the Arctic region and separated the Lomonosov Ridge from Eurasia.

A proposal to study the crustal nature of the Alpha Ridge has been approved. This EMR-sponsored sequel to LOREX 79, named CESAR 83 will be deployed early in 1983. Gravity measurements are among the many geophysical techniques that will be used to study this part of the Arctic Ocean.

A study of the utility of the gravity method for the discovery of Athabasca unconformity-type uranium deposits has been completed. If the Midwest deposit is typical then the gravity method appears to be of marginal use because the amplitude of the associated anomaly is small (less than 0.5 mGal) and the width of the anomaly is narrow (less than 350 m).

Detailed gravity surveys were conducted along two east-west profiles located within the Wopmay Orogen of the Bear Structural Province. Station spacing in both profiles varied from 1 to 4 km. Both profiles were designed to define faults that bound approximately hexagonal-shaped crustal blocks that constitute a large sector of the orogen. A total of 67 gravity observations were made.

A positive gravity anomaly, defined by regional gravity surveys, coincides with a structural unit defined as the Parry Sound Domain. A knowledge of the subsurface form of the domain will provide an important constraint in developing tectonic models of the Grenville province. A total of 124 new gravity observations was made mainly along three profiles. Station spacing varies generally between 1 to 4 km.

The symmetrical distribution of residual positive gravity anomalies in southern and eastern Hudson Bay suggests a model for suturing of the Superior and Churchill plates by a process of double indentation of the relatively hot, plastic Churchill plate by the Thompson and Ungava salients of the cold, rigid Superior protocontinent. Double indentation proceeded until the Hudson Bay re-entrant was completely closed by outward flow along slip lines of Churchill material from the paths of both indenters.

The gravity survey of the Monteregian Hills in the Eastern townships of Quebec was completed with 161 stations being occupied on and around Mt. Shefford and Mt. Brome and more than 275 stations observed on Mt.

Royal. An interpretation of the gravity data over Mont Saint Bruno was made by J. Goddard in a Bachelor's thesis for Concordia University and a combined analysis of the gravity and magnetic fields over Mont Saint Bruno was made by S. Fogarasi in a Bachelor's thesis for Carleton University.

A method for the computation of geoidal height at elevation from surface gravity data has been developed using recurrence relations with a finite numbers of terms.

A direct method for evaluation of the position and inclination of a two-dimensional fault from its gravity profile has been developed and applied to gravity profiles over the South Appalachian and Gloucester faults.

A system has been developed which permits the user to access the National Gravity Data Base or an ancillary file for the purpose of producing interpolated grids, line contour maps or Applicon colour maps.

(f) Final adjustments to the digital control and data acquisition system for LaCoste and Romberg gravimeters based on the LSI-11 microprocessor were made. Testing was carried out during a routine survey operation and this sytem is now deemed to be fully operational. The new LaCoste and Romberg Straight Line meter (Ser. No. SL-1) was used for routine survey operations.

(g) Semi-annual resurveys of precise gravity networks in seismically active areas of Charlevoix, Quebec and Vancouver Island, British Columbia continued. The standard error of gravity values with respect to the network datum is now 2-3 microgals (20-30 nm/s^2) or better. Gravity variations will be compared to the results of relevelling carried out by the Geodetic Survey of Canada in 1982.

The observed gravity and level changes induced by the loading of the La Grande 2 reservoir between 1978 and 1981 will be compared to the theoretical changes for a realistic earth model. Work on the theoretical model and on the evaluation of levelling results is in progress.

Records from short baselength tiltmeters operated by EPB in a buried near-surface vault are dominated by thermoelastic and groundwater effects. Modelling of these effects reduces the RMS noise to a level of from 1 to 4 microradians depending on the location and orientation of the tiltmeters. A precise 40 m diameter levelling array maintained by the Université Laval is also influenced by thermoelastic and groundwater effects but can be similarly corrected to achieve an RMS noise level of 1 microradian. Investigation of attenuation of noise level with depth by Dalhousie University is continuing.

A ten-station trilateration network was surveyed to establish a precise (less than 1 part in 10^6) network for future horizontal strain determinations in the seismically active region near Gold River on Vancouver Island. Possible surface deformation associated with the 1957 earthquake will be investigated through comparisons with a triangulation done in 1946-47. The work is a joint project involving Pacific Geoscience Centre (EPB), and the University of British Columbia, Geodetic Survey of Canada and the U.S. Geological Survey.

A hydrological model has been developed to predict the water level in deep wells at the Charlevoix Observatory from precipitation and temperature data.

Tidal monitoring in packed-off sections of borehole at Chalk River was carried out in 21 zones in 5 boreholes during the winter. Good

results were obtained in demonstrating and calculating the features of this technique for characterizing fractures.

An improved data analysis method has been developed to eliminate systematic effects due to low frequency vibrations in a free-fall absolute gravity meter. A preliminary study indicates an improvement of one order of magnitude in precision; the accuracy of the results should also be improved.

In order to evaluate atmospheric effects on absolute gravity determinations, the published absolute determinations of gravity at Sevres (Bureau International des poids et mesures) are being analyzed in comparison with atmospheric pressure, rainfall measurements and water level records. The results will be generalized and made applicable to Canada.

3. Atlantic Geoscience Centre (AGC) (R. Macnab, J. Woodside, S. Srivastava, R. Hawarth)

(a) In collaboration with CHS and EPB, hydrographic-geophysical surveys were undertaken to extend our regional mapping program to two areas: the northwestern Grand Banks of Newfoundland and the western part of the Scotian Margin. On the Grand Banks, gravity data were collected over some 4800 km of parallel ship's tracks spaced 36 km apart. For the most part, these measurements were taken in water depths of 200 m or less. On the Scotian Margin, data were collected over 10,440 km. This survey consisted primarily of long profiles extending from nearshore to the abyssal plain.

(b) The AGC Labrador Sea gravity data set consists of some 1,000,000 data points collected on numerous cruises dating back to 1965. Merging these various cruise sub-sets has proven to be problematic on account of some serious discrepancies. In an attempt to rationalize data, they are being subjected to an adjustment procedure designed by EPB.

As a by-product of the compilation and adjustment of the sea gravity data, all harbour base stations used by AGC have been compiled, checked and placed in a new data base which is compatible with the EPB data base containing all gravity stations in the Canadian National Gravity Net. Another data base containing data from all calibrations of AGC sea gravity meters has been set up to facilitate data retrieval from a new geophysical data management system. The calibration data base also permits examination of sea gravity meter performance with time, and has direct links to the data base containing harbour base stations to which all calibrations must be tied.

(c) Investigations in the Greenland-Norwegian Sea/Eurasian Basin and southern Labrador Sea reveal significant asymmetry with respect to crustal age. Though no single mechanism could be found to account satisfactorily for these asymmetries, several possibilities have been identified, such as proximity of these regions to hot spots, oblique spreading, and asymmetric absolute plate motions.

(d) As a contribution to IGCP Project 27 "The Caledonide Orogen", the gravity and magnetic compilations for the Appalachians were republished at a scale of 1:2,000,000 compatible with a new edition of the Tectonic Lithofacies Map of the Appalachians. A compilation covering much of the Appalachian, Caledonide and Mauritanide orogens was prepared at a scale of 1:5,000,000 for the annual Project 27 meeting in Fredericton. Various aspects of this compilation will be published by Reidel in 1983. The gravity and magnetic data on the Newfoundland and Irish continental shelves were used to examine the continuity between the geological zonation of Newfoundland and Ireland.

4. Memorial University of Newfoundland (H. Miller)

(a) An underwater survey was conducted jointly with EPB. A total of 373 gravity stations were occupied using LaCoste and Romberg underwater meters. The station spacing was 3 km in Conception Bay and 6 km outside the bay in the region east of St. John's. Primary navigation was provided using a Mini Ranger system with estimated position uncertainties of ± 25 m achieved. This underwater survey is part of a continuing programme to map the Avalon Zone of Newfoundland.

(b) This project is part of a multi-disciplinary study of the Carboniferous Deer Lake Basin of western Newfoundland. The basin has both uranium and hydrocarbon potential. In 1982 an additional 100 gravity stations were occupied using Memorial's Sharpe CG2 gravimeter.

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

Additional gravity stations were measured over the Sydney coalfield on Cape Breton Island to complement previous gravity surveys in this area. The gravity data have been reduced and plotted. Terrain corrections have been computed.

Gravity stations were also measured in the New Glasgow-Thorburn coalfield to complete the survey started in 1981. Data reduction is complete, though computer plots have yet to commence.

Commercial gravity projects included sale of gravity stations, gravity interpretation integrated with seismic results, and a gravity survey on a frozen lake surface for oil and gas exploration.

6. New Brunswick Department of Natural Resources (J. Chandra; K.B.S. Burke, U.N.B.)

The Department of Natural Resources has conducted a gravity survey in the epicentral region of the 1982 Miramichi earthquakes with assistance from the University of New Brunswick. A gravity low coincides with the position of a large granitic intrusion, called the North Pole pluton, reflecting a density contrast of 100-200 kg/m^3 between the plutonic and metamorphic rocks. Thickness estimates and the extent of the gravity low indicate that the relatively shallow Miramichi earthquakes are confined to the pluton.

The Department of Natural Resources has also completed gravity measurements at about 150 recently established survey bench marks in the Fredericton and Fredericton Junction area.

7. Université Laval (M.K.-Seguin)

M.K.-Seguin et un groupe d'étudiants ont effectué un levé gravimétrique détaillé de la région de la Malbaie en relation avec: 1) les failles de gravité reliées au rift du Saint-Laurent, 2) la structure d'impact météoritique de Charlevoix, et 3) la masse anorthositique de Saint-Urbain. Quelque 400 points de mesure ont été effectués dans une aire s'étendant de Saint-Joseph-de-la-Rive à Saint-Siméon sur une largeur d'environ 20 km à l'intérieur des terres.

A présent, nos résultats indiquent: 1) une excellente corrélation entre les unités géologiques cartographiées par Jehan Rondot (MERQ) et l'anomalie de Bouguer; 2) une excellente corrélation entre les forts gradients linéaires de gravité et les failles actives telles celles situées au sud de Grand Fonds; 3) une corrélation (moins évidente celle-là) entre les anomalies positives et négatives alternantes en forme de croissant et la bordure est de l'impact météoritique; 4) une anomalie négative de Bouguer dans l'extrémité sud du massif anorthositique de Saint-Urbain.

8. McGill University (O.G. Jensen, D.E. Smylie, D.J. Crossley, P. Keating. W. Yang)

(a) The null-test instrument provided by D.E. Smylie of York University was operated under temperature cycling for 3 months to determine the apparent transfer function (i.e. temperature transient on case - to - apparent gravity signal) of the gravimeter under temperature excitation. It appears that the instrument behaves quite linearly in response to relatively large temperature ($\pm$10°C) transients showing a strong low-pass character. The mechanical temperature compensation system of the Linton-Moore gravity meter appears to perform according to the original design specifications.

(b) Currently underway is an extensive geophysical analysis of data from the Abitibi greenstone belt/Grenville front area which is supported by an NSERC Strategic Grant to several Quebec Universities. A preliminary gravity map incorporates data from Quebec and Federal government surveys. This will be compiled at scales of 1:250,000 and 1:1,000,000 for correlation with geologic and future magnetic maps.

Conventional processing shows that most of the structure can be explained by density changes assigned to the upper 10 km of crust. Certain selected areas are being processed by a new technique which uses a finite element integration approach to the regional/residual separation problem.

9. Ontario Geological Survey (OGS), Ministry of Natural Resources (V.K. Gupta, D.R. Wadge and others)

As part of studies on the Night Hawk Lake Geophysical Test Range in Thomas Township near Timmins, Ontario, gravity and magnetic gradiometer surveys were conducted on the established grid.

Data synthesis and interpretive studies of gravity and aeromagnetic data from the Sudbury-Cobalt area of north-central Ontario continued utilizing signal enhancement techniques to prepare various computer processed maps.

The OGS is engaged in developing an interactive computer modelling system for 2 1/2 D gravity data. This system allows the geophysicist to manually or automatically (by least squares fit) vary the geometry of geological models to fit observed gravity data via a Tektronix graphics terminal CRT.

10. University of Western Ontario (A. Beck, D.A. Wilkinson, M.C. Ceccanese)

(a) A quantitative interpretation was made of the New Liskeard gravity high using gravity anomaly data provided by EPB. The density data for the study were supplied by OGS. An iterative, non-linear least squares refining program was incorporated into the modelling process.

(b) The Canadian Shield of western Quebec is characterized by an unusually large number of earthquakes. Bouguer and free air anomalies were compared with geologic and topographic data to examine the possible causes of the earthquakes. An investigation of the glacial history of the area was also undertaken to see what effect this event may have had on regional stress fields.

11. University of Manitoba (W. Moon , A. Carswell, R. Tang)

(a) A potential field modelling technique at satellite heights is currently being developed. This involves mathematical transformation for continuation fields and application of Radon transformation in 3-D space.

(b) A study of long period oscillation of the Earth has been completed. Using the variational method it was possible to solve the normal mode periods for a slightly elliptical Earth in the spectral ranges from seismic normal modes to Chandler wobble.

(c) Development of a rheological modelling method for the formation of greenstone belts in the Canadian Precambrian shield is in progress.

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

The investigation of gravimetric terrain corrections has been continued. Computer software was developed to optimize the computations using direct access to the Earth Physics Branch Digital Terrain File or any similar topographical data base, with a minimum of supplementary topographical detail in the immediate neighborhood of the gravity stations. Different options are available for the near zone depending on the nature of the available topographical data. Further work is being carried out to optimize topographical data gathering near the gravity stations.

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II SEISMOLOGY AND PHYSICS OF THE EARTH'S INTERIOR

Compiled by: E.R. Kanasewich

1. Canadian Seismicity - Earth Physics Branch, Ottawa, and Pacific Geoscience Centre, Sidney, B.C.

Provisional data for more than 700 earthquakes in 1982 in or near Canada are available. Forty-nine earthquakes had magnitudes greater than 4.0, six greater than 5.0.

The most significant change in the earthquake distribution from previous years was the extensive activity in the Miramichi area of New Brunswick, that included four earthquakes of magnitude 5.0 or greater. The sequence began on 09 January 12h U.T. with a magnitude 5.7, and was followed by M5.1 four hours later, M5.4 on 11 January, M5.0 on 31 March and M4.7 on 16 June. Two magnitude 4.0 or greater earthquakes occurred elsewhere in eastern Canada: M4.4 on 13 August east of Temiscaming, Québec, and M4.0 on 04 December near La Malbaie, Québec.

In western and northern Canada there were 36 earthquakes with magnitude 4.0 or greater, but only two with magnitude 5. These were near Icy Bay, Alaska on 02 and 03 May.

Thirty-six earthquakes in and near Canada were reported felt in 1982, twenty-one in the east and fifteen in the west. The most widely-felt earthquake (maximum intensity V, with isolated intensity VI) was the first Miramichi, New Brunswick event, which caused isolated cases of minor property damage, but no structural damage, in New Brunswick and Maine. The most widely felt earthquake (maximum intensity V) in the west was the magnitude 4.2 event on 28 May on the Queen Charlotte Islands.

Staff from the Earth Physics Branch (EPB) conducted three aftershock field surveys in the Miramichi region of New Brunswick in 1982. The first took place between 10 and 22 January and included personnel from EPB (R.J. Wetmiller, P. Morel, J. Adams, D.A. Forsyth, P. Munro, R. Grogan, E. Berndt and R. Groulx), the U.S. Geological Survey, M.I.T., the Lamont-Doherty Geological Observatory, State University of New York, the Atlantic Geoscience Centre and Rondout Associates. The field work, which took place in extreme winter conditions, was made possible by the active assistance of three New Brunswick provincial agencies: the Emergency Measures Organization, the Department of Highways and the Forest Service. Twenty-nine recording locations were occupied, nine within 15 km of the aftershock zone. One hundred and fifty-eight aftershocks have been located in an area of 4 km north-south by 6 km east-west with depth ranging from 0 to 7 km. Aftershock distribution and composite P-nodal studies suggest that the 09 January

mainshock and the 11 January aftershock occurred on conjugate, north-striking thrust planes.

The second aftershock survey by J. Adams and R. Grogan of EPB and J. Chandra of the New Brunswick Department of Natural Resources took place from 01 to 07 April, following the 31 March, M5.0 aftershock. Eighty-four aftershocks were located with a concentration on the shallow part of the east limb of the January activity. Composite P-nodal solutions for the January and April aftershocks indicate that both the eastern and western thrusts steepen toward the surface.

The third aftershock survey by A.E. Stevens, J. Bérubé and E. Berndt of EPB was from 17 to 23 June following the 16 June M4.7 earthquake near Trousers Lake, 30 km west of the January activity. Fourteen aftershocks were located at a depth of 8 km. Composite P-nodal solutions show thrust faulting on a north to northeast trending plane.

Additional studies of the New Brunswick earthquakes by EPB staff have included the following. H.S. Hasegawa has made a detailed analysis of surface waves from the larger events to determine more definitive source parameters. A.E. Stevens and M. Cajka have prepared isoseismal or intensity distribution maps for the six largest earthquakes. J. Adams has prepared a lineament map of the epicentral region based on aerial photography flown by the Canada Centre for Remote Sensing in January, and participated in a geological field survey of the epicentral region. D.H. Weichert and P. Munro, with P.W. Pomeroy of Rondout Associates and P.N. Mork of the U.S. Geological Survey, have analysed the strong motion recordings of the 31 March, M5, and a number of smaller aftershocks. These recordings were made with a strong motion seismograph network installed in the epicentral region in February with the assistance of the U.S. Nuclear Regulatory Commission. R.J. Wetmiller, with E. Cranswick, C. Mueller and E. Sembera of the U.S. Geological Survey, have analysed 25 small, digitally-recorded aftershocks to determine moment, source size and stress drop. Preliminary results from these, and studies by other Canadian and U.S. agencies are described in an EPB Open-File report prepared by A.E. Stevens.

R.J. Wetmiller and J.A. Drysdale have investigated local magnitude scales for application to small eastern Canadian earthquakes. They have found that Nuttli's formula, originally defined for distances greater than 400 km, can give unbiased estimates of magnitude at near distances.

F.M. Anglin and G. Buchbinder have continued their studies of microearthquake patterns in the Charlevoix region using data from the six-station telemetered array. Aseismic zones are still found within the active zone. Projection of hypocentres to the surface has shown that the active zone is confined between mapped faults on the north shore and a bathymetric feature in the river near the south shore.

H.S. Hasegawa has completed his research on spectral scaling of Lg recorded on the Eastern Canadian Telemetered Network to establish source parameters for eastern Canadian earthquakes.

To aid in the analysis of seismicity data, D.A. Forsyth organized the compilation of 1:1,000,000 scale GSC magnetic anomaly maps 1562A, 1563A and 1564A covering Ontario and western Québec to 48°N. The data were drawn from parts of the original manuscript map for GSC 1255A with the permission of P.J.Hood.

D.H. Weichert and staff in co-operation with Dome Petroleum continued the Beaufort Sea special seismicity study. One land station was added to the network at Shingle Point. Preparations for an experimental tethered ocean bottom seismometer have been completed.

R.D. Hyndman in co-operation with Dome Petroleum has undertaken relocation of Beaufort Sea events using improved crustal velocity models.

G.C. Rogers has revised epicentres of earthquakes occurring in the Queen Charlotte Islands region. Almost all earthquakes have epicentres close to the Queen Charlotte fault with no evidence that significant earthquakes have occurred in Hecate Strait or Queen Charlotte Sound in historic time. The revised seismicity pattern plus microearthquake observations on the Queen Charlotte Islands suggest there is little, if any, seismicity on other major fault systems to the east of the Queen Charlotte fault. However, during 1982 one magnitude 3 1/2 event occurred on the east side of Hecate Strait and one magnitude 4 event occurred east of the fault near Masset.

G.C. Rogers has examined the distribution of large earthquakes and their aftershocks along the Queen Charlotte fault and there appears to be a seismic gap just south of the Queen Charlotte Islands which would require an earthquake on the order of magnitude 7 to fill.

G.C. Rogers has examined the focal mechanisms of earthquakes along the Queen Charlotte fault. They suggest the fault is not a pure transform at its southern end but has an element of convergence across it.

R. Horner has completed a microseismicity study in the St. Elias region. The most active zone of seismicity follows the Pacific-America plate boundary along the coast of Alaska. A less active zone follows the Denali fault system through the SW Yukon, but does not continue into Chatham Strait. Instead, it turns south into the Glacier Bay region to connect with the Fairweather fault.

P.W. Basham, F.M. Anglin, M.J. Berry (EPB) and D.H. Weichert (PGC) have completed new seismic risk maps that have been adopted by the Canadian National Committee on Earthquake Engineering as zoning maps for the next edition of the National Building Code. Basham and Berry, with A.C. Heidebrecht of McMaster University and J.H. Rainer of the National Research Council, have prepared new seismic design provisions for the code that will reference the new risk maps.

P.W. Basham and J. Adams have prepared a review of earthquake risk on the eastern Canadian continental shelf. Adams is currently analysing low-level seismicity and historical earthquakes, and evaluating the seismotectonic setting in the region of the Laurentian Channel. He is also planning an ocean-bottom seismograph deployment for mid-1983 in the region of the 1929 "Grand Banks" earthquake, in cooperation with PGC and AGC.

As part of the joint AECL/EMR nuclear fuel waste management program, H.S. Hasegawa has undertaken a review of near-field stress changes created by an underground vault and of transient stress generation at shallow depth in the Shield.

D.A. Forsyth, P. Morel and others have compared geophysical and geological information on the Kapuskasing-Temiskaming area. Seismic data show a general north-northwest trend. However in the northern part of the area, the trend appears to be associated with the north-northeast trending Kapuskasing structure. Earthquake coverage is limited and is being improved with new stations. The most active features of the area are the Ottawa-Bonnechère graben, the Temiskaming rift and the Kapuskasing structural zone, all features that have had a very active geological history.

Weichert and Hyndman began a special study of the seismic risk in the Queen Charlotte area. The point source model of earthquake occurrence used for the National Building Code of Canada is inappropriate for the large earthquakes along the Queen Charlotte fault.

2. Atlantic Geoscience Centre

LASE: Data processing from this experiment off the Eastern U.S. has now proceeded to the point where assessment of the large aperture array data quality and some geological interpretation can be made. So far little improvement is seen in reflection record sections from a 10 km array length, compared to a 4 km array. However, record sections from both array lengths show good reflections down to 7s two way time. The development of new processing techniques for this data set is continuing. The expanding spread profiles have been analyzed and when combined with the reflection data, the cross-section of this margin suggests that "oceanic" layer 3 continues beneath the continental crust. Preliminary interpretation suggests that this velocity structure is consistent with melt migration through a thinned lithosphere which underplates the continental crust during rifting.

FRAM: Joint work with MIT (Dr. A. Baggeroer and G. Duckworth) is currently in progress on refraction data collected on Fram II, an ice station located in the south-western portion of the Eurasian Basin of the Arctic Ocean. The initial results have been published. The refraction data collected with the L-shaped MIT hydrophone array and the AGC ocean bottom seismometer are being integrated. The combined special abilities of the array to accurately measure sedimentary and upper crustal velocities and of the ocean bottom seismometer to record shear wave data enable more sophisticated models and better synthetic seismograms to be produced. Thus a better definition of the thin ocean crust in this region of slow spreading (5 to 10 mm $yr.^{-1}$) is possible.

The Fram III experiment was in the southeastern area of the Arctic Ocean, north of Spitsbergen. The refraction data indicates that the Yermak Plateau has a dual crustal structure. The northern section is thickened oceanic crust produced by hot spot activity, and the southern region is stretched continental crust produced by the initial rifting processes. This result is confirmed by magnetic, gravity, and heat flow data, and dredged samples. The dual structure of the plateau stimulated interest in plate reconstructions for the area.

I. Reid participated in co-operation with Earth Physics Branch in the determination of earthquake activity following the New Brunswick earthquake in January, 1982. Three Ocean Bottom Seismometers were used to detect and locate events, and this rather unusual use of OBS proved to be very successful. The data were analyzed and event times were picked. These results were contributed to the larger study undertaken in Ottawa by the Earth Physics Branch.

An evaluation of the earthquake activity in the region of the 1929 Grand Banks earthquakes has been undertaken by J. Adams (EPB) and Ian Reid. The objective is to design an OBS experiment to measure this activity more precisely than present land stations allow.

C. Keen, with C. Beaumont, Dalhousie, have continued their study of the rift processes responsible for the evolution of rifted continental margins. Various aspects of the dynamics of rifting have been investigated, including melt production and migration, the depth dependent extension process and finite, episodic rates of extension. Model predictions have been compared to data from the LASE experiment and from the Labrador margin. Thermal modelling of sediment paleotemperatures has been improved by measurement of thermal conductivities on sediment samples from deep exploratory boreholes. A study was conducted of the effect of salt diapirs on thermal maturation of source rocks. It was concluded that salt diapirs do not, of themselves, enhance thermal maturity, but that they may act as conduits for fluid circulation which could create a favourable environment for a high degree of maturity in the overlying sediments.

3. Earth Physics Branch

R. Haddon has developed an algorithm for the computation of synthetic seismograms in laterally heterogeneous media using Kirchoff diffraction theory. His work on the efficient computation of synthetic seismograms in layered structures using modal theory is continuing.

A. Green has started to reprocess high resolution seismic reflection data collected at the Underground Research Laboratory site on the Lac du Bonnet batholith in Manitoba.

A. Green, Z. Hajnal and W. Weber are interpreting a multi-disciplinary data set across the Superior-Churchill boundary zone.

P. Morel, A. Green, R. Haddon, and C. Pike are currently interpreting data from the 1977-79-81 COCRUST refraction surveys across the Superior-Churchill boundary zone and the Williston Basin using ray-tracing and synthetic seismogram modelling.

D.A. Forsyth, P. Morel, A. Green, G. Buchbinder, R. Haddon, C. Pike, F. Andersen and C. Michaud participated in the COCRUST seismic refraction survey, August 3-16, across the Ottawa Valley rift, the Central Metasedimentary Belt, the Quebec Gneiss Belt, the Grenville Front and the Abitibi greenstone belt.

As part of a continuing Earth Physics Branch program to search for changes in seismic velocities in the seismically-active La Malbaie, Québec area, three more calibration shots were fired, one in June and two in October, 1982, by G. Buchbinder and recorded by EPB staff using up to 16 instruments at up to 16 sites. The observed changes with respect to 1981 are minor.

J.A. Lyons has continued to maintain and develop the ECTN/WCTN operating and application software systems. Recent developments include (i) implementation of a light panel and software monitoring system to provide visual indication of ECTN hardware/software status; (ii) ability to recognize and count samples flagged as missing by the new "smart" concentrator software; and (iii) ability to recognize and store ancillary timing information issued by the new concentrator.

C. Wong has continued development of the Seismic Analysis Monitor (SAM), a fully integrated software package designed to display, store, retrieve, and analyze digital seismic data. Automatic ECTN event location has been instituted, on an experimental basis, whereby all events that trigger on 3 or more stations are processed by the epicentre location program assuming that new trigger times represent P-phase arrivals.

A. Vesa has continued to look after hardware maintenance of all Datalab systems.

J.A. Lyons is supervising a contract to modify the existing ECTN software to run on a single MICRO-11 computer for installation in the new Sudbury Science Centre. This system will be able to process the data from up to 4 remote outstations and transmit digital event files to Ottawa over a dial-up telephone link on demand.

Roy Ball Associates were commissioned to develop a second generation of data concentrator software with provision for improving the timing uncertainty inherent in the original software. The new software has been delivered and acceptance tests performed. Installation into the concentrators at St. Johns, N.B., Rivière du Loup, Qué. and elsewhere in the ECTN/WCTN system is scheduled for the coming year.

The aging Sprengnether MEQ 800 smoke recorders have been replaced with 10 new units from the same manufacturer.

In response to the series of earthquakes occurring in New Brunswick this past year, a telemetered station was installed atop Mt. McKendrick in late January, followed by purchase and installation of 5 Kinemetrics SMA-1 strong motion recorders in the spring.

Telemetered stations were installed at Welcome, Ontario and Hauterive, Qué., with the collaboration of Ontario Hydro and Hydro Québec respectively. The Atomic Energy Commission Ltd. collaborated in the installation of a telemetered station at Eldee, and with installation of regional monitors at Sioux Lookout, Geraldton and Kapuskasing, all in Ontario.

Physics of the Earth's Interior.

The Earth Physics Branch geothermal group has, over the last several years, encountered many examples of water movement in fractures, permeable formations, and in boreholes themselves, that are revealed by accurate temperature measurement. J. Morowicz and A. Jessop have shown that large scale water migration in the deep aquifers is probably a major controlling factor in the temperature field of the entire Western Canada Sedimentary Basin. M. Reiter and A. Jessop have shown that major heat flow differences on the eastern continental shelf may be explained by water migration. M. Drury has examined detailed logs of wells in the Canadian Shield, and he has shown that the shape of the temperature anomaly may be used to distinguish between different modes of water movement in fractures and in the well, including fractures that have allowed flow for a long time, fractures that feed water to the new channel provided by the well, either upwards or downwards, and fractures that accept fluid only under pressure during the drilling operation.

A. Jessop, T. Lewis, A. Judge, A. Taylor and M. Drury have compiled the existing heat flow data on the Canadian continental crust and have examined heat flow profiles over areas where the density of measurement sites makes this worthwhile. Definite patterns, which may be related to terrain features are identifiable in the east and west coastal districts. Although the data from the Superior Province show uniform heat flow similar to other Archaean areas, and are one of the better sets of data from any Archaean terrain, average heat flow from some other areas does not match values derived from the World Heat Flow Data Collection - 1975 (Jessop et al., 1976) for terrain of the same general age. Some of these differences may be attributable to the influence of water, and some to an inadequate sample size.

At Mt. Meager, British Columbia Hydro has drilled 3 wells to depths exceeding 3000 m, each testing a different direction from a central drill pad. Temperatures up to 270°C have been measured, and all wells have produced some steam, although permeability seems to be limited to the major fault zones. Further diamond drilling at Mt. Cayley has been contracted by J. Souther (GSC, Vancouver) and a line of shallow holes has been contracted by T. Lewis, placed across the axis of the Garibaldi Volcanic Belt. A further set of shallow holes has been drilled in the Alert Bay volcanics of northern Vancouver Island.

F.W. Jones and his geothermal team are analysing, under contract to EPB, the temperature and network data of Alberta in order to define in detail the temperature and heat flow field in the sediments, and to provide information on the availability, mobility and temperature of water for energy exploitation.

In the Atlantic Region the collection of available data has been completed by J. Leslie, under contract, and two diamond-drill holes have been completed in granitic batholiths of New Brunswick to examine the possibility of hot dry rock resources similar to those in the granites of Cornwall, England.

The acquisition, preservation and abandonment of northern wells has been continued by A.S. Judge, A.E. Taylor, M. Burgess and V. Allen. A volume in

the geothermal data collection series was published containing data from new sites on Little Cornwallis Island in the Arctic Islands and a number of new sites in the Yukon, bringing to a total of 140 the deep well sites for which subsurface temperatures and permafrost thickness has been established for northern Canada. A contracted study by EBA Engineering Ltd. has begun to look at how similar data might be acquired in offshore areas. A. Taylor and A. Judge have examined the relationship between the shoreline history, post-glacial emergence and the geothermal and permafrost fields in several arctic areas.

All of the existing thermal data for the Yukon was collected together by M. Burgess and A. Judge, analysed in terms of mean surface temperature, geothermal gradients and permafrost thickness and open-filed.

Studies of the freezeback at the Illisarvik drained lake site continued with a detailed modelling of the pre-drainage talik beneath the lake bottom. In a paper authored by M. Burgess, A. Judge and A. Taylor a minimum age of 1,000 yrs. is suggested for the present lake. Monitoring of the post-drainage freezeback was continued. The results of such work are being compared with the freezeback history of the Calgary chilled pipeline test facility, now jointly managed as a research site by E.M.R., and with contracted studies conducted by Carleton University in a controlled environment facility at Caen in northern France. J. Pilon has joined the group to conduct these investigations with A. Judge and M. Burgess.

The science and behaviour of gas hydrates continues to grow in interest and A. Judge has continued to examine in-house and under contract the distribution in Canada, the implications for northern development and the geological implications of more extensive distribution during the Pleistocene.

4. Pacific Geoscience Centre

A compilation of magnetic, bathymetric, photographic, seismic reflection and dredged sample data has revealed the nature of the propagating offset on the Juan de Fuca Ridge at 47°30'N; the Ridge is currently spreading along a continuous, curved centre which connects the northern and southern straight ridge segments (E.E. Davis with University of Washington and UBC).

A synthesis of seismic refraction and multichannel seismic reflection data from the Winona sedimentary basin has demonstrated that Pleistocene turbidite sediments have seismic velocities in excess of 5 km s^{-1}, as a result of extremely rapid de-watering and diagenesis (E.E. Davis with R.M. Clowes).

The physical properties of oceanic crustal samples from the mid-Atlantic ridge DSDP hole 395A have been examined (R.D. Hyndman with N.I. Christensen and M. Drury).

G.C. Rogers has proposed that the large, widely scattered oceanic plateaus may be impact structures.

A new PDP11/23 computer was interfaced to the 7010 EG&G gamma-ray spectrometer used to analyze rock samples to obtain the rock's heat generation. Several hundred samples were measured. (T. Lewis and H. Bennetts).

The radioactivity in sediments in Alice Arm and in the mine tailings from the Amex mine on Alice Arm was determined to be much less than that of many normal surface rocks, including the outcrops sampled on Alice Arm. (T. Lewis).

The average heat generation of sediments of the Scotian Shelf were measured and their contribution to the heat flow causes the temperature at the bottom of the sediments to be 17°C, higher than if there were no heat generated within the basin. (T. Lewis with C.E. Keen).

A cruise of CSS VECTOR to Jervis Inlet further defined the large transition in heat flow from low coastal values to high inland heat flow. The bottom sediments of Bute Inlet were found to be too hard to penetrate with long oceanographic heat flow probes.

The thermal regime of the Queen Charlotte fault zone area and Queen Charlotte Basin was examined through ocean probe and petroleum exploration well temperature and thermal conductivity data. Thermal models for the oceanic lithosphere underthrusting and a margin rift basin were developed. (R.D. Hyndman, T. Lewis, C.J. Yorath).

Cores obtained and heat flow measurements attempted in the Queen Charlotte Sound and on the adjacent continental margin have shown that coarse-grained and over-consolidated sediments are pervasive as a result of Holocene non-deposition and erosion, and that bottom water temperature variations prohibit making reliable heat flow measurements with penetrations of 9 m. (E.E. Davis).

Analysis of four suites of closely spaced heat flow stations in the Jurassic northwestern Atlantic has shown that the heat flow from lithosphere ranging in age from 110 to 155 Ma is too uniform and too high to be explained by boundary layer cooling or by plate cooling; lithosphere re-heating may be the cause of the heat flow pattern observed. (E.E. Davis with J.G. Sclater and C.R.B. Lister).

A review of all heat flow measurements obtained in boreholes by the Deep Sea Drilling Project ship Glomar Challenger has been undertaken by R.D. Hyndman with M.G. Langseth and R.P. Von Herzen.

The heat flow and hydrothermal regime in a DSDP deep ocean crustal borehole on the mid-Atlantic ridge has been examined. The heat flow measured in the deeper part of the hole is high, very close to the theoretical cooling lithosphere value. (R.D. Hyndman with K. Becker, and M.G. Langseth).

A compilation of all geothermal heat flow values offshore and onshore for the area of Juan de Fuca plate map has been completed. (R.D. Hyndman).

A suite of 20 shallow, cased and grouted geothermal boreholes were completed in the Okanagan Highlands of southcentral British Columbia; the use of grouted casing proved highly successful in preventing axial water flow; heat flow along the 200 km line of measurements is remarkably uniform at about 75 mWm^{-2}. (E.E. Davis).

A manuscript assessing the geothermal energy potential of the White Lake Basin near Penticton, B.C. was prepared. (T. Lewis).

G.C. Rogers has proposed that the shallow seismicity in the southern Georgia Strait-Puget Sound region can be explained by an oblique subduction model. The amount of seismicity, its character and its distribution are consistent with this hypothesis.

G.C. Rogers has proposed that forearc basins above shallow angle subduction zones are caused by crustal response to phase changes in the subducting lithosphere. The size and location of forearc basins in western North America, southern Alaska and southern Chile support this hypothesis.

5. University of Alberta

Analysis of 1981 data obtained by three-dimensional refraction profiling (TDRP) is being carried out by E.R. Kanasewich, Stephen Chiu and C. Macrides. The data were obtained by COCRUST (Consortium for Crustal Reconnaissance using Seismic Techniques) in a large scale program in south-central Saskatchewan. An east-west profile from the 1979 and 1981 series is being analyzed by M. Shahriar and G.L. Cumming.

Synthetic seismogram studies using the Cagniard-Pekeris method are being carried out for point sources in the near and far field by E.R. Kanasewich, P. Kelamis and F. Abramovici. Work has expanded from a two layer case to a general N-layered elastic medium. Attenuation is being treated as a separate problem in the solution. A cooperative program between F. Hron and P.F. Daley at the University of Alberta and P. Gutowski at Amoco Research Center in Tulsa has resulted in the identification of several non-geometric S* type events in both field data and synthetic seismograms. R. Chan and F. Hron are working on diffracted seismic waves.

Dr. E. Nyland and colleagues have been engaged in finite element modelling of stress states in rock formations prone to earthquakes and on a major investigation into seismicity observed around in-situ heavy oil recovery projects.

Finite element calculations of an elastic model of the crust under Mexico City indicate that it is possible to predict the locations of seismicity near Mexico City if the seismic structure (seismic velocities) of the area can be estimated.

It is very important to be able to monitor the progress of fireflood heavy oil recovery projects and of steam injection heavy oil recovery projects. Together with Professor Maurice Dusseault of the Department of Earth Sciences, University of Waterloo, Nyland and colleagues have constructed a monitoring methodology which will allow detection of microseismicity associated with these projects. The technology involves standard oilfield service company tools combined with event detecting microseismicity monitors. Nyland and colleagues have successfully monitored two firefloods and one steam injection project and have demonstrated that event location is possible and the density of seismic events that occur appears to be related to thermal conditions in the in-situ project.

The limiting feature on the technique currently is the low (200 samples per second) sampling rate that can be achieved with event detecting seismic stations. Design is underway to create event detecting logic which can be plugged in to the DSF-V. This logic should allow sampling rates of 1000 samples per second on considerably more than the three channels which can now be sampled.

F.W. Jones and J.S. Rogers have constructed 10 Stacey-type mercury tiltmeters for use in measuring Earth tides and local tilts. Instruments are operating near Edmonton, Victoria, Penticton and Regina.

D.I. Gough, J.S. Bell and C.K. Fordjor are continuing with studies of breakout azimuths in oil wells. The results show the orientation of stress in the lithosphere in Alberta.

6. University of British Columbia

J.R. Horn, Dr. R.M. Clowes, Dr. R.M. Ellis, and D.N. Bird have derived a seismic structural model across the active Queen Charlotte transform fault zone which separates the oceanic Pacific plate from the continental America plate.

Analysis of data obtained during the 1980 Vancouver Island Seismic Project (VISP) carried out by COCRUST is continuing. The principal objective of the refraction program was to obtain a seismic structural section from the deep ocean of the subducting Juan de Fuca plate to the inland volcanic arc of the overriding continental plate. To this end, four profiles were run. Two deep crustal reflection experiments were carried out on the western edge of Vancouver Island. G.A. McMechan of the Pacific Geoscience Centre and G.D. Spence have interpreted a two-dimensional crustal model along Vancouver Island. D.A. Waldron and Dr. Clowes have completed interpretation of offshore

shots recorded at 3 ocean bottom seismometers (OBS's) to derive a two-dimensional seismic structural section of the subducting Juan de Fuca plate. Drs. W.R.H. White and Clowes are proceeding with interpretation of data from 3 other OBS's in the deep ocean. G.D. Spence has developed an iterative inversion technique for traveltimes from explosions in which shots at several locations are recorded on the same set of receivers. Working with Drs. Ellis and Clowes, he has applied the procedure to the VISP onshore-offshore data. Drs. Clowes, Ellis and Hajnal (U. of Saskatchewan) have demonstrated that reflections from the subducting lithosphere were recorded on the 10 km 1200% coverage land-based explosion reflection line. Reflections to depths of at least 25 km also were recorded from a 32 litre airgun firing into the 48-channel system on land, as shown by work of I.F. Jones.

R.R. Coenraads and Dr. Ellis have completed a study of 366 seismic events recorded by a microseismicity network established around the Sullivan Mine, Kimberley, B.C. Most microearthquakes occurred within 10 minutes after a mine blast and were localized to the working areas. Regional stress conditions probably are unsuitable to allow fault reactivation below the mine.

Drs. E. Gens-Lenartowicz and Clowes are proceeding with 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, R.D. Meldrum and Dr. Clowes carried out a sonobuoy reflection/refraction program with a new 32 litre airgun in the southern Strait of Georgia to determine upper crustal structure.

R.D. Meldrum and Dr. Clowes participated in the 1982 COCRUST cooperative experiment, a major seismic program across the Ottawa Graben, Grenville Front and Abitibi Greenstone Belt in the Ontario-Quebec border region.

I.F. Jones with S. Levy, Drs. Clowes and Ellis is investigating the problem of frequency dispersion in seismic reflection data with a view to developing a direct hydrocarbon detector, ways of removing dispersion from the data, and inversion to obtain the Q structure.

J. Cabrera with S. Levy and Dr. Clowes is investigating alternative methods of wave equation migration of seismic reflection sections, concentrating on the Kirchhoff integral formulation.

Dr. D.W. Oldenburg has developed a new method, based on funnel functions, to appraise the nonuniqueness in linear and nonlinear problems.

Drs. Oldenburg and T.J. Ulrych with S. Levy, C. Walker and T. Scheuer are developing new inverse approaches for the processing of reflection seismograms. One primary goal is to compute the broadband acoustic impedance from bandlimited reflection seismograms.

Dr. W.F. Slawson, Dr. W.H. Mathews (Geological Sciences) and R.W. Jeffery instituted a microseismicity survey and dendrochronology investigation of the Holocene age Beaufort-Cruickshank fault, Vancouver Island.

Dr. Slawson and M. Lisowski, in cooperation with the Earth Physics Branch and the Geodetic Survey, have established by precise triangulation a 9-station network near Gold River, Vancouver Island.

7. University of Calgary

Dr. James H. Justice assumed the Chair in Exploration Geophysics at the University of Calgary in July, 1982.

E.S. Krebes is continuing his theoretical and numerical studies of the reflection and transmission of generally inhomogeneous seismic plane waves at a boundary separating two layers of viscoelastic material.

D. Hearn and E.S. Krebes are investigating in detail the effects of physical dispersion on the propagation of generally inhomogeneous plane waves in a layered viscoelastic medium.

Detailed reflection seismic studies have been carried out by D.C. Lawton over various coalfields in Alberta using a shotgun surface seismic source. Processed sections show that in favourable conditions, coal seams at depths of 100m to 400m subsurface can be detailed. Seam thickening, splits and washouts can be detected. Successful application of the method depends primarily on getting good energy coupling into the ground.

R.J. Brown is investigating a new 'equidistant' latitude for use in determining seismic source-receiver distances with greatly reduced discrepancies vs. those involved with geocentric latitudes. R.H. Weedmark and R.J. Brown are continuing studies in the area of multichannel filtering, in particular f-k filtering and the τ-p transform. A.J. Aming is studying the application of synthetic acoustic impedance logs in reflection interpretation. N.L. Anderson is examining the effects of various deconvolution and other techniques in reflection interpretation. R.R. Santos and R.J. Brown are investigating micropolar thermoelasticity and related continuum theories and their application to wave propagation in porous media with various kinds and degrees of saturation. R.J. Brown is studying empirical models of EM coupling in IP in the frequency domain and their transformation to the time domain. F.A. Cook is intending to conduct seismic reflection studies in and west of the Rocky Mountain Trench.

8. Dalhousie University

I. Reid is studying earthquake activity following the New Brunswick earthquake of January, 1982. The work is a cooperative program with the Atlantic Geoscience Centre and uses 3 ocean bottom seismometers. The 1929 Grand Banks earthquake is also being re-examined by I. Reid and J. Adams.

9. University of Manitoba

Derbew Messfin and Wooil Moon have completed the seismic reflectivity study of Canadian Precambrian shield crust. Currently they are carrying out the seismic modelling of selected Greenstone belts in the shield area of interest. Roger Tang and W. Moon are developing an efficient method of generating VSP synthetics and also VSP data inversion scheme. Allan Carswell and W. Moon are testing the τ-sum velocity analysis method with marine seismic data supplied by industry. Tom Millar, D.H. Hall and W. Moon are interpreting the seismic data collected in Red Lake area (Northwestern Ontario) during the summers of 1980 and 1981.

Patrick Lui and W. Moon completed the transient behaviour study of sea surface heights in Hudson Bay area by solving HDE (Hydrodynamic Differential Equation) with satellite wind field. The result is being correlated with SEASAT data and the ocean-earth tide coupling mechanism is being reinvestigated. Roger Tang, Allan Carswell and W. Moon are developing a rheological modelling method for the formation of Greenstone belts in the Precambrian shield area. The result will be inferred back to the thermal history model of the Earth in Precambrian time.

10. McGill University

As part of the Abitibi greenstone belt project (see Gravity), D.J. Crossley and C. Parker of McGill University were involved in a COCRUST-organized refraction experiment which included reversed profiles

across the Grenville front and a reversed/fan shot profile across the Abitibi belt from Val d'Or to north of Matagami. This portion of the experiment was logistically very successful and produced a high percentage of usable records. A preliminary interpretation of the travel-time and delay-time data is underway.

Work by D.S. Crossley and J. Todoeschuck continues on the construction of valid theoretical spectra of long period modes of oscillation for liquid core models. The internal gravity waves at periods less than 12 hrs. and the Rossly waves at periods much greater than 12 hrs. have been adequately computed. Attention is focussed on amplitude-dependent mechanism for seismic and lower-frequency excitation of mantle-like materials. Currently in progress is an attempt to use published Q results at different frequencies to choose unique parameters of our non-linear model. Our goal is a whole-Earth free-oscillation program with the Q mechanism included. Dr. Ken Heaton recently completed his Ph.D. degree based upon his research into the theory of the response of the whole earth to long-period quadrupolar gravitational radiation. This research has demonstrated the essential importance of considering the self-gravity of any massive planet in order to calibrate its response as a gravitational-wave antenna.

O.G. Jensen and Dr. P. Tyraskis have analyzed multi-component or multi-channel geophysical data modelled as an auto-regressive random process, generalizing the Wiggins and Miller (1972) data-editing technique and the exact least squares solution of auto-regressive parameter estimation (Ulrych and Clayton, 1976). These new techniques were applied to some large magnitude earthquakes recorded at Glen Almond, Quebec.

Mr. C. Tsingas has completed geophysical surveys of the Boucherville Intrusion south of Montreal, Quebec. This intrusive appears to be similar in form to a Monteregion Hill which has not penetrated to the surface. Magnetic, gravity and seismic data were obtained and analysed in determining the intrusion's structure.

Mr. A. Vafidis and O.G. Jensen are carrying out research concerning the development of a generalized filter theory parallel to the Wiener theory but optimizing with respect to the skew and kurtosis of the error sequence.

11. Memorial University

The seismic field study conducted by I.C.F. Stewart using quarry blasts to determine the crustal structure in central Newfoundland has been completed. Interpretation of the refraction data is continuing.

H.G. Miller and J.A. Wright are continuing a combined reflection/refraction study of the Deer Lake Carboniferous basin. Preliminary interpretations of the depth to basement along a line in the north of the basin indicate an average sedimentary thickness of 600 m. A high resolution reflection survey using a Betsy source and a 48 channel recording system will be conducted in the spring of 1983.

H.G. Miller and J.A. Wright have commenced a high resolution seismic study of the St. George's Bay basin as a part of an NSERC strategic award to evaluate the fossil fuel potential of the basin.

C.-L. Fang and J.A. Wright are continuing a marine geothermal program in cooperation with C.E. Keen (A.G.C.) and K. Louden (Dalhousie). A microprocessor version of a heat flow probe with conductivity measurement and telemetry has been constructed and will be tested in next year's work. The program of heat flow in Newfoundland inlets is continuing and shows dramatic correlation between the physical oceanography of the inlets and the transients in the geothermal gradient.

12. University of Saskatchewan

Z. Hajnal continued work on interpreting the COCRUST data gathered in the 1979 and 1981 field programs.

13. University of Toronto

C.H. Chapman and R. Drummond completed development of a program to implement Maslov asymptotic theory for the computation of synthetic seismograms. This theory combines the advantages of asymptotic ray theory and transform methods. It represents the extension of the WKBJ seismogram to laterally inhomogeneous media.

N. Bregman and C.H. Chapman completed a study of the inversion of seismic reflection waveform data. The instabilities which normally arise due to noise and lack of low-frequency data were overcome by inverting simultaneously a suite of slant-stack data.

P. Cary and C.H. Chapman completed a study on the Radon transform. The filtered back projection was improved by starting with a physically realizable interpolation of the data. The streak artifacts normally found in interpretations were removed.

D. Pai and C.H. Chapman are investigating the scattering of seismic waves in laterally inhomogeneous media using Maslov asymptotic theory for the Green's function. They hope to unify and extend the methods for studying reflections from velocity gradients.

C. Thomson and C.H. Chapman are investigating the reflection of seismic waves from second-order discontinuities. Various methods - asymptotic, iterative and numerical - are being compared.

M. Weber and C.H. Chapman are comparing several methods of computing seismograms in laterally inhomogeneous media. It is hoped to study ray theory, Maslov asymptotic theory, the Gaussian beam method, the parabolic wave equation method and exact results for a very simple model.

Further applications of the gravitationally self-consistent model in glacial isostasy have led W.R. Peltier and P. Wu to strong constraints on the thickness of continental lithosphere based upon relative sea level data from the U.S. east coast. The preferred thickness is near 250($\pm$30) km. This estimate has been verified by employing the same glacial chronology to predict the secular drift of the earth's rotation pole. Fitting the drift observed in the ILS path requires the same continental lithospheric thickness.

New work on the effect of mantle phase transitions upon thermal convection (Peltier and Kay) has established that, in a thick spherical shell like the earth's mantle, the effect of latent heat release dominates the effect of phase boundary displacement for both endothermic and exothermic reactions. This implies that the Olivine Spinel reaction is strongly stabilizing whereas the Spinel-Perovskite and Magnesiowustite reaction is strongly destabilizing. The results have important consequences for the whole mantle vs. layered mantle convective circulation debate.

14. University of Western Ontario

An analysis of over 300 induced micro-earthquakes in the Gobles oilfield west of Woodstock, Ontario was completed by R.F. Mereu, Brunet, Price and Yapp. The results showed that the events occurred in two distinctly separated areas which do not correlate with the oil well positions. First motions of the seismic onsets showed that at least two active faults roughly perpendicular to each other were present.

The 1982 COCRUST seismic experiment was carried out across the Ottawa Valley Graben and Grenville Front this year. R.F. Mereu from the University of Western Ontario coordinated the experiment. Other major participants were the Earth Physics Branch, the Universities of Montreal, McGill, Québec à Chicoutimi, UBC, Toronto and Ecole Polytechnique. Both in-line and fan-type profiles for two-dimensional and three-dimensional analysis were recorded on lines from North Bay to Arnprior and from Arnprior south of the Graben all the way to Matagami in Quebec. The three-dimensional characteristics of the wave-field generated from sources used in the FENNOLORA deep-seismic sounding experiment were studied by R. Mereu with E. Husebye and S. Mykkeltveit using data recorded on the large areal array of seismometers at NORSAR Norway. The results indicated that the energy in the coda did not contain any coherent later arrivals that could be attributed to large regional velocity gradients in the upper mantle but was generated almost entirely by the scattering effects of lateral heterogeneities.

P.Y. Shen and L. Mansinha have studied the earthquake frequency-magnitude relation using the principle of maximum entropy. Shen is also studying the oscillations of the earth's fluid core in a rotating earth. The approach replaces the conventional spheroidal and toroidal representation by invoking the "solenoidal flow" approximation which neglects the flow pressure. It has been possible to develop analytic solutions for the inertial and gravitational oscillations.

Using simulated data, P.Y. Shen and A.E. Beck have systematically examined the time span and resolution of surface temperature history for various noise levels at different sampling range and rate. The major implications are that the 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.

An interlaboratory exchange between scientists using different materials, different experimental methods, and different P.T. generating equipment, has been initiated by H. Schloessin and A.E. Beck. Dr. U. Seipold and Professor H. Vollstaedt of the Akademie der Wissenschaften, Potsdam, visited the UWO laboratory in November-December to make measurements using both their own and our sample assemblies. Dr. R. Govindarajan went to Potsdam during May-June 1982 to continue these investigations using the UWO type of sample assembly with the equipment provided by the Akademie. Materials under Study are KBr, Al_2O_3, crystalline quartz, fused quartz and granulite.

H. Schloessin is involved with the following studies together with W.R. MacPherson, R. Godvindarjan, A. Carmichael and A.P. Yapp:

(1) Lattice and radiative thermal conductivity through polymorphic structure transformation and melting; (2) High pressure studies and high vacuum magnetic studies; (3) Grueneisen's gamma.; (4) Optical absorption measurements together with high pressure, T.E.P., electrical conductivity, radiative thermal conductivity and thermo-luminescence of Al_2O_3 and AlOOH.

15. York University

W.H. Cannon has studied the seismic response of the earth to gravitational radiation together with K. Heaton and O.G. Jensen of McGill.

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III (A) GEOMAGNETISM

Compiled by P.J.C. Ryall

1. Introduction

It is always difficult to pick out one or two areas from the diversity of topics embraced by geomagnetism. Of note is the continuing high level of activity in electromagnetic induction techniques. Work is concentrated in three areas to address major tectonic problems: i) in the vicinity of the Queen Charlotte Islands (Pacific Geoscience Centre, Toronto & Victoria) ii) the Rocky Mountain Trench (Alberta) and iii) the Garden/Avalon Zone in Newfoundland (Memorial and Victoria). In addition numerous magnetotelluric surveys are being undertaken to investigate various continental structures, eg. the Abitibi Greenstone Belt (Earth Physics Branch).

Several of the magnetic studies have obvious political/energy - related relevance. Examples include the aeromagnetic survey over Georges Bank (Geological Survey), surveys (Geological Survey) and rock magnetism (Earth Physics) in support of the Nuclear Fuel Waste Management Program, magnetotelluric surveys in a geothermal area (Earth Physics, Toronto) and palaeomagnetism on cores from offshore oil-wells (Memorial).

A new trend is the active participation of visiting Chinese scientists in ongoing programmes at Canadian Universities (Chen & Wang - Alberta, Wu - Dalhousie and Hu - Victoria).

2. Geomagnetic Surveys, Charts and Compilations

(a) Atlantic Geoscience Centre (R. Macnab)

(i) In collaboration with the Canadian Hydrographic Service (Department of Fisheries and Oceans) and the Earth Physics Branch (Department of Energy, Mines and Resources), hydrographic-geophysical surveys were undertaken to extend our regional mapping program to two areas: the northwestern Grand Banks of Newfoundland, and the western part of the Scotian Margin. On the Grand Banks, magnetic data were collected over some 4800 kilometres of parallel ship's tracks spaced 36 km apart. For the most part, these measurements were taken in water depths of 200 meters or less. On the Scotian Margin, data were collected over 10,440 kilometres. This survey consisted primarily of long profiles extending from nearshore to the abyssal plain.

(ii) Magnetometer data from the Labrador Sea have been compiled and released through the GSC Open File in digital form and in the form of maps portraying contours of magnetic anomaly. (Hunter, Shih, and Macnab), 1982).

(b) Earth Physics Branch, Ottawa (L.R. Newitt)

As part of a continuing study of geomagnetic secular variation, 11 repeat stations were occupied throughout Canada, primarily in the high Arctic. Six of these were occupied by contract. In addition, to commemorate the centennial of the First International Polar Year, observations were made at the three IPY stations which had been established in Canada in 1882-83 (Fort Conger on Ellesmere Island, Clearwater Fjord on Baffin Island and Fort Rae near Great Slave Lake).

(c) Geological Survey of Canada - Regional Geophysics Subdivision (P.J. Hood, D.J. Teskey)

The aeromagnetic survey of Canada continues and during 1982 122,811 line kilometres were flown in Labrador and the Georges Bank area of offshore Nova Scotia to bring the grand total flown in Canada since 1947 to 8,193,212 line kilometres.

A total of 70 aeromagnetic maps were published by the Geological Survey of Canada during 1982: fifty were 1:50,000, and nineteen were 1:250,000 scale total field aeromagnetic maps, and one was a 1:3.5 million coloured magnetic anomaly map of Arctic Canada.

High resolution aeromagnetic gradiometer surveys were flown by the GSC Queenair aircraft in the Lynn Lake and McLarty Lake areas of Manitoba (15,589 line km) and in the Guysborough County area of Nova Scotia (9,786 line km). Seven coloured total field and seven coloured vertical gradient maps on a scale of 1:50,000 were issued for the Val d'Or area, Quebec and the Yarmouth, Halifax and Antigonish areas of Nova Scotia. In addition three open files were issued to make available aeromagnetic gradiometer survey data obtained in 1981 in the Cormorant (OF 877) and Sherridon-Heming (OF 876) areas of Manitoba, the East Bull Lake (OF 879) and Caviar Lake (OF 879) areas of Ontario. The two latter surveys were flown on behalf of AECL as a contribution to the Nuclear Fuel Waste Management Program. Interpretation of the Val d'Or survey shows the ability of the aeromagnetic gradiometer to delineate the intrusive diorite-granodiorite vertical stocks with which gold is associated.

A new software technique for data enhancement of magnetic anomaly maps has been developed in a joint program with Geospectra Corp. and Asamera Oil Corp. Ltd.

The aeromagnetic survey of the Kane Basin, NWT using the NAE Convair 580 aircraft was completed with the infilling of the lines flown in 1981.In addition the remainder of Nares Strait was aeromagnetically hemstitched. An aeromagnetic reconnaissance of the northern Ellesmere continental shelf was also completed.

(d) University of British Columbia (R.M. Clowes and A. von Breymann)

Under the terms of a contract with Recope, the National Oil Company of Costa Rica, a marine geophysical reconnaissance study of the Caribbean continental margin of Costa Rica for the purpose of petroleum exploration has been carried out. Using a range-range navigation system installed specifically for the project, more than 3300 km of marine magnetics, gravity and bathymetric profiles were recorded in early 1982 with the assistance of scientific staff from Oregon State University. Reduction of the data for preparation of a marine magnetic anomaly map is nearing completion.

3. Interpretation of magnetic surveys

(a) Atlantic Geoscience Centre (Haworth, Jacobi, Lefort, Srivastava, Vogt, Kovacs, Bernero, McNab, Shih, Doherty)

(i) As a contribution to IGCP Project 27 "The Caledonide Orogen", the gravity and magnetic compilations for the Appalachians were republished at a scale of 1:2 million compatible with a new edition of the Tectonic Lithofacies Map of the Appalachians (Zietz et al. 1982). A compilation covering much of the Appalachian, Caledonide, Hercynide and Mauritanide orogens was prepared at a scale of 1:5 million for the annual project 27 meeting in Fredericton. The gravity and magnetic data on the Newfoundland and Irish continental shelves were used to examine the continuity between the geological zonation of Newfoundland and Ireland. The magnetic data were also used to examine structural discontinuities and changes in deformation on the Newfoundland continental shelf that might indicate the location of the Variscan/Hercynian Front.

(ii) Investigations in the Greenland-Norwegian Sea/Eurasia Basin and southern Labrador Sea reveal significant asymmetry of geophysical signatures with respect to crustal age.

(iii) Investigations were undertaken to improve the efficiency of two processing techniques that are routinely applied to marine magnetic data: automatic contouring, and derivation of the International Geomagnetic Reference Field. An assessment of gridding techniques has resulted in improved methods for the construction of reliable contour maps for this class of data while the development of approximation techniques for geomagnetic reference fields has accelerated substantially the processing of large data sets with no loss of accuracy.

(b) Earth Physics Branch, Ottawa (J.A. Ostrowski, L.R. Newitt)

(i) Secular variation (SV) of the Earth's magnetic field has been represented by its non-longitudinal drift (rotation about arbitrarily oriented axis) and by the amplitude changes of the individual nth-degree harmonics. The best-fitting parameters have been obtained numerically using non-linear least squares for total, non-dipole and non-quadrupole fields and for the separate nth-degree harmonics of three field models at epoch 1968.0. All observed drifts are non-longitudinal and most of them have a predominant westward component.

(ii) Magnetic repeat observations taken at selected sites in North America during historic times are being used to study the secular variation of the magnetic field, with particular emphasis on westward drift. Results indicate that the anomalously low westward drift previously observed in Canada has endured for at least a century.

(c) Dalhousie University

Interpretation continues of the anomalies over certain small areas of ocean spreading ridges, viz., Explorer Seamount in the northeast Pacific and a peak on the mid Atlantic Ridge at 36°25'N. A magnetic profile across Explorer Seamount and the Explorer Trench shows a reversal pattern identical to that for the past 2.4 Ma indicating that the Explorer Trench is the site of recent spreading. If this is true the fracture zone joining the Juan De Fuca and Explorer Ridges must be south of the Sovanco F.Z., the previous candidate for that role.

(d) McGill University (D.J. Crossley, M. Pilkington)

The possibility of using Kalman filtering for potential field data is currently being investigated. Some initially encouraging results have been obtained for fast surface susceptibility determination along magnetic profiles. Attempts to model deeper magnetic structure have encountered, and not yet surmounted, the problem of the long-wavelength instability phenomenon well-known in magnetics. Two dimensional Kalman filtering is also being considered.

(e) University of Manitoba (D.H. Hall, T. Millar - U of M; D.E. Ajakaiye, K. Ibe, M. Olatinwo - Ahmadu Bello University; M. Chan)

(i) Interpretation of anomalies over the Younger granites province and the Benue trough in Nigeria has continued. Maps of anomalies in the area 6° to 12° N lat. and 6° to 12° E long., in several wavelength ranges have been interpreted to reveal crustal structure beneath several ring complexes and beneath the Benue trough.

(ii) Large aeromagnetic and gravity anomalies in the Selkirk region, Manitoba, which lie over suspected electrical anomalies indicated by electromagnetic sounding are being interpreted to map subsurface magnetic and density distributions. Sources extend as deep as 20 km, and similar anomalies are found near Brandon, Manitoba in the Williston basin.

(iii) Surface magnetic properties in the area between the Aulneau peninsula and Rainy River, Ontario have been measured to aid in defining the thickness of the Southern granite.

4. Magnetic Observatories and Instruments

(a) Earth Physics Branch (Energy, Mines and Resources, Ottawa K1A 0Y3)

(i) The Geomagnetic Observatory Unit of the Division of Seismology and Geomagnetism continued its management of the Canadian Magnetic Observatory Network (CMON) comprising the following 12 magnetic observatories: Alert, Resolute, Mould Bay, Cambridge Bay, Baker Lake, and Yellowknife all in N.W.T., Fort Churchill, Man., Great Whale River, Que., Meanook, Alta., St. John's Nfld., Ottawa, Ont., and Victoria, B.C. Glenlea, Man. was operated in cooperation

with University of Manitoba in Winnipeg. The standard digital recording interval for CMON is one-minute, except for Mould Bay and Igloolik N.W.T., where ten-second data are available.

The final digital 1980 magnetic observatory data were deposited in the World Data Centre in Boulder, Colorado in September, 1982. One-minute digital variation data for the Fort Churchill chain of the International Magnetospheric Studies (IMS) stations covering the period September, 1976 to July, 1980 were also deposited in the World Data Centre in Boulder in June 1982. Copies of magnetograms and raw or edited digital data are available at cost plus 100% handling charge from the Branch.

Twenty-seven day forecasts of geomagnetic activity are issued every three weeks and distributed on request by the Geomagnetic Prediction Services. Short term predictions (72 hrs in summer and 7 day in winter) are also available (tel. 613-824-5595).

(ii) The program to replace the aging AMOS MKI at all Canadian magnetic observatories was completed in 1982. Observatories at Resolute Bay, N.W.T., Cambridge Bay, N.W.T., Baker Lake, N.W.T., Fort Churchill, Man., Great Whale River, Que., Meanook, Alta., St. John's Nfld., Ottawa, Ont., Victoria, B.C. and Glenlea, Man. have all been equipped with the new AMOS MK III. Testing of the replacement mass storage devices for the incremental tape decks is nearing completion. The Columbia 300D cartridge drives with improved software are scheduled to be placed in the Observatories in early 1983.

(b) University of Alberta

In 1980 two institutes of geophysics in Beijing (Peking), that in Academia Sinica and that in the State Seismological Bureau, agreed to a collaborative program with U. of A. Chinese geophysicists are participating in our array studies. It is planned to initiate magnetometer array studies across one or more of the great earthquake belts in China beginning with the Tangshan Fault Zone with our active participation in the interpretation of results.

5. Electromagnetic Induction in the Earth

(a) Earth Physics Branch, Ottawa (R.D. Kurtz, E.R. Niblett, M. Chouteau, P.A. Camfield, Ottawa; J.M. Delaurier, P.G.C.; C. Flores-Luna, U. of Toronto; D.F. Krentz, S. Handa)

(i) Magnetotelluric fields 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. Recording at the reference station 120 km north of Québec City was terminated in May as no significant variations in magnetotelluric parameters were observed in the 6.5 years it was in operation. The equipment was moved to St-Siméon, close to the zone of most of the larger earthquakes that have occurred in this century. Surveys with the Phoenix Geophysics Ltd. magnetotelluric system indicate that the large changes in impedance observed at the Charlevoix station may be related to a significant geoelectric structure several tens of meters south of the station.

(ii) A magnetotelluric survey consisting of 18 soundings using the Phoenix Geophysics Ltd. magnetotelluric system was conducted on a north-south profile from Val d'Or to Matagami across the Abitibi Greenstone Belt (Québec). The work was part of a major geophysical project to construct a tectonic model for the origin and evolution

of this Belt. Preliminary results show the subsurface structure to be very complex and largely three-dimensional in character but with no strong indication of structural changes across the east-west "gravity boundary". A conductive layer was observed to exist all along the profile in the lower crust at a mean depth of 16 km.

(iii) The magnetotelluric survey of the East Bull Lake, Ontario gabbro intrusion consisted of three tensor soundings with the Phoenix Geophysics Limited MT system, and scalar measurements in two orientations at 52 sites with a SYGEQ AMT system. Inversion of the data reveals a conducting layer at approximately 100 m dipping westward to greater depths near the center of the intrusion. The major shear zone and other faults were well defined by the scalar survey.

(iv) A magnetotelluric survey was conducted at seven stations across the geothermal area near Meager Creek, B.C. using the Phoenix MT system. Inversion of the data, performed in the field by the system, indicates a good conductor at a depth of one kilometer in the Angel Creek area, deepening to five kilometers to the east and west. The results outline a conductive region which agrees well with the known extent of the geothermal anomaly.

(v) Transfer functions have been calculated in the period range 2-40 min at seven sites traversing the extension in north central Saskatchewan of the North American Central Plains conductivity anomaly. At sites straddling the Rottenstone - LaRonge Magnetic Belt, the transfer functions can be modelled by a two-dimensional conductor, 100 km wide by 20-25 km thick with its top at depth 7-10 km, having a conductivity contrast of 100-1000. We believe that the enhanced conductivity is related to Proterozoic collisional suturing in this part of the Churchill Province.

In a similar study executed jointly with the Geological Survey of Canada, eight variation stations were operated in June 1982 across the Wopmay Orogen in the Northwest Territories. Visual inspection of magnetograms shows no anomalies in pulsation and substorm signals, suggesting a greater uniformity in deep-crustal electrical conductivity than in Saskatchewan. Audiomagnetotelluric measurements across the Wopmay Fault do show a well-developed anomaly originating from shallow inhomogeneity.

(b) Pacific Geoscience Centre, Victoria (L.K. Law, J.M. Delaurier, D. Auld)

Ocean Bottom Magnetometers were deployed at sites near the top and bottom of the continental rise in Queen Charlotte Sound and at a site on the Pacific Plate about 120 km west. The three magnetometers were successfully recovered after 33 days of recording on the seafloor. At the shelf site, further testing of the controlled source magnetometric method, using a vertical electric dipole, confirmed that signals can be detected out to ten dipole lengths. This is a co-operative project with the University of Toronto.

The previous field results from across southern Vancouver Island and the adjoining continental shelf were modelled using a 2-dimensional finite-difference method. The response of a subducting slab with a conductivity of 0.1 Sm^{-1} and dipping landward at 5 to 10 degrees fits the observed results.

(c) University of Alberta (D.I. Gough, D.K. Bingham, M.R. Ingham, K. Wilson, V.R.S. Hutton, G. Dawes, Chen Guangming, Wang Xishuo, M. Day, S. Kapotas, D. McKirdy, R. Fowler, M. Connors, D. Rankin, F. Pascal, R. Singh, H. Pascal, F.W. Jones, H.-L. Lam

(i) The results of the two array studies of 1980 have now been fully worked out. A paper on structures identified by the large "discovery" array, 1980A (southern British Columbia and Alberta) has been published. The array 1980B, a small, high-resolution array in the Alberta foothills over a known geothermal anomaly yielded evidence of a conductive structure underlying the high temperature-gradient anomaly. To show this it was necessary to invert the induction matrix, with the normal fields represented by least-squares fitted planes.

(ii) The 1981 arrays were medium-resolution with magnetometers typically 50 km apart, designed to map and study conductive structures detected by means of the 1980A array.

The 1981A array was centred near Tête Jaune Cache in the Rocky Mountain Trench west of Jasper, Alberta. It extended across three mountain ranges, from the Alberta foothills at its northeastern limit into the Anahim belt of recent volcanics in its southern part. Fourier transform anomaly maps, for spectral peaks at periods from 3 to 30 min or more, show characteristic anomalies (under interpretation).

The 1981B array was located to map the anomaly which runs across southern Alberta and the southeastern corner of British Columbia, across strike of the Rocky Mountains. There may be an association of this with the lower-crustal rift structure proposed by Kanasewich, Clowes and others from seismic, gravity and magnetic data some fourteen years ago. The array recorded many magnetovariation events at high efficiency. The data are about halfway through the process of digital conversion and editing.

(iii) The magnetotelluric method offers a powerful approach to the problem of the depth to the highly-conductive structures mapped by means of magnetometer arrays. Using broad-band MT equipment, with partial processing of the higher-frequency data in real time at each field site, Dr. Rosemary Hutton and Mr. G. Dawes (University of Edinburgh) are collaborating in a study of the anomaly centred at Tête Jaune Cache in the Rocky Mountain Trench west of Jasper, guided by the magnetovariational anomalies mapped by means of the 1981A array. Stations were located on a profile along the floor of the Trench (which is the valley of the Fraser River) and along three creeks tributary to the Fraser River, two giving penetration into the Rocky Mountains northeast of the Trench and one running southwest into the Cariboo Mountains. The preliminary in-field results, for the frequency range 0.1-800 Hz, show several kilometres depth of highly-conductive sediment in the Trench but give indications of a deeper conductor under stations 15-20 km from the Trench in the Rockies.

(iv) A field program using magnetotelluric methods was carried out in southeastern Saskatchewan to extend the knowledge of the crust under the relatively shallow sediments of the region. These data have been extensively analyzed and interpreted. A new inversion method is proving very useful in the interpretation. Details of structure within the sediments corresponding to the prairie evaporites have been obtained.

Additional fieldwork has been carried out at experimental heavy oil sites in cooperation with the Alberta Oil Sands Technology and Research Authority, with the aim of obtaining information on the flame front. In connection with field programmes, two-dimensional numerical studies are also being carried out.

(v) Laboratory measurements of dielectric constant in clay-containing sands and sandstones have been carried out to obtain fundamental information on the effect of clay inclusion in reservoir rocks. These measurements are in the microwave band up to 1 gigahertz. The dielectric constant and conductivity measurements are a first step to evaluating porosity and permeability of oil-bearing rocks. Measurements will continue using various percentages of saline solutions as well as oil-water emulsions in typical drill samples.

Theoretical studies of microwave propagation as a multiphase phenomenon are also continuing. A mathematical model has been formulated in order to improve laboratory data to elaborate the relationship between electrical properties and the porosity and permeability of reservoir rocks.

(vi) The perturbation of uniform and nonuniform electromagnetic fields by two-dimensional and three-dimensional electrical conductivity anomalies is being investigated by numerical techniques. Programs for the calculation of perturbation and induction arrows associated with three-dimensional models are being improved. The electromagnetic response of a subducting slab, in which the electrical conductivity is derived from the thermal regime obtained from heat flow modelling work, has been studied and the effects of shear strain heating and upward movement of partial melt are being considered.

(d) Memorial University of Newfoundland

B.K. Pal and J.A. Wright have completed a 10-station survey of the Gander Zone - Avalon Zone tectonic boundary in Newfoundland. The survey, covering the frequency band 0.025 Hz to 5 Hz, shows generally high transfer functions at all stations. This is indicative of the crustal conductor in this zone, apparently associated with a subduction zone that was active in Carboniferous-Devonian time. The field results have been compared with the model results for the area based on an analogue model study. The transfer functions at 0.1 to 1 Hz are generally quite high (0.6 - 0.8) and may be associated with upper crustal structure related to the Gander Zone.

(e) The University of Victoria (H.W. Dosso, W. Nienaber, R. Charters, G. Heard, D. Hebert, W.B. Hu, J.T. Weaver, D. McA. McKirdy, E.L. Friesen))

(i) In collaboration with Dr. J.P. Lokken (Defence Research Establishment Pacific) a model study and a field station study of the coast effect in an Arctic bay is continuing. The electric and magnetic field measurements for stations over land and at the surface of the ocean (using the ice as a platform) for the 8 Hz Schumann resonance field are being analysed with the aid of a laboratory analogue model.

An analogue model study of the Queen Charlotte Islands regions, and a comparison of model results and field station results, has been completed in collaboration with Dr. L.K. Law (Earth Physics Branch, Department of Energy, Mines and Resources, Sidney). A comparison of analogue model and field station in-phase

and quadrature induction arrows for both coastal and inland locations was carried out for the period range 4 min to 120 min.

In collaboration with Dr. J.A. Wright (Memorial University) a laboratory analogue model study of the Newfoundland region has been carried out. Contour plots of the model field components as well as of induction arrows have been compiled. The model and field station induction arrows were compared for both coastal and inland sites. The effects on the field components due to sea channels, capes, and the continental margin were examined.

A laboratory model of the Hainan Island region of China has been constructed and electromagnetic model measurements are underway. This project is of particular interest to W.B. Hu, a visiting scientist from the People's Republic of China. It is planned to employ these results as an aid to interpreting field station measurements for the Hainan Island region.

(ii) A number of extensions have been made to the three-dimensional thin sheet program for modelling electromagnetic induction in the Earth. Included among them is the incorporation of layering in the sub-structure.

A theoretical study of "current channelling" has been made by considering a synthetic model in which a half-plane ocean is connected to a quarter-plane ocean by a thin conducting strip. The extent to which channelling takes place is dependent on both the period and the angle of the connecting strip relative to the direction of the inducing field.

Numerical modelling of the Val de Ruz in Switzerland has been completed for comparison with AMT field data obtained by Dr. G. Fischer (Neuchâtel) and his group. The effects of topography, layering and a geological overlap have been included in the model, and the results show that apparent resistivity/phase measurements are quite sensitive to the angle of the overlap.

6. Palaeomagnetism & Rock Magnetism

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

(i) The Redstone River Formation and several units of the Neohelikian MacKenzie Mountains Supergroup in the Northwest Territories are currently under study. These units are the Little Dal Group, the Katherine Group and the Tsezotene Formation.

The Michael gabbro suite in Labrador was sampled during the last field season. Final results on the Mealy dykes of Labrador have revealed four distinct magnetic components, the major ones being the original magnetization and a pervasive overprint by Grenville tectonism.

(ii) Paleomagnetic sampling of the Permian formation of Cap-aux-Meules (upper and lower members) was carried out this summer on the Iles-de-la-Madeleine in the Gulf of St. Lawrence.

Paleomagnetic studies of the South Mountain Batholith and related intrusions of the Meguma Zone in southern Nova Scotia, have revealed to date two magnetizations, attributable to two distinct phases of igneous activity.

A brief review of paleomagnetic results from Paleozoic rock units from the Appalachian Orogen of North America is being prepared as part of a joint project with the Canadian Committee of the International Geological Correlation Programme, Project No. 27: "The Caledonide Orogen".

The Ordovician ophiolitic Fournier Complex in northern New Brunswick has been studied by Morris Magnetics under contract to the Earth Physics Branch. Preliminary reports indicate a complexity of magnetic signatures related to remanence acquisition events of different ages.

(iii) Results from the Peel Sound formation, located in the northeast corner of Prince of Wales Island indicate that the central Arctic was located in equatorial latitudes in Lower Devonian times. Investigation of the Red River Canyon formation from Ellesmere Island is currently in progress.

(iv) The Earth Physics Branch and Geological Survey of Canada are co-sponsoring the development by CTF Systems of a second generation of Superconducting Quantum Interference Devices (SQUID).

The development of the Continuous High and Low Temperature (CHALT) magnetometer is now in progress at the Geomagnetic Laboratory of the Earth Physics Branch.

(v) A compilation of paleomagnetic data from the Carboniferous of North America has revealed a distinct change in the behaviour of the Earth's magnetic field during this time period. A time-line horizon marker is apparent, and can be used for separating rock units into time-stratigraphic sequence on the basis of paleomagnetic results.

(vi) The paleomagnetism section of the Earth Physics Branch is responsible for the rock magnetic property task within the Nuclear Fuel Waste Management Program/AECL. Magnetic susceptibility studies are being carried out on deep borehole cores, drilled in the areas of Chalk River, Ontario, Lac du Bonnet, Manitoba, and Whiteshell, Manitoba. This logging tool is sensitive for the detection of fracture zones, lithological changes and compositional homogeneities.

(b) Pacific Geoscience Centre, Victoria (E. Irving)

The paleomagnetic laboratory at P.G.C. is about 60 percent installed and operating. Collections made and currently under study are from Ellesmere Island (Cretaceous, Permian and Carboniferous in collaboration with I.S.P.G.) and the southern Cordillera (Triassic of Vancouver Island in collaboration with Carleton University and Cretaceous of southern B.C. and Alberta in collaboration with G.S.C. Vancouver and I.S.P.G.). A new sequence of maps of global continental drift(since the late Carboniferous) on a wall chart and set of 35 mm coloured slides has been prepared. The slide set is available from the Publications Office of the Earth Physics Branch, and the wall chart from K.G.Campbell Corp., Ottawa.

(c) The University of Alberta (M.E. Evans, G.M. Turner, G.S. Hoye, D.I. Gough, T.S. Hamilton, W.I. Gough, M. Mareschal, J.F. Lerbekmo, Department of Geology, and V. Frnoch)

(i) Work on the Olympia Interglacial sediments from the Bessette Creek section (British Columbia) has been completed, and the results published. The sequence studied represents an interval of about 12,000 years starting 31,000 years ago, and was sampled uniformly at 212 stratigraphic horizons, with a sampling interval ranging from 25

to 80 years. There are three relatively large perturbations which may represent a recurrent phenomenon affecting the site approximately every 4,000 years. If the perturbed zones are eliminated, the mean direction (D=1.2°E, I=67.2°, α_{95}=0.8°, N=125 horizons) does not differ from that of a geocentric axial dipole, despite the small cone of confidence.

The Mackereth corer built last year is now fully operational and has been used to collect 12 cores from Mara and Wood Lakes (B.C.), and 6 from Lesser Slave Lake (Alberta). The former have been shipped to New Zealand where Dr. Turner will continue to study them. The latter possess very low susceptibilities and are very weakly magnetized, and may therefore prove unsuitable for paleomagnetic investigation.

(ii) The results obtained from a paleomagnetic study of Level Mountain (northern B.C.) have been documented in a paper which is currently in press. Fifty lava flows were sampled and fourteen polarity intervals are defined by the resulting magnetostratigraphy. Most of the flows yield acceptable normal or reversed paleopoles, but two of them record the Gauss/Matuyama polarity transition, and a further four yield a tight group of divergent directions which may represent a geomagnetic excursion. This, and other published information, suggests that a local, long-lasting source of geomagnetic perturbations may exist in the outermost core beneath this region.

(iii) A study of a modern kiln has been completed and published, in order to confirm the reliability of such features for archeomagnetic work, and to investigate the importance of magnetic refraction and mechanical disturbances.

Work on the paleodirections recorded by 9 baked features covering the interval from the 8th century B.C. to the 4th century A.D. has been completed. New samples from a dozen sites in southern Italy have been collected and the samples are currently under investigation. In addition paleointensity investigations have been commenced on selected samples of this material, including the lavas from Vesuvius.

A preliminary study of the magnetic properties of ancient struck coins has been completed and is in press. The results indicate that while coins may not be reliable recorders of the ancient magnetic field direction (compared to other artifacts such as pottery and bricks), it is possible for the original upper and lower faces to be discerned magnetically. However, it is unlikely that quantities such as remanent intensity will be unambiguous indicators (as has been proposed) of the provenance of the metal used.

(iv) A composite magnetostratigraphic section for the latest Cretaceous Maestrichtian stage, and extending across the Cretaceous-Tertiary boundary into the Lower Paleocene, has been completed in the Red Deer Valley. The polarity pattern permits correlation with sea floor geomagnetic anomalies 29 to 33. The composite section encompasses five subsections between Scollard Canyon and Willow Creek totalling 330 meters stratigraphically, and the entire Edmonton Group above the No. 1 coal seam in the Horseshoe Canyon Formation. The magnetostratigraphy is based upon some 450 sites and 1500 samples taken systematically at vertical spacings of 0.1, 0.5, 1.0 and 1.5 meters.

In addition, the magnetostratigraphy of parts of the Maestrichtian and Lower Paleocene have also been completed in the Cypress Hills of southwestern Saskatchewan, the Hell Creek area of central Montana and near Bismarck, North Dakota. These sections have been correlated with the Red Deer River section through a combination of magnetostratigraphy, palynology and radiometric dating.

(d) Dalhousie University

During the last year we have initiated paleomagnetic studies of the Troodos, Cyprus, ophiolite and have been involved with rock magnetic and oxide petrographic studies of crustal sections in Iceland and Cyprus.

The paleomagnetic properties of a 500 m drillcore section of the topmost part of the extensive component of the Troodos ophiolite have been measured. The results indicate a low, about 15°N, latitude of initial magnetization probably in a uniformly normally directed geomagnetic field. Intensities and Q ratios are comparable with values for in-situ oceanic crust. The rock magnetic work indicates that alteration decreases downwards over this internal, a result that is also consistent with observations from DSDP drillholes in present oceanic crust.

The rock magmatic and oxide study of a 3 km vertical section of Iceland is complementary to a previous paleomagmatic study. The previous study (Bleil et al, 1982) raised a number of questions regarding the change in material remanence intensity and polarity with depth. The nature of these changes suggested that hydrothermal alteration was extensive at depth, and that polarity remagnetisation occurred in epidote-containing flows where dike density was high. The present study is confirming these implications and a model for the history of the section is being constructed.

(e) Université Laval

(i) Extensive paleomagnetic sampling of Archean rock units (lavas, gabbros and granodiorites) from the Troilus-Frotet greenstone belt. Paleomagnetic study undertaken by E. Gahé and M.K.-Seguin in collaboration with A. Simard from the Québec Department of Energy and Natural Resources.

(ii) An extended study of the gabbro sills of the northern sector of the Labrador Trough is still under way by the geological party of Dr. T. Clark and Mr. D. Fournier from the Quebec Department of Energy and Natural Resources. Additional sites were sampled during the 1982 summer season.

(iii) A paleomagnetic study of the Cheneaux gabbro at the Québec - Ontario border undertaken by M.K.-Seguin and Mr. J. Brun from the Québec Department of Energy and Natural Resources is completed.

(iv) The paleomagnetic studies of the Finn Hill Sequence and the porphyrite intrusives from the Harbour Main-Colliers area are completed. The interpretation of the results is practically completed as well.

(v) France - L'étude paléomagnétique entreprise par M.K.-Seguin en Vendee ouest est terminee et les resultats sont sous presse.

(vi) Nova Scotia - The paleomagnetic research done by M.K.-Seguin and K.V. Rao in collaboration with E.R. Deutsch (Memorial) is under way. The Morrisson River Fm paper is written and we are concentrating our effort on the Antigonish alaskite and Eden pluton.

(vii) Newfoundland - The Cambrian Brigus Shale formation was investigated paleomagnetically by K.V. Rao and M.K.-Seguin. The paper is now being written.

(viii) New Brunswick - A paleomagnetic study of the Lower Devonian metavolcanic units and Upper Devonian diabase and diorite dykes in the Campbellton - Dalhousie area by M.K.-Seguin, E. Gahé and L. Fyffe (NBDNR) is now completed.

(ix) Québec - Ile d'Anticosti - Golfe Saint-Laurent. M.K.-Seguin et A.A. Petryk (MERQ) ont entrepris une deuxième étude paléomagnétique (détaillée, 18 sites) dans la section type de l'Ordovicien-Silurien de l'île Anticosti.

(x) Basses-Terres du Saint-Laurent. M.K.-Seguin a fait un échantillonnage complémentaire de tous les affleurements de roches plus ou moins arénacés de la formation de Chazy.

(xi) Baltic Shield (Norway, Sweden and Baltic islands) - A joint project between Université Laval (M.K.-Seguin) and the University of Lund in Sweden (Goran Bylund) with the collaboration of P. Nystrien (Norway) was started in late-81 and is now underway. A study of the tillites of Vendian age is completed and the Cambrian sequence is now the subject of an exhaustive investigation. In the fall of 1982, the specimens with weak magnetization were measured with the cryogenic magnetometer of the USGS in Flagstaff, Arizona.

(f) Memorial University of Newfoundland (E.R. Deutsch, J.P. Hodych, K.L. Buchan, G.S. Murthy, R.R. Patzold)

(i) A comparison of mid-Ordovician paleomagnetic results from NW and SE of the presumed collision suture in Ireland with results of the same age in western Newfoundland and mainland eastern North America was made. Results suggest that the western as well as eastern segments of the British Isles must have drifted substantially relative to the North American eastern margin between mid-Ordovician and late Paleozoic time.

A paleomagnetic re-examination of the early Ordovician Wabana Group hematite ores of the Avalon Peninsula of Newfoundland was also made and yielded a paleopole not very different from the Ordovician paleopoles for cratonic North America. This suggests that the latitudinal width of the Iapetus (Proto-Atlantic) ocean was not very great in the early Ordovician, or that the Wabana Group was remagnetized by the Devonian orogeny.

A paleomagnetic study of Silurian hematite ores from Alabama was begun. The ores pass a fold test and are yielding what will be only the third reliable Silurian paleopole determination for cratonic North America.

Studies of magnetic properties of granites and gabbros from the Gander zone of the Newfoundland Appalachians are continuing. The studies on the diabase dikes intruding the granites yielded several pole postions. Conjoint radiometric studies undertaken by P. Reynolds at Dalhousie University on samples used for these paleomagnetic investigations yielded an age of 371 $\pm$ 9 m.y. for the diabase dikes. Thermal demagnetization experiments are in progress on samples of granites from the area. The Carboniferous Codroy Group and the Devonian Clam Bank Group in western Newfoundland are being re-examined to establish the paleomagnetism for these sandstones. Systematic thermal demagnetization is in progress. A fold test is available for these rock units which would help in establishing the minimum age of the isolated magnetization.

A paleomagnetic investigation of late Precambrian and Paleozoic rocks of the Avalon zone was continued in cooperation with M.K.-Seguin (Laval University). In 1982 this work centered on rocks in Nova Scotia and New Brunswick (see in this chapter under "Université Laval").

(ii) The first paleomagnetic results were obtained from offshore Labrador, based on vertically oriented short core sections from three oil company wells dated latest Jurassic to Early Cretaceous. AF and thermal treatment revealed a stable remanence mostly of N polarity and in one case an R-N polarity change. Virtual pole loci calculated from the paleo-inclinations agree fairly well with published Early Cretaceous poles for eastern North America.

Early Tertiary basalts from Durban and Padloping Islands off Baffin Island were studied and give a paleomagnetic pole of N polarity at 74.3°N, 98.5°W (dp,dm = 3.3°, 3.4°, N = 33 flows). This is identical to the pole position obtained after AF treatment, or that obtained without any treatment, of the NRM which appears to reside in a single component of highly stable, single-domain magnetite. A 21° angular separation between this pole and a published pole for Disko, west Greenland, implies a wide Baffin Bay in the early Tertiary, assuming that the two poles are contemporaneous. Such a reconstruction poses some problems.

(iii) Studies of magnetic properties show that coercive force varies in proportion to magnetostriction constant, for two multi-domain and one pseudo-single-domain magnetite powders cooled to liquid nitrogen temperature. The same was shown to be true of six igneous rocks containing multi-domain or pseudo-single-domain magnetite. Hence, magnetostrictive control of coercive force - presumably through internal stresses - may be a common source of stability of remanence in igneous rocks. Similar results were obtained in multidomain titanomagnetite.

A magnetic study has begun of oolitic iron ore from the early Ordovician Wabana Group, Newfoundland. It is planned to investigate especially the interaction, during heating, of hematite, chamosite and siderite present in these rocks, where heat treatment in the laboratory had been observed by previous workers to result in dramatic magnetization changes.

(g) University of Toronto (K.S. Argyle, C.R.W. Duff, D.J. Dunlop, C.J. Hale, M.E. Bailey, L.D. Schutts, H. Hyodo, T. Knight, A. Steele, M.O. McWilliams)

(i) Domain state energy calculations for cubic grains of magnetite are being made based on magnetization by domain wall motion. Domains are assumed to be rectangular with antiparallel magnetizations of magnitude Js, and their corresponding (magnetostatic) energies are calculated. Domain walls are taken as being rectangular with alternating wall magnetizations of $\frac{2}{\pi}$Js. Wall energies are calculated (1975) with the introduction of magnetostatic energy terms due to all four wall surfaces. Results show that minimum zero field energy states have net magnetizations. For even numbers of domains this remanence is due to the odd number of domain wall moments, and for odd numbers of domains the remanence is due to net domain magnetizations as wall moments cancel.

(ii) Synthetic magnetite samples (1% volume concentration) have been made by the reduction of 3 cubical hematite powders of size ranges 0.3 - 1.2 μm, 2.0 - 4.0 μm and 3.8 - 5.9 μm. Room temperature hysteresis and ARM demagnetization curves show that

these samples exhibit PSD behaviour. Further domain state calculations for these particles as well as high temperature hysteresis and TRM experiments are being conducted to test current models of the PSD mechanism.

(iii) Intermediate CRM directions have been studied in greater detail using the reduction of Fe_2O_3 to Fe_3O_4 and the oxidation of Fe_3O_4 to Fe_2O_3. When hematite was reduced at 500°C in the presence of a 50 mT ambient field, CRM aligned with the field was produced unless the sample initially contained a strong-field remanence. This initial strong remanence was able to deflect the CRM toward its direction, as in the original TiMt experiments. The dependence of CRM direction on the strength of a pre-existing NRM was clearly shown when comparison samples containing "NRM's" acquired in 50, 200, 500 mT and saturating fields were reduced at 500°C in a 50 mT field. A systematic arrangement of CRM's resulted between the ambient field direction (50 mT sample) and the NRM direction (saturated sample). All of the CRM's produced appeared to be single stable components of magnetization.

(iv) For the first time it has been possible to recover <u>two</u> paleofield intensities from a single sample carrying multicomponent NRM. As a test, a Matachewan diabase sample was given a sum of pTRM's: 600-525°C in 50 μT + 525-20°C in 25 μT. The AF demagnetization of this composite was compared to the AF demagnetization of a total TRM in 50 μT. The resulting van Zijl plot yielded the correct field intensities of 25 and 50 μT. A companion sample carrying a hybrid NRM (Matachewan overprinted by Abitibi dike intrusion) showed a clear separation of Abitibi (0 - 17.5 mT) and Matachewan (17.5 - 80 mT) NRM's. The near-polar Abitibi field was about twice as intense as the near-equatorial Matachewan field, as would be expected for a dipole field.

(v) The Tudor gabbro yields numerous examples of Grenville A-type magnetizations, overprinted by what is apparently a reverse C-type magnetization, like that found in the Cordova gabbro and shown to be a Paleozoic overprint. However, vector diagrams leave no doubt that the Tudor "C" is an intermediate direction, the true overprint being NE and moderately steeply down. Because of its high blocking temperatures (up to 500-525°C), it is not likely a PEF viscous overprint. Thellier paleointensity determinations indicate rather similar field intensities of one-half to one-third the PEF intensity in south-central Ontario. The Thellier experiment demonstrates the thermal origin of the Tudor A NRM. The high blocking temperatures (500-575°C) imply that the A could well be primary TRM that survived $\sim$500°C reheating in this part of the Grenville Province.

(vi) Progressive resetting of characteristics remanences of Nipissing diabases is now documented up to 5.8 km NNW of the Grenville Front near Temagami, Ontario.

A very surprising result is that 15 samples from 7 sites give a mean direction D = 198° I = -20° (k = 27.2, α_{95} = 7.4°), with a paleopole indistinguishable from that of the 2700 Ma old Matachewan diabase, a formation much older than the Nipissing.

Sampling has been extended during 1982 to the Cobalt and Sudbury areas, more than tripling the overall collection. A primary target has been Archean metavolcanics, since in the Temagami area, these rocks show possible Grenvillian overprinting.

(vii) The Wabigoon gabbro of the western Superior Province yields a single characteristic NRM. After AF and thermal cleaning, D = 245.5°, I = 12° (k = 19.5, α_{95} = 10.5°, N = 11 sites), based on 29 samples. A N→R reversal is recorded by the thermal data. The reversal temperature varies from 305°C near the margin of the pluton to 400-450°C in the interior, allowing one to deduce the temperature profile across the body at one "instant" during its cooling.

(h) University of Windsor (D.T.A. Symons, M. Stupavsky, I. Osmani, U. Atuanya, C.P. Gravenor)

(i) The rock magnetic and paleomagnetic characteristics of the Griffith Mine iron deposit near Red Lake, Ontario have been studied. By including the effects of anisotropy of magnetic susceptibility and remanence, a reasonable fit of the calculated anomaly to the measured aeromagnetic anomaly is obtained. The iron formation contains a prefolding remanence component of ~2.9 Ga age, a second prefolding component of ~2.65 Ga age, and a postfolding Algoman orogenic component of ~2.5 Ga.

(ii) The Gunflint iron formation has been studied and contains an ~2.3 Ga component which is either a primary or a Penokean orogenic component related to diagenesis. It also contains a Hudsonian orogenic overprint acquired at ~1.7 Ga. The interpretation is supported by a conglomerate test and by contact tests with a Logan sill and a Keweenawan lava.

(iii) A thermal demagnetization study on the Jurassic Island Intrusions has been completed and submitted for publication. The unit contains an early Jurassic and a mid Cretaceous remanence component. The results indicate that the Vancouver Island segment of the Insular Belt (Wrangellia) has either: a) been rotated by ~23° clockwise since mid Cretaceous time, or b) been translated ENE by ~9° between early Jurassic and mid Cretaceous time and by a further ~13° since mid Cretaceous time. A second paleomagnetic study of the Topley Intrusions in the Intermontane Belt (Stikinia) has been completed and submitted for publication. It shows that this terrain has been translated northward during lower to mid Tertiary time by ~16° but that the terrain has not been rotated as previous studies indicate.

(iv) A major conglomerate test has been carried out on the Port Askaig tillite, Scotland. The results show that this upper Dalradian unit was remagnetized during the Ordovician Caledonian orogeny so that the paleolatitude data cannot be used to support the concept of a late Precambrian worldwide glaciation.

(v) The basal Huronian Dollyberry Lake volcanic unit outcrops in the Elliot Lake area. It carries a postfolding Penokean (~2.2 Ga) remagnetization which corresponds to and indicates that the remanence of the equivalent Thessalon volcanics is also postfolding and Penokean in origin.

(vi) Two studies have been published on the paleomagnetism of rock units along the Grenville Front. One is on Nipissing diabase and the Gowganda Formation in the southwest Lake Temagami area north of the Grenville Front, and the other is on the anorthosites in the French River area south of the Front.

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III (B) AERONOMY AND SPACE PHYSICS

Compiled by: D. Venkatesan

1. Introduction

This report is compiled for the Canadian Geophysical Bulletin. Much of the data for this report was provided by Dr. R.E. Horita, Department of Physics, University of Victoria, Victoria, B.C., who has edited the DASP/CAP Newsletter for Aeronomy and Space Physics for the year January-December, 1982. The primary purpose of this report is to present an overview of activities of the various institutions; thus no bibliography has been included.

2. University of Alberta, Department of Physics (G. Rostoker, W. Baumjohann (Univ. Munster), C.T. Russell (UCLA), Samson)

Isolated large substorm expansive phases are found to occur simultaneously with clear northward turnings of the interplanetary magnetic field (IMF). In one study, in a background southward IMF, each northward turning coincided with a substorm recovery phase, and the westward electrojet collapsed piecewise from E to W; this sequential disappearance is attributed to a drop of field-aligned current density below $\sim 10^{-6}$ A/m^2, resulting in sudden shutdown of the auroral particle accelerator on auroral oval field lines.

Evidence of Kelvin-Helmholtz (K.-H.) instability accounting for Pc 4,5 activity seen on the dayside auroral oval is being examined in view of inconsistent past evidence of mechanism of K.-H. instability on the magnetopause boundary. The study uses Pc 4,5 power distribution across the auroral oval for various solar wind velocities under controlled distribution of the IMF orientation.

The onset of polar magnetic substorm triggered plasma waves (eg. Pi 2's, 6-15 MHz) in the earth's magnetosphere is being studied, seeking (a) to map the location of the field-aligned currents (FAC) and ionospheric currents associated with the Pi 2's and (b) to obtain a mathematical estimation of the polarization parameters of the waves and to filter multi-channel data to extract these polarized waves.

A study of polarization states of Pi 2's near the high latitude substorm enhanced electrojet using ground-based magnetometer data shows two areas of Pi 2 localization; a predominant poleward Pi 2 within the westward travelling surge (WTS) and to the east; and a predominant equatorward Pi 2 to the west of the WTS. The orientations of the polarization ellipses of the Pi 2's suggest oscillation of two distinct regions of field-aligned current (FAC). A strong net upward FAC is centered near the region of the WTS and a net downward FAC is centered at the same latitude, but $\sim 14°$ to the E. Oscillations of these FAC contribute significantly to observed perturbation pattern of Pi 2's; remaining significant contribution arises from the westward ionospheric (Hall) electrojet oscillations.

Utilising mathematical analysis of polarization states three estimators of the polarization parameters have been determined. The methods are extremely useful in designing adaptive filters for the detection of seismic signals and Pi 2 pulsation bursts.

In the magnetospheric substorm phenomenology workshop, the substorm was redefined in terms of basic processes (i.e. the storage process, the release process). The substorm is a primarily driven process with the solar wind energizing magnetosphere-ionosphere current systems with a predictable time-lag. (Participants among others: Rostoker, Akasofu, Baumjohann, Kamide, McPherron. Proceedings under preparation).

3. University of Calgary, Department of Physics, Space Sciences (C.D. Anger, T.A. Clark, R.T. Boreiko, L.L. Cogger, J.S. Murphree, S.M. Krimigis, S.P. Agrawal, D. Venkatesan, L. Varga, R. Lieu, H.G. James, D.B. Muldrew, J. Bamber)

(a) The UV auroral imager (under development, UVI Science Team, NRC, and Canadian Astronautics Ltd.) for the Swedish Viking spacecraft (launch, Oct. 1984) will be piggy-backed on the French SPOT remote sensing spacecraft (Arianne launch vehicle). Considerable effort by the science team involves design flight hardware fabrication, ground calibration system, design work for ground data handling and mission planning system for receiving site (Kiruna, Sweden). Compensation for scattering and absorption effects of UV emissions in residual atmosphere over aurora (not-trivial) is under active study by science team and its associates.

(b) The high resolution far-infrared absorption spectrum of the stratosphere between 100 and 500 μm (0.1 μm resolution) is automatically measured by the Michelson Interferometer during balloon observations of the sun by solar telescope, tracking the sun to the earth's limb during sunset period; this provides a measure of stratospheric molecular constituent concentration profiles for H_2O and O_3, the major absorbers, and HCl, N_2O, OH and H_2O_2 (detectability expected in such spectra). Two flights were made in summer from Gimli; the second had an emission interferometer monitoring this complementary spectrum. Absorption and emission data from this flight are under analysis.

(c) A 15-cm Fabry-Perot spectrometer, a 1-m grating spectrometer and a scanning photometer have been installed in a trailer near Calgary (51°N, 114°W) (Assistance from National Science Foundation, Collaborators: L.L. Cogger, U of C; P.B. Hays, J.W. Meriwether and C.A. Tepley, Univ. of Michigan). The operation of instruments by computer control helps in high data yield. The Fabry-Perot (FP) spectrometer has measured winds near 100 km from Doppler shift of 5577 Å emission; and before April F-region temperatures and winds were routinely recorded using 6300 Å emission. Combined photometer and grating spectrometer measurements allow observation of a number of airglow and auroral optical features. Global study of thermospheric dynamics by world-wide FP stations is also done. An image display/processing system for CCD-based images is nearing completion.

(d) An image analysis facility for analysis of imaging data from ISIS-2, Viking, Galileo, WAMDII and CANOPUS is being developed. Specialized display and analysis hardware will be coupled via an Ethernet link to a VAX 11/750 (shared with the Faculty of Environmental Design). Bob King has written a command-driven interpreter for image manipulation and management to run under the UNIX operating system on the VAX.

(e) Analysis of ISIS-2 optical data continues, especially for a large review paper under progress. Effort is being made to revive the processing system for the optical data on EVDS VAX 11/750 computer, particularly because of availability of image data from the DE

satellite. The DE and ISIS imagers provide complementary temporal and spatial resolutions. Exchange of data is underway. The system will also enable analysis of data from the Red Line Photometers onboard ISIS-2.

The Viking UV Imager ground station design has progressed considerably including hardware and software specifications.

(f) Several manuscripts on cosmic rays were completed.

(g) Two balloons were launched successfully from Cold Lake in Sept. and Oct. 1982 carrying auroral x-ray payloads. For the first time, simultaneous observations of auroral optical emissions were made by the Anger-Cogger group using the ground-based CCD system, when balloon payload was registering auroral x-rays.

(h) Work was done on the x-ray photon-electron interactions in a strong magnetic field regime. This is reminiscent of pulsar polar cap environment and has led to interesting results in areas of astro- and fundamental physics.

Collaboration with the Institute of Space and Aeronautical Sciences (ISAS), Japan (M. Oda and Y. Tanaka) has led to study of Cen X-3 spectra. Collaboration with Imperial College, London, UK (J.J. Quenby and A.R. Engel) is for studying celestial x-ray sources with hyper-pure germanium detector system on board a balloon; launch due for August 1983 from Gimli, Manitoba. Collaboration took place with Dennis Leahy (Marshall Space Flight Centre, Huntsville, Alabama), with Bell Laboratories (L.J. Lanzerotti), and with L. Nkemdirim (Department of Geography, Univ. of Calgary), on Sun-Weather relationship.

(i) Communication Research Center, Radio Propagation Lab: WISP: SPAR negotiations on Design and Development proposal for HFSS, continued having problems. Responses from SPAR and Canadian Astronautics Limited to a new RFP on the phase 2+3 contract issued by DSS for NRCC/CCSS are under study and decision toward an acceptable contract is likely by early 1983.

NRCC and NASA exchanged letters of agreement on WISP (June 1982); Canada will supply a receiver for the RPDP subsatellite and units for the orbiter payload bay. New proposals are under evaluation. Spacelab-6 mission is not yet in high gear at NASA due to budget uncertainties for 1983 and 1984.

In Dec. 1981, the ISIS-I spacecraft was used in collaboration with the ionospheric heater of the Max-Planck-Inst. fur Aeron. located near Tromso, Norway. Format of 4 frequencies (between 525 and 4125 Hz) were used to amplitude modulate the 2.8 MHz carrier. ELF waves radiated by the modulated auroral electrojet were received by ISIS-I (at 1200 km) along a 450-km stretch of orbit centered S and W of the heated region. All signal frequencies were above the gyrofrequency of the dominant ion, O^+, and below the lower hybrid resonance frequency at ISIS-I height. Harmonics of fundamental modulation frequencies, present because of square wave spectrum were also observed.

Spatial limits of radiation zone observed agree with computed ray paths for righthand polarized wave mode in a O^+-e^- plasma. The observed group dispersion with frequency indicated that the ionospheric E- and F- region densities were low compared to median values. The radiated power fluctuations had a period of about a fraction of a second. Received power varied over several orders of magnitude. Estimate of effective AC current of electrojet was based on short-dipole theory for a cold plasma. Even harmonics of the ELF fundamental frequency seen is evidence of distortion of applied square-wave modulation. This provides a measure of heating and cooling rates.

Stanford Radioscience Laboratory recently commissioned a telemetry readout for ISIS at Siple, Antarctica. Simultaneous use of data from Siple VLF transmitter, ISIS and other instruments at Siple and Roberval should enhance collaborative studies underway with ISIS users.

ISIS I and ISIS II data coincident with Dynamics Explorer spacecraft are being gathered (STADAN stations like Alaska and Orroral), relevant to high-latitude phenomena, like AKR, and low-latitude plasma bubbles.

CRC Satellite Controller expects continuance of D.N.D. financial support for 1983-84 ISIS operations. The radio scientific instruments on both ISIS are functioning.

(j) Most plasma resonances observed by ISIS topside sounder are explained in terms of propagating electrostatic waves, but not the cyclotron resonance, although observed cyclotron resonance pattern on fixed frequency ionograms suggests waves are responsible. Earlier, dispersion relation for electrostatic waves was derived assuming that the real part of the wavenormal vector K (normal to surfaces of constant phase) is parallel to the imaginary part of the wavenormal vector K_i (normal to surfaces of constant amplitude), thus only highly damped waves were obtained near the cyclotron frequency. Removing this assumption and assuming generation of a continuum of K_r and K_i by the transmitted pulse provides for possibility of low damped electrostatic wave generation near the cyclotron resonance. Results from ray calculations underway indicate promising results.

A large scale periodic electron density structure has been seen from low to mid-latitude ionograms (Collaborator: S. Gross, Polytech. Inst. N.Y.). The wavelength perpendicular to the magnetic field (tens of km) suggests acoustic or gravity waves are responsible.

4. Herzberg Institute of Astrophysics, Planetary Sciences, NRC
(F. Creutzberg, R.L. Gattinger, F.R. Harris, A. Vallance Jones, M.C. McNamara, D.R. McDiarmid, A.G. McNamara, J.M. Chaker, I. Halliday, A.A. Griffin, A.T. Blackwell, P.M. Millman, B.A. McIntosh, D.A. Naylor)

(a) A rocket-borne six-channel photometer during the Waterhole III project will provide a time-position history of the water cloud at selected wavelengths and other data for study of cloud chemistry. Broad-band all-sky television imaging systems and narrow-band narrow field triangulation systems will study morphology. Ground-based multichannel photometers will record related auroral characteristics.

During the barium release project (SABRE), the six-channel photometer (part of SABRE payload) will provide data on the O_2 atmospheric bands in airglow and aurora and permit the study of radiative transfers within and growth of the Barium cloud. Imaging television systems will study cloud motion and shape by triangulation measurements. Ground-based photometers will provide general auroral morphological information.

A three-channel photometer, OASIS rocket (Launch, White Sands, May 1983) should provide volume emission rate profiles for O_2 Atm(0,0) and (0,1) banks in airglow. Hardware and software for OASIS are under development. A zenith photometer and a meridian scanner will verify auroral absence during rocket flight and provide additional relevant data.

Ground-based support for the Auroral Modelling Campaign (ARIES) includes a line of 3 sensitive 1° resolution, meridian scanning, multi-channel photometers deployed along footprint of the rocket flights. These will provide multi-station determinations of auroral height profiles and auroral morphology along the trajectory before, during and after each rocket flight.

During Jan.-Feb. 1982 new-moon period, photometric instrumentation, a narrow-field height finding TV system and a TV spectrograph, functioned at Gillam, Manitoba and at Churchill. Program objective was to gather data and to test on type-B aurora and determine spectral variations as functions of altitude. Preliminary results place type-B lower edge at 90-95 km.

A paper on O_2 Atm(0,0) volume emission rate profiles for aurora and airglow from VA-52 rocket flight submitted for publication was also presented at the 10th European Optical Meeting, Grasse.

Project CENTAUR concluded; prime rocket experiments unsuccessful (2nd stage failed); but extensive ground-based data obtained. All rockets went into very soft precipitation events (geomagnetically very quiet). Preliminary results of study (Collaborator, D.J. McEwen) using ground-based (Sachs Harbour, Cape Parry) optical data reported at Ottawa COSPAR Meeting.

Published IMS meridian photometer chain results on proton and electron aurora substorm development. Detailed comparisons between optical characteristics of selected substorms and associated current system is underway.

An echelle spectrograph with an image tube detector constructed; hope this will give auroral spectra with 1 Å resolution over 1000 Å intervals in much shorter times than with scanning spectrometers using photomultipliers.

The NRC 0.5 m Ebert spectrometer is to be installed in 1983, at the Greenland Optical Facility at Sondre, Stromfjord (Collaborator, J. Meriwether, U. of Michigan). The 15-channels zenith photometer will also be operated to study auroral pulsations.

(b) Radio Aurora research - Resumed analysis and interpretation of the pre-BARS data of 1980 and 1981 campaigns (Collaborators, Sofko, Koehler). Presently available comparisons between EISCAT and STARE may be essential for proper interpretation of our results.

Collaborators Sofko and Koehler carried out experiment using VHF c.w. transmissions from Inuvik and Cambridge Bay to Fort Franklin receiving station. The common scattering volume was located in polar cleft region, near Cape Parry. This would extend our knowledge of scattering mechanisms through Doppler Spectra studies, and aid interpretation of Doppler velocities when BARS comes on stream.

Upgrading at Ottawa of the pulse radar system (used for many years at many locations) will provide range resolution of 20 km and 60 kw pulse power. This will aid high spatial resolution Doppler studies during rocket launch SABRE, satellite project HI-LAT, and 1983 Saskatchewan auroral campaign.

(c) We have shown that our non-uniform transmission line description (D-I) of toroidal pulsation resonances is equivalent to the more common wave equation description (D-II) involving the electric field. The electric field and current density parameters of D-II can be transformed directly into voltage and current parameters of the D-I. In the process, the reason for the 'probe' nature of transmission line solutions becomes clear. Since D-I accommodates and, indeed, requires an independently constructed generator circuit, the physics of the energy source can be treated separately. In contrast to other formulations, D-I yields transient and steady state solutions. This is important since pulsations often reveal a significant transient component.

(d) Many members of the section are heavily involved in the evolving Canadian Space Science Program, developing scientific objectives (e.g. for WAMDII), and detailed design parameters (e.g. for VIKING optics and for BARS radar system). CSSP includes: (1) CANOPUS - Major participation by Section in developing specifications for meridian scanning photometer (MPA), the auroral radar (BARS), and the data analysis system (DAN). (2) BARS - Carrying out the system design concepts and specifications for antenna arrays, radar transmitters and receivers, and digital signal processing. (3) VIKING - Considerable effort in design activities related to VIKING satellite UV imager, including calculation of instrument response for various filters to aurora excited by primaries of different initial energy spectra and refinement of baffle system design. (4) WAMDII - Participation in scientific objectives development and discussions of hard- and soft-ware system specifications. (5) HILAT (USA) - Investigating possible Canadian participation. (6) WISP - Participation in developments of scientific objectives, system design and specifications.

(e) Measurements on plasma probe expts. on AAF-IVB-38 (launch, Cape Parry, 6 December, 1981 during CENTAUR campaign) were plasma density, electron temperature, and ionization fine structure as the rocket flew through cleft region. A plasma probe expt. on AMF-VA-51 (launch 15 September 1982, White Sands), obtained data on ionospheric densities and temperatures in an undisturbed low-latitude ionosphere. Good analog data permits recovery of data over at least half flight time despite some telemetry problems.

Plasma probe expts. constructed for flight in 1983 campaigns Waterhole III, SABRE and OASIS.

Conversion of a number of old FM/FM analog flight tapes to digital format has enabled detailed analysis of interesting past data, made possible by digital processing methods.

(f) Meteorite Research - A spectacular fireball was observed from Calgary and photographed by the MORP camera network on January 15, 1982; indication was that a meteorite ($\sim$2 kg) fell near Vauxhall, Alberta. A modest search was undertaken. MORP observations identify 55 events (main mass $>$50 gms; 10 events $>$1 kg) which may have survived as meteorites. Orbit study of suspected meteorite from 3-camera networks supports previous conclusions that they arrive in direct orbits of modest inclination with aphelia in asteroid belt. Correlation between mass and the entry velocity (related to perihelion distance) is indicated. Preliminary MORP data study indicates $\sim$1 fall/day in Canadian land area, depositing 100 gms or more on the ground.

(g) Analysis of Geminid meteor spectra (video taped with SEC Vidicon equipment, Mt. Hopkins, Arizona) identifies 7 neutral atoms (N, O, Na, Mg, Ca, Mn, Fe) exhibiting 44 different multiplets in the atomic-line spectra of this shower; also 6 band systems of 3 diatomic molecules (CN, C_2, N_2). In WL range 3100-9000 Å 60 different features measurable in the best spectra with accuracy of $\sim$5Å. Positive identification made by calibration, using 5 or 6 strong atomic lines present in vidicon and in photographic meteor spectra. Spectral measurements of standard stars, recorded on same video tape as meteor spectra enables photometric calibration. This research is in cooperation with NASA-Marshall Space Flight Center, Huntsville, Alabama.

(h) Meteor radars (Springhill Meteor Observatory) operate few days during each of the major meteor showers; such data accumulated for $\sim$ 20 years determine meteor stream cross-section and particle distribution around stream. Distribution difference as function of meteoroid size is important for assessing past and present evolution of meteor showers.

Combined Quadrantid meteor shower observations from Springhill and Ondrejov, Czechoslovakia, provide a continuous 25-year sequence. Analysis shows on the average, time of peak of small particle flux precedes that of large particles; reversal possible on year-to-year basis. Wide variations in peak flux time are ascribed to Jovian gravitational perturbation of stream. Monitoring Perseid shower continues for possible activity increase associated with parent comet's return (1862 III, P/Swift-Tuttle).

(i) Orionid and Eta-Aquarid meteor showers' association with Comet Halley long recognized but lacks a satisfactory explanation for comet's relation to detailed showers' features. Some specifics are: 1) Earth encounter with particles is well away from the nodes of comet's present orbit; 2) durations and intensities of the 2 showers are roughly similar but spacings between showers and Comet orbit are in a ratio greater than 2:1; 3) fine-scale structure exists in both showers.

A new stream model with particles distributed over a belt with dimensions at the Earth's distance of 0.44 AU normal to orbital plane and about 0.05 AU parallel to the plane has been developed. Since Earth passes through the belt twice, two showers of $\sim$ equal strength and duration result. Major structural features are ascribed to multiple belts from libration cycles. (B.A. McIntosh)

5. University of Lethbridge, Department of Physics (D.A. Naylor)

Infrared Astronomy/Aeronomy: D. Naylor (Ph.D. -Atmospheric physics, Calgary, 1979) has recently joined the Department of Physics, University of Lethbridge. He spent 2 years with Infrared Astronomy Group, ESA, Noordwijk, Netherlands. A current interest is analysis of far-infrared atmospheric spectra taken with a balloon-borne telescope at both high spectral and spatial resolution.

Preliminary results show unambiguous detection of telluric 63 micron line of atomic oxygen, and the first measurements of the extended infrared spectrum of molecular oxygen. The spectra also contain line emission due to several minor stratospheric constituents. (Collaborators T.A. Clark, Rita T. Boreiko, Calgary).

6. University of Saskatchewan, Institute of Space and Atmospheric Studies (J.A. Koehler, E.J. Llewellyn, D.J. McEwen)

Radio Backscatter: G. Sofko and J.A. Koehler made in 1982, some observations of E region 50 MHz backscatter over Sachs Harbour, NWT, simultaneous with University of Western Ontario scientists making F region radio drift observations, etc., at Sachs Harbour and other Arctic locations.

We observed frequent echoes and have partially analyzed two events characterized by very strong backscatter signal strengths. During these periods, the Doppler spread and shift were extremely small; thus echo characteristics are similar to those from specular reflection from a stationary object! J.A. Koehler Infrared Group - Aeronomy: Experiments on rockets launched last year from Sweden, Spain and Scotland investigated airglow emissions resulting from atomic oxygen recombination. (Collaborators: University of Stockholm, the Queen's University, Belfast, the Institute for Astrophysics, Andalucia, the Appleton Laboratory, England and University of Saskatchewan). From observation that different emissions do not originate at same altitude, concluded that different excitation mechanisms involving different transfer species in a Barth type process must be acting. However, the processes are complicated by the significant effects of vibrational relaxation even at 100 km. It is shown vibrational relaxation coefficients for the Herzberg I system can be used to explain green line excitation from O_2 C^- in agreement with recent laboratory measurements. A preliminary determination of the height profile of the Chamberlain bands of O_2 has been made.

Extending our ideas to auroral excitation of oxygen emissions, it is shown that the transfer mechanism is apparently effective. Molecular dissociation by electron impact is reduced by invoking an autodetachment from an O_2 - state; some laboratory evidence exists for this idea.

Data on emission height profiles from pulsating aurora campaign rockets clearly indicate that the delay between prompt 3914Å emission and green line may exceed the radiative lifetime (in one instance 10 seconds delay). Note that we are looking at altitudes near 130 km, well above the main auroral emission.

The analysis of 1979 eclipse data shows a doubling of the ozone concentration at all altitudes during the eclipse. A significant increase of the lower mesospheric ozone concentration is seen. Unfortunately, definite association of this increase with a stratospheric warming or an auroral precipitation event in progress during the eclipse is not possible. However, comparison with other publications indicates that precipitation may lead to the atmospheric composition change at quite low altitudes.

We have concluded that resonance lamp systems may sometimes be used to determine the atmospheric temperature. However, accurately measured line shapes are necessary. A software package to determine the results from a resonance lamp experiment in an on-line fashion potentially useful for OASIS and ARIES rocket flights, is being added. Middle Atmosphere Dynamics (60-110 km): Medium Frequency Radar (2.2 MHz) is used; group includes J.B. Gregory, A.H. Manson, C.E. Meek and M.J. Smith. Continuous real-time observations of wind field in upper part of the "Middle Atmosphere" made; mean wind and tidal parameters available for 1978-1982 and enabled global comparisons with radar observatories in New Zealand (1978-79) and France (1979-80).

Campaigns involved projects within dynamics area of MAP, e.g. global - tidal observations by all existing radars were made in November 1981, May 1982; workshop scheduled at IUGG/IAMAP in Hamburg 1983. Saskatoon winter observations included within SWAMP (StratWArm Mesosphere Project), an activity of MAP'S DYNAMICS project. We are also part of WINE (MAP), "Winter in Northern Europe".

Plans for 1982-83 include continued MAP involvement; in dynamics area, this is done by radars, rather than satellites. Our system is extended to include two remote sites, to obtain gravity wave-characteristics, fluxes and momentum deposition, of great importance for new modelling and theoretical studies. A.H. Manson Auroral Physics: Analysis and interpretation of CENTAUR campaign data during November-December 1981 from a meridian scanning photometer (Sachs Harbour) and an electron spectrometer flown on BB IVB-38 (Cape Parry, December 6) carried out.

The electron data (18 KeV - 12 KeV) processed by David Steele shows rocket flight along and across the dayside oval with electron measurements evidently characteristic of the noon-time cleft. The major parts of the rocket's ascent and descent being within the oval provides measure of energy deposition versus height up to 600 km (apogee). The electron spectrum was exceedingly soft and quite different from that in the post-noon periods investigated in 1974 and 1977. Most optical data from Sachs Harbour were processed by Myrna Schacheri (NSERC summer student).

Analysis of dayside optical data is over. (Spitzbergen expedition, C. Duncan and J. Gilmer, 2 months around winter solstice in 1978-79) 23 days were clear through noon and a good profile of 6300 and 5577Å emissions through those days available. There were hardly 2 days alike, occasionally 5577Å emission was exceedingly high and over most of the sky through noon. The cause is unknown. PDF D.C. Agrawal has been active in this area.

7. University of Victoria, Department of Physics (H.M. Sullivan, R.E. Horita)

Airglow Studies: Power Flat Lithium Releases - Strong enhancements of twilight lithium emission were observed at Victoria following two rocket releases of lithium vapour in height range 210 km down to 90 km (early morning twilight, April 15 and 16, 1982), and one point release at a height of 1200 km (April 20, 1982), all releases being at Poker Flats Range near Fairbanks. Released lithium masses were: 1.0 kg, 2.0 kg and 0.882 kg respectively.

Emission intensities of $\sim$380 rayleighs were seen during mornings of April 18 and May 1, 1982 with smaller peaks in between. Short time interval between releases leads to effect of each release somewhat blurred. The relatively long time delay between the last high-altitude release and the time of appearance of the last bright emission is, however, interesting. Plasma Waves: Work on VLF saucers obtained on Alouette and ISIS satellites continues with particular focus on their attenuation bands. Spectra of VLF saucers are obtained to explain their generation mechanism using the Hewlett Packard spectrum analyzer. Spectra of other magnetospheric wave phenomena will be sought with improvement of our spectral analysis facilities.

K. Gwal, P.D.F. from India, made computer calculations of growth rates and stability criteria for whistler, magnetosonic and ion cyclotron waves; reports on results on way.

Cooperation with T. Watanabe of UBC and R.M. Shier of B.C. Hydro continues. Electric power transmission trip-outs seem to occur oftener due to geomagnetic disturbances than previously thought. A number of recent trip-outs are under study, e.g. a trip-out at the Glennanan sub-station near Prince George, B.C. on April 13, 1981 one minute after the minimum in the magnetic field variation. (R.E. Horita)

8. University of Western Ontario, Centre for Radio Science (P.A. Forsyth, J.A. Fulford, G.F. Lyon, J.W. MacDougall)

Ionospheric Physics: In November 1981, we participated in the Cleft (or CENTAUR) Campaign. A. Fulford and J. Haycock went to Cape Parry and John MacDougall went to Sachs Harbour. We gathered a large amount of ionospheric content and convection measurements. Our convection measurements from Sachs Harbour (J. MacDougall) showed rather dramatic difference in ionospheric convection speeds for quiet versus disturbed days around the local noon period. The ionospheric content measurements from Cape Parry (A. Fulford and J. Haycock) gave a good statistical picture of the very large variations in ionospheric electron density which are seen in the vicinity of the cleft.

The Waterhole II rocket launched from Churchill carried one of our TEC beacon packages to aid in monitoring the reduction in ionization caused by an 'explosion' over an auroral arc. Unfortunately, the rocket failed at low altitude. Another beacon package will be flown on 'Waterhole III' scheduled for February 1983.

The July 'summer cleft' campaign with University of Saskatchewan was aimed at sampling convection measurements from many stations. Convection measurements were made at Cape Parry by Eric Griffioen (U.W.O.), Sachs Harbour (Jake Hofstee, Ian Hare, Rick Niciejewski, U.W.O.), Resolute Bay (Harold Wong, U.W.O.) and Inuvik (Jim Koehler, U. of Sask.). A large amount of data was collected which needs analysis.

The NNSS satellite receiving system complete with brand new digital recording systems and 9-track magnetic tapes was very successfully operated from Sachs Harbour. A good collection of amplitude, phase and angles of arrival data has now been obtained.

The Australian Type IVB Ionosonde was also along on this campaign with some modified more flexible circuitry allowing digital output not restricted to just virtual height-time information. The outputs were arranged so that at least two users could read the data although arbitrarily one at a time only can control the A/D output.

In all, 15 days of continuous data was recorded. The h'(t) information is read from tape, converted to video information and transmitted to a Z80-S100 system by an 8-bit parallel line using handshaking. The Z80 has a Micro Angelo colour system installed. The data are written to the Micro Angelo for presentation on a colour monitor. At the moment only four colours are possible, but the hoped-for addition of another colour board will increase them to eight. The data then can be viewed as height versus time with colour indicating the signal strength.

Preliminary effort for the Canadian utilization of the HILAT satellite is going ahead. The application from U.W.O. under NSERC's Strategic Grants program that would have permitted the acquisition of a ground station received a favourable assessment but was considered "premature" by NSERC, presumably because the spacecraft is not yet in orbit. The CCSS of NRC is endeavouring to find enough money to start setting up a Canadian program to be in place not too many months after the spacecraft launch scheduled for June 29, 1983. Meantime a Canadian Science team has been set up (chaired by P. Forsyth) and Bob Hendry of CCSS has been assigned the task of expediting the physical arrangements. Hendry, Don McEwen and P. Forsyth attended the last HILAT Science Team Meeting in Baltimore and learned that both the spacecraft and the U.S. ground station preparations are well ahead of original schedule. The recent second round request for proposals sent out by the CCSS, netted some 16 letters on behalf of some 26 scientists of whom about 4/5ths are at Universities.

9. University of Windsor, Department of Physics (J. William McConkey)

Planetary Atmospheres: The Voyager Fly-by mission to the outer planets not only presented the scientific community with marvellous new photographic records but also much fascinating and puzzling spectroscopic information. The far EUV radiation from Jupiter's plasma torus was found to be dominated by radiation from highly ionized oxygen and sulphur atoms, the original source of which is thought to be SO_2 from the active volcanos on Io. We have just completed a program to measure the electron impact excitation cross-sections of these lines following single-step dissociative excitation of SO_2, (to be published in Planetary and Space Science in early 1983). We are also in the midst of a detailed investigation of the excitation of the Lyman and Werner bands of H_2 and D_2 again under controlled electron impact. These are also very important in connection with planetary atmospheres.

10. York University, Department of Earth and Atmospheric Science
(R. Gladstone, J.C. McConnell, Gordon Shepherd, D.R. Moorcroft)

VIKING Radiative Transfer Modeling: The radiative transfer of the OI 1304A resonance triplet in the auroral region is exceedingly complex, partly due to the phenomenon of frequency redistribution, which must be considered in detail for any optically thick resonance line. More troublesome is the fact that in the auroral region the initial source of photons varies horizontally as well as vertically, i.e. the atmosphere is not plane-parallel. If the source were plane-parallel, as in the dayglow, the radiative transfer could be solved by matrix methods. For the auroral problem, we are forced to use Monte Carlo methods to obtain a solution. We are currently developing a Monte Carlo code to handle both frequency redistribution and two-dimensional radiative transfer. So far, the program works only for a constant temperature, conservative matrix with uniform sources. We will soon be able to include vertical variations in temperature, absorption, and vertically and horizontally varying sources. R. Gladstone and J.C. McConnell IUE Studies of

Jupiter: In collaboration with Caltech, the UV reflectivity of various regions of the Jovian atmosphere is being modelled. Observations have been made using the International Ultraviolet Explorer (IUE) over the last two years. The data include limb-darkening observations of belts and zones at Lyman α and from $\sim$ 2000Å to 3300Å. The modeling of these data will yield information about the distribution of atomic hydrogen in the upper atmosphere and the nature and distribution of haze in the lower stratosphere of Jupiter. R. Gladstone ISIS Data Analysis: Bluma Gertner has been carrying out a calibration study for the Red Line Photometer over its first ten years in orbit. Bhatnagar is working on an analysis of 6300Å tropical arc emissions, using both ISIS data and some groundbased measurements made in collaboration with V. Agashe at the University of Poona. Jack Meek has recently returned from the University of Tokyo and will again be spending some time at CRESS.

Spacelab WAMDII Project: W. Gault has been working with SED systems and Bomen on the design of the developmental model. The design review will be at the end of November and fabrication will begin soon after. Work on the large hexagonal beamsplitter has already begun at Interoptics in Ottawa. R. Wiens has been working on an atmospheric emissions model and P. Kostinuk, based in Saskatoon, has begun work on the WAMDII science software.

Rocket Projects: R. Koehler has been analysing his TEOL (Three-Element, Orbit Limited) probe data from the CENTAUR campaign, as well as constructing and calibrating a new triple-probe experiment for the WATERHOLE III campaign. N. Hustis, NSERC summer student, assisted with part of the probe data analysis this past summer.

W. Gault is analysing ground-based cleft detector data from the CENTAUR campaign. R. Link is modelling these results on the basis of rocket particle data provided by A. Yau, and Dynamics Explorer data provided by D. Winningham (Southwest Research Institute). B. Solheim is completing the construction of his CCD photometer for OASIS which will derive 32 spectral channels covering the extent of the O_2 Atm(0,0) band. The original electronics design was done by J. Pieau, and has been completed by J. Gilmer.

Ground-based Measurements: R. Weins has been preparing the cleft detector for measuring the O^+ 7320Å doublet separation, a number needed for WAMDII fabrication. Meanwhile, he has been measuring OI 5577Å and 6300Å emissions in twilight. R. Link recently extended his atmospheric model to include solar input, which will provide model results for the analysis. W. Ward is preparing to make WAMI wind observations near Toronto. It is planned to take the cleft detector to White Sands for OASIS, and possibly to Gillam for SABRE. (Gordon Shepherd)

IV VOLCANOLOGY

Compiled by: Léopold Gélinas

1. Introduction

Forty-three reports have been submitted from twenty-four institutions including Federal and Provincial government groups, many universities and mining industries. Most of these reports concern new or continuing study of Precambrian and Cenozoic geology - fewer concern Paleozoic and Mesozoic, and Quaternary rocks.

The work focuses mainly on volcanic suites in support of mapping projects and specific geological information relevant to stratigraphy, geochemistry, geochronology, paleomagnetic studies, and economic geology.

Unfortunately, we include fewer progress reports than expected, the main reason being the lack of information provided from the different institutions.

2. Geological Survey of Canada (W.R.A. Baragar, M.B. Lambert)

(a) Mapping of Smith Island and adjoining mainland was completed in summer 1982, in the Aphebian circum-Superior belt. The sequence is composed of komatiitic lavas with the exception of minor tholeiitic lavas and sills inter-layered with siliceous and pelitic sediments at its base. The komatiitic suite is divisible on the basis of field characteristics into units corresponding to varying MgO content as follows: low MgO (11%), medium MgO (11-16%), and high MgO (16%). Layered flows with olivine cumulate zones and one with spinifex texture are most abundant in the high Mg flows.

(b) Paleomagnetic studies of the Natkusiak Basalts, Victoria Island, N.W.T. show two reversals within the flow sequence: from base upward the polar directions are reversed, normal, reversed with underlying sills in the reversed direction, probably the same reversed period as the lower flows. The pole positions vary slightly between sediments, lavas, and sills, but are essentially similar to Franklin directions. Rb-Sr isochron studies show complexities that can be interpreted as due to contamination by older crust with a tentative magma age of about 700 Ma.

(c) Mapping of the Back River Volcanic Complex at scale 1:31,680 is completed. Recent work focuses on the evolution of felsic domes and their flank deposits that formed during the waning stages of volcanism in this complex. G.S.C. Open File 848 is a compilation of geology at scale 1:50,000. This Open File contains a preliminary lithologic map, legend, structural notes and references to previously published data.

(d) Recent work on the Cameron and Beaulieu River Volcanic Belts, District of Mackenzie shows synvolcanic intrusions forming extensive swarms of dykes and sills which were feeders to the lavas. They play a fundamental role in the growth of the belt and form an integral part of the volcanic stratigraphy.

The present belt reflects the width of a deformed belt, not its thickness.

(e) Detailed mapping at scale 1:160 and chemical sampling of a section of the sheeted dyke complex (Troodos Ophiolite Complex) at Kiona Peak was carried out in conjunction with the International Crustal Research Drilling Group, Cyprus, during June and July 1982. Field work documents precise structural and "chilling" relationships for every dyke in the section. Chemical analyses for major and minor elements of samples from 66 dykes are being carried out.

3. Ministry of Energy, Mines and Resources, Province of British Columbia
(G.E. Ray, A. Panteleyev, T.G. Schroeter, L.D. Diakow)

(a) Detailed and reconnaissance geological mapping continues north of Carolin Mine along the Coquihalla Gold Belt (near Hope, B.C.). A basement of oceanic pillowed basalts of possible lower Triassic age is uniformly overlain by Lower to Mid Jurassic sediments of the Ladner Group. The volcanics and sediments are in faulted contact with the Coquihalla Serpentine Belt and gold mineralization is hosted mainly in the lower Ladner Group close to this major fault structure.

(b) Geological Mapping at 1:25,000 of the Toodoggone Volcanics (N. Central B.C.) was initiated in 1981, continued in 1982 and will be finished in 1983. Sites of gold-silver mineralization and related silica-clay-alunite alteration were mapped in detail (1:5,000, 1:10,000). Extensive sampling was done for geochemical/petrochemical studies.

4. Pacific Geoscience Centre (Geol. Surv. Canada), Sidney, B.C.
(T.S. Hamilton)

The Masset Formation, Queen Charlotte Islands, has been mapped geologically and comprises extensive sections of subaerial deposited basalts with some submarine and hypabyssal equivalents. There are also extensive accumulations of rhyolite flows and tuffs. Initial petrography suggests alkaline affinity. Also, 300 samples were collected from the field last year.

5. Geological Survey of Canada, Calgary

The mapping of Lower Paleozoic and older volcanics, northern Ellesmere Island, and sampling have largely been completed in 1982 and several sets of samples have been chemically analyzed and classified by computer. The regional stratigraphic-structural framework is becoming better known although many basic problems remain. Petrographic, chemical and geochronological analyses will be continued.

6. Department of Energy and Mines, Province of Manitoba (E.C. Syme, A.H. Bailes)

Mapping at a scale of 1:15,840 was completed for a 80 km^2 area of Early Proterozoic volcanic rocks near Flin Flon, Manitoba. Primary structures and textures are generally well preserved in the volcanic rocks allowing the identification of depositional mechanisms for most units. This will allow at least partial reconstruction of volcanic paleo-environments. As in the adjacent White Lake-Mikanagan Lake area, the study area is subdivided by a series of faults into distinct fault blocks, each with an unique stratigraphic sequence.

The objective is to develop a regional stratigraphy for the Amisk Group, the main rock formation of the Flin Flon greenstone belt. The geochemical and paleogeographical evolution of Amisk volcanism and the volcanologic control on deposition of massive Cu-Zn sulphide deposits are also under investigation.

7. Ontario Geological Survey (R.M. Easton, F. Frey, M.O. Garcia, B.J. Fryer)

(a) The study of samples of recent sediments of Kilauea Volcano is completed and conclusions are that they are mechanically-derived sediments similar to parent basalts; sediments from Mauna Loa reflect Mauna Loa lava chemistry, likewise for Kilauea.

Weathered samples (palagonite, laterite) have undergone significant trace element mobility. Additional collecting was done in September 1982 in order to further document effects of chemical weathering.

(b) In addition, two types of REE patterns are found to be present in the Hilina Formation on the basis of La/Ce and La/Yb ratios. One type has Mauna Loa affinities, the other Kilauea affinities, although the major and trace element geochemistry of the lavas is typical of Kilauea lavas. Sr isotopes from the formation (all tholeiitic lavas) indicate a range of variation similar to that reported for alkaline lavas of Maleahalo Volcano.

(c) 1:10,000 scale mapping was conducted in the Duck Formation (Yellowknife Greenstone Belt, N.W.T.) in order to examine possible depositional environments and relationship to Kam Formation. The Duck Formation could be: a) a rift zone from the Kam Shield Volcano, now separated by late faults, or, b) several isolated Surtesyian type cones. Field relations cannot eliminate either possibility, although a) is the most reasonable explanation (see Easton et al., 1982).

8. Ministère de l'Energie et des Ressources, Gouvernement du Québec

Mapping in the Abitibi region (Région du Lac Bigniba (DP-82-05) shows that volcanic rocks of this area are reoriented E-W and are of basaltic type. The acid pyroclastite band is continuous from Octave River (Hocq, 1981) eastward to Bigniba River. At Chicobi Lake, outcrops with homotaxial sediments are found.

9. University of California at Santa Barbara (M.L. Bevier)

Study of the geology and petrogenesis of Mio-Pliocene Chilcotin Group basalts, south-central British Columbia is completed. The objectives were to determine age, stratigraphic variation, geochemistry and petrogenesis of a Mio-Pliocene plateau lava field in south-central B.C.

10. University of British Columbia (R.L. Armstrong, J.E. Harakal, K. Scott)

Geochronological studies of several volcanic belts and areas are proceeding.

11. University of Alberta (Dingwell, Shimada, Harris, Scarfe, Fujii, Shimada, Brearley, Virgo, Goff, Rose, Metcalfe)

Current studies continue on: silicate melts; petrogenesis of mid-ocean ridge basalts; petrogenesis of alkalic and calc-alkaline magmas; geochemistry and petrology of mantle xenoliths and their host alkalic basalts in British Columbia; geochemistry and petrologic significance of mafic crystal clots in Mount St. Helens dacite from the March 19, 1982 eruption; fluorine, chlorine, carbon dioxide and water in melts; oxygen diffusion in silicate melts; infrared and Raman spectroscopy of water and carbon dioxide in silicate liquids and glasses; igneous and metamorphic petrology of volcanic suites in the Proterozoic Athapuscow aulacogen, East Arm, Great Slave Lake; quantitative models for vesiculation, ascent, and explosive eruption of subduction zone magmas; Radar remote sensing of volcanic ash in the atmosphere and techniques for real-time forecasting of ashfall amounts; volatile contents of basic alkaline volcanics in B.C. and their role in the genesis and eruption of the alkali basalt suite; concentrations and sources of H_2O, K_2O, Cl, S, and P in magmas at Kilauea volcano and Loihi Seamount, Hawaii.

12. University of Calgary (J. Nicholls, M.Z. Stout, J.K. Russell)

(a) The chemistry and minerology of nephelinite lavas from oceanic and continental volcanic centres in British Columbia, Canary Islands, Hawaiian Islands, and Uganda (Recent-Quaternary) were compared to determine why such rocks are common on oceanic islands but rarely found on continents.

(b) Petrology and geochemistry of the historic lavas of Mauna Loa, Hawaii, and Diamond Craters, Oregon (Quaternary) are being studied to put constraints on source rock compositions and/or processes operating during magma transport, inferred by chemical variations in lavas and coexisting mineral phases.

13. University of Saskatchewan (L.C. Coleman, E.G. Nisbet, M.R. Stauffer)

(a) Detailed mapping and geochemical sampling has been carried out near Flin Flon, in the Aphebian Amisk volcanics of Saskatchewan and Manitoba. Samples from the area have been studied petrographically, chemically analyzed for major and trace elements, and selected minerals have been analyzed by electron-microprobe. Further studies will involve cooperation with a team of workers from the Max Planck Institut, Germany.

(b) As part of a study of Archean komatiites and granulites, field work was carried out in various parts of Zimbabwe, including the Belingwe area and the Limpopo Belt. Two graduate students are working in northern Saskatchewan, one on metavolcanics and spatially associated granulites, the other on gold mineralization in metavolcanic terrain.

14. University of Manitoba (L.D. Ayres, N.A. Van Wagoner, S.L. Van Wagoner, W.S. Ferreira, W. Moon)

The 9+ km thick sequence in the Amisk Lake area of Saskatchewan is characterized by 1) subaerial (40%) and shallow water (60%) deposits; deep-water deposits are absent, 2) both transgressive and regressive subaerial-subaqueous transition zones marked by distinctive tuff-breccia units representing lava flow advance into water, 3) a high proportion (>50%) of massive to bedded, in part turbiditic, basaltic vitric tuff in the subaqueous basaltic flow sequence, and, 4) a possible komatiite sequence. Detailed stratigraphic sections have been measured through this sequence and lateral and vertical variations are being analyzed. Preliminary comparisons have been made with sequences, farther east near Flin Flon. Future work will involve geochemistry, computer modelling of subsidence rates, and paleomagnetism.

15. University of Western Ontario

The McDougall-Despina Structure (Noranda, Québec) has been interpreted by previous workers as a synvolcanic fault which localized volcanic activity and ore deposition. Preliminary mapping shows the structure to be occupied by a multiphase rhyolitic, spherulitic to ignimbritic dike complex. Wallrock adjacent to the structure is commonly foliated. Similarities between the McDougall-Despina structure and ring fracture complexes around calderas are apparent. The 5 km exposed strike length of the structure is to be mapped in detail. Macroscopic and microscopic textures of the dike complex will be studied to determine the mode of emplacement. Petrographic and chemical features will be used to attempt to relate the dike material to one or more of the enclosing volcanic flows.

16. University of Toronto (J. Lukosius-Sanders)

The objectives are to assess the rare earth chemistry of a unicyclic sequence of volcanics, and determine effects of mid-up amphibolite facies metamorphism, in the (Archean) Healey Lake Volcanics, Slave Province, Canada. The G.S.C. geochronology division is dating some rocks from this volcanic belt. Donald James (Queen's) will begin a Ph.D., covering the Healey Lake region, likely on structural and metamorphic relationships.

17. Waterloo University & G.S.C. (W.R.A. Baragar, M.B. Lambert, I. Gibson)

The objectives are to determine the age relationships and the composition and distribution of compositions of the individual dykes in the Troodos complex composing the swarm with a view to their role in the evolution of the complex. About 800 m of dykes in 7 sections have been mapped and sampled in detail, and samples prepared for thin sections and analyses. Research plans are to complete studies on the petrochemistry of the dykes and relate these to the compositions of the pillow lavas above and plutonic complex below. The study is part of the Cyprus Crustal Study Project.

18. Queen's University (K. Ashton)

Field work on the age relationships in the "Woodburn Lake Group" northwest of Tehek Lake, District of Keewatin indicates that both sequences have been deformed together masking any obvious signs of a pre-existing unconformity. The tentative model favours Archean deposition of the quartzites shortly after the emplacement of the volcanic suite. Age dating of komatiites (Nd/Sm) and step heating felsic volcanics (zircon), cross within granites and orthoquartzites (zircon). The main volcanic interest of this study lies in the description of an Archean, komatiite-bearing metavolcanic sequence.

19. Carleton University (D.H. Watkinson, H. Gibson, J. McEwen, C. Roots)

(a) Remapping and interpretation of the regional and local alteration is being done of the volcanic rocks in the "Mine Series", Noranda, P.Q. hosting Cu-Zn sulfides. Mapping of the Amulet Rhyolite Formation is essentially complete with accent on flow morphology and regional alteration.

(b) Geological mapping of the Faymar Gold Deposits, Timmins, Ont. has been completed. Detailed petrographic and geochemical studies will follow to determine the mineralization characteristics in the mine.

(c) Characterization and documentation of the first known case of cyclical volcanicity in the Grenville Province (Belmont Lake Metavolcanic Complex, Southeastern Ontario (Helikian)) is in progress.

(d) The description of tectonic and structural setting of the ore body, the petrographic description of enclosing felsic rock units, the petrographic description of ore texture, and the relationship of anomalous values of Au and Ag to the ore body at the Gallen Mine, Noranda, P.Q. are being carried out.

(e) Detail mapping of the volcanic complex and the measurement of sections and sampling for geochemistry and radiometric dating of the Proterozoic-Cambrian Mount Harper Volcanic Complex & Ogilvie Mountains, Yukon is being carried out.

(f) The description of the geology of the Quaternary Telica Complex and the Tertiary Mine El Limon area and petrology and chemistry of two areas of Cenozoic volcanism in Northwestern Nicaragua, Central America are being carried out.

20. Université de Montréal (J.N. Ludden, C. Brooks, L. Gélinas, R. Darling, J. Lajoie, P. Verpaelst)

(a) Geochemistry of the volcanic rocks of the Kane Fracture Zone, Atlantic Ocean at 23°N is being studied in order to understand the evolution of the oceanic crust and upper mantle.

(b) Geochemical evolution of volcanic series in the Rouyn-Noranda, Val D'Or region is being studied in order to understand geochemical processes in the evolution of the Archean mantle and crust. Studies are complete in the Rouyn-Noranda region and are presently in progress in the Val D'Or and Chibougamau regions.

(c) Geochemical evolution of the Proterozoic volcanic rocks from the Cape Smith-Wakeham Bay belt and the Belcher Islands is being studied by trace element and isotopic identification of petrogenesis processes in the evolution of a mafic Proterozoic volcanic suite.

(d) Geochemistry of the Archean host rocks surrounding the Manitou Barvue volcanogenic deposits, Val D'Or, Quebec is being used to document wall-rock alteration and mode of formation of volcanogenic deposits.

(e) Detail mapping of the various volcanoclastites and associated rhyolite porphyries in the Blake River Group, (Archean) (Rouyn-Noranda Region, Abitibi, Québec) is being done.

(f) Mapping of sedimentary structures and samplings within recent pyroclastic flows at Mt. Pelée, Martinique is being done in order to elucidate their mode of emplacement.

(g) A study on the volcanology, sedimentology and geochemistry of Archean volcanic complexes, Abitibi, Québec has been completed.

21. Laval University (R. Laurent, J. Bélanger, J. Dostal, M.J. Girard)

(a) A petrological study is being conducted on the Siluro Devonian Volcanics of the Chaleur Bay area, Gaspé, Québec in order to determine the environment of formation and the evolution of these volcanics.

22. University of Québec in Chicoutimi (UQAC) (E. Dimroth, H. Yamagishi)

Volcanology, sedimentology, and paleogeography of the Transition from Roy to Opemiska Group, Chibougamau area, Quebec is being studied, and a comparison made with three rhyolite hyaloclastite bodies of the Miocene in Japan and a rhyolite hyaloclastite of Rouyn-Noranda area.

23. Acadia University (S.M. Barr)

Field relations, petrology, age and tectonic implications of some paleozoic volcanic rocks were studied. These were: 1) Volcaniclastic rocks and basaltic flows with associated dykes and plugs within and overlying lower Carboniferous sedimentary sequences in the Magdalen Islands (Gulf of St. Lawrence), and 2) volcaniclastic rocks and mafic to felsic flows of possible Silurian age in the Mabou Highlands of western Cape Breton Island.

24. Saint Mary's University (J. Dostal)

A study is under way to better identify the role of mantle metasomatism and crustal contamination during the genesis of non-orogenic volcanic rocks.

25. Uranerz Exploration and Mining Limited

The company is conducting a search for U and/or base metal mineralization associated with favorable conductors and/or structures in: Beaver-Zoran/Otish west; Otish Mountains Area (300 km NE of Chibougamau); Archean/Aphebian metavolcanic belts.

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V ISOTOPE STUDIES AND GEOCHRONOLOGY

Compiled by: A. Hayatsu

1. Introduction

This report has been compiled from 12 contributions from 10 institutions. The majority of researches reported here are studies of specific problems by means of various isotope methods and hence there is not much point in summarizing the whole activity in this field.

A new dating technique called Lase Age Microprobe has been developed at the University of Toronto. Although it is not reported here, it deserves special mention.

2. University of Alberta - Physics Departmment (G.L. Cumming, J. Gray, D. Kristic, H. McCullough, L. Tober, C. Yonge, J.R. Richards, C. Jong Song)

(a) This past year we installed a new digital voltmeter on the Micromass 30 mass spectrometer. This has resulted in a noticeable improvement in measuring precision, particularly for Pb isotope ratios. We are now able to obtain precisions of better than 0.2% per mass unit difference (2σ) on samples of standard Pb, a factor of two improvement over previous results.

Construction of two new instruments is proceeding very slowly, mostly due to lack of personnel, although this continuing problem has been partly alleviated recently with the return of Mr. L. Tober to the laboratory on a half-time basis. Mechanical construction of the 5" radius Ar instrument is essentially completed and the 9" radius solid source machine is under vacuum with only a small amount of work remaining before testing can commence.

(b) Pb isotope variations in sulfides of the Flin Flon area are being examined in order to compare the systematics with those observed for the Thompson nickel belt deposits where several later Pb remobilizing events were detected. Most of the data obtained so far are on galena samples but the results indicate a distinctly different behaviour. There are clear differences in the isotopic composition amongst the various deposits and real variations in the $^{207}Pb/^{204}Pb$ ratios, different deposits along the lines suggested by the "plumbo-tectonics" models of Doe and co-workers. Analyses of trace Pb in the other sulfides have begun and data presently available are consistent with the interpretation of real age variations amongst the various deposits.

We have reanalyzed 19 galena samples from the Pine Point deposit and find no variation in excess of experimental error. The sampling is reasonably representative of the area and it appears that no variations amongst the various deposits will be found. On the other hand we have

some preliminary results on Pb compositions of the host rocks and find substantial variations.

(c) An extended investigation of the climatic interpretation of stable isotope ratios of cellulose from tree rings and other organic materials has now been completed and has led to the following. (i) A new method for the simultaneous extraction of hydrogen and oxygen for isotopic analysis in organic material and water. This technique is now being widely adopted by other workers in the field. (ii) A functional relationship between both $^{18}O/^{16}O$ and D/H ratios and mean annual temperature at the growth site of the plant with correlation coefficients greater than 0.9 in some cases. (iii) A model developed which allows the prediction of the isotopic composition of cellulose deposited in annual growth rings of trees for both D/H and $^{18}O/^{16}O$.

The major conclusion is that the isotopic composition of stratified datable organic material such as tree rings or peat carries past climatic information as demonstrated for periods in excess of 400 years. Some periodicities (using maximum entropy techniques) have been found in all the climate curves.

A program of detailed $^{18}O/^{16}O$ and D/H analysis of a peat core supplied by B.H. Luckman is now underway. Pollen analysis has been carried out on this core (Luckman) and it is hoped that isotope data will correlate well with the palynological data. The core covers a time period from the present to about 10,000 years B.P. (^{14}C dated).

Work has begun on the simultaneous D/H and $^{18}O/^{16}O$ analysis of included water extracted from cave deposits (samples supplied by H.P. Schwarcz). It is hoped that simultaneous measurement of these ratios will allow a more precise interpretation of the $CaCO_3$ isotope ratios in terms of a temperature of deposition and hence yield unambiguous climate data for a time period up to 250,000 years B.P.

3. Bedford Institute of Oceanography - Atlantic Oceanographic Laboratory
(F.C. Tan, P.M. Strain)

A cooperative program on the organic composition of the St. Lawrence River to assess the global flux of carbon in world rivers is being conducted under the auspices of SCOPE/ UNEP. The quantity and chemical nature of this flux is currently not known in detail. A second purpose of this program is to examine the monthly variability of $\delta^{13}C$ of particular organic carbon being contributed by the St. Lawrence River for the examination of the origin of organic matter in the Upper St. Lawrence estuary. The samples are being collected by personnel at OSS Québec Region and will continue until the entire SCOPE/UNEP program is completed.

It is planned to extend the sampling program to the measurements of $\delta^{13}C$ of dissolved organic carbon. We are currently working on a procedure (UV photo-oxidation method) for the analysis of dissolved organic carbon.

A large suite of samples collected from the eastern Canadian Arctic during 1980 has been analysed and the interpretation of the distribution of sea ice meltwater is under way. The oxygen isotope data will be used to evaluate the extent of glacial meltwater in Melville Bay and to examine year-to-year variations in sea ice meltwater distributions in areas that were previously investigated.

In order to examine the distribution and fluxes of freshwater derived from sea ice meltwater, we have collected a large set of samples from the Hudson Bay-Hudson Strait area in August-September, 1982. Sea ice meltwater may play a significant role in the circulation in this area.

Stable isotope paleoclimatic work is being continued in collaboration with scientists from the Atlantic Geoscience Centre, BIO. The isotope data will be used to examine changes in the marine environment in eastern Canada during the last 15,000 years.

A study of plant degradation and coastal food web studies by the stable isotope method is being conducted to examine the potential application of stable carbon isotope method in tracing carbon flow from marine macrophytes through the coastal food webs. Work to date includes the studies on isotope variability on two source plants (sea grass zostera and kelp laminaria) and its natural degradated products. Future work will involve studies on carbon isotope ratio changes in selected organisms to determine the magnitude of ^{13}C enrichments and carbon food source. This is a cooperative program with scientists from Marine Ecology Laboratory, BIO.

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

(a) Aim 65 and Apple Microprocessors have been interfaced for various aspects of mass spectrometer operation and data handling. A combination gas chromatograph combustion - mass spectrometer system has been developed for C and H isotope analysis of individual gases in gas wells. Isotopic analyses of nano-mole quantities of gas have been accomplished. A stainless steel reactor with direct heated platinum boats has been developed to prepare CO_2 for O isotope analyses of sulphates. A high temperature preparation technique for C and O isotope analyses of carbonates has been tested. Preparation time for some carbonates is reduced from weeks to less than one hour. A simplified technique for preparation of SO_2 from sulphates using sodium metaphosphate has been developed.

(b) The following stable isotope studies have been completed: S and O Isotopic Geochemistry of Sulphates; studies of springs in western Canada; studies of cave formation as the result of sulphide oxidizing bacteria; investigating the feasibility of a barite age curve; contributions to the evaporite age curve; studies of barite sinter deposits; biogeochemistry of wells in tills of southern Alberta; analysis of sulphur compounds in Mt. St. Helen's ash; carbon, sulphur, and hydrogen isotope studies of oil, gas, kerogens in Alberta, the Arctic, and eastern offshore deposits; studies of carbon and sulphur isotope composition of coal in Western Canada; sulphur isotope studies of fluviatile sedimentary rocks in the Elliot Lake Area (these suggest low atmospheric oxygen pressure during the Early Proterozoic); studies of S isotope selectivity during sulphite reduction by C. pasteurianum; N-isotope selectivity in NO_3 reduction in groundwaters; N-isotope selectivity during urease-urea decomposition; studies of sulphur isotope composition of H_2S released during linearly temperature programmed thermal decomposition of oil, bitumen, extracts, coal, etc.; testing and further developments of multi-high volume atmospheric sampling arrays to collect SO_2 and particulates for isotopic analyses; S isotope profiling of soil cores to evaluate penetration of industrial sulphur compounds; S isotopic composition of sulphate in rain, snow, and surface waters; studies of H, O, S isotope abundances in a stratified lake on Ellesmere Island; studies of O isotope abundances and ^3H stratification in the Disraeli Fiord; and studies of ice cores from the Ward Hunt Ice Shelf.

5. Dalhousie University - Departments of Physics and Geology (P.H. Reynolds, M. Zentilli, G.K. Muecke, D.B. Scott, P.E. Schenk, F. Medioli, P. Elias, S. Akande)

(a) An extensive suite of diabase dikes from Newfoundland's Gander Zone has been dated (K-Ar and ^{40}Ar and $^{40}Ar/^{39}Ar$) and compared with the paleomagnetic data for these samples. Studies in the Gander Zone are continuing in an attempt to clarify apparently anomalous geomagnetic field behaviour in Devonian times.

Tin greisens in southern Nova Scotia have been dated providing further evidence for a Hercynian metallogenic epoch in the Nova Scotian Appalachians.

A comprehensive $^{40}Ar/^{39}Ar$ study of metamorphic and intrusive rocks from the southern part of the Meguma Zone in Nova Scotia has been begun in order to clarify cooling and uplift histories in the region. The dating of intrusive phases will complement the paleomagnetic study currently being carried out by Pierre Lapointe (Earth Physics Branch).

The second phase of a study of rock units in the vicinity of the Indus suture zone has been completed.

Reynolds (with E.R. Deutsch and J.N. Prasad, Memorial University) is carrying out a dating study of selected lamprophyre dikes from the Notre Dame Bay area in north-central Newfoundland for comparison with magnetic studies on these samples.

Reynolds (with J.K. Park, Earth Physics Branch) is attempting to date the diabase dikes which intrude the Mealy Mountains anorthosite complex in Labrador. Park has previously reported on the paleomagnetic data for these dikes.

(b) Recently an O, C and S isotopic study of the Gay's River (N.S.) deposit has been completed.

A detailed study of selected marine sediment cores using (among other things) oxygen isotope techniques is continuing.

6. Lakehead University - Department of Geology (R.H. Mitchell, R.G. Platt)

The following have been completed: Rb-Sr geochronology of the Coldwell alkaline complex, N.W. Ontario; Rb-Sr and K-Ar geochronology of lamprophyres from the McKellar Harbour region, N.W. Ontario; Rb-Sr geochronology and Sr isotope geochemistry of alkaline rocks of the Freemans Cove Volcanic Suite, Bathurst Island, N.W.T.; Rb-Sr geochronology of Somerset Island kimberlites.

7. University of Manitoba - Department of Earth Sciences (G.S. Clark)

(a) An HP 95F computer has been installed on the 10" radius solid-source mass spectrometer for on-line data acquisition and processing, and partial instrument control. An ultrastable filament current supply has been installed on the same instrument (used in Rb-Sr isotope studies). It was built in the Dept. of Physics electronics shop at the U of Manitoba. Work is in progress to rebuild the source and collector assemblies.

(b) A Rb-Sr whole-rock age determination of a metarhyolite from a measured section of the Klondike Schist gives a good isochron age of 202 $\pm$ 11 Ma along with an initial ($^{87}Sr/^{86}Sr$) ratio of 0.7140 $\pm$ 0.0001 (one sigma). This is interpreted as a metamorphic age with the estimated age of the protolith being about 260 Ma.

The Rb-Sr isotopic age investigation of the major tectonic domains of the Churchill structural province is progressing. The purpose of the study is to establish the temporal relationships of plutonism and metamorphism within and between the major tectonic domains by studying the Rb-Sr isotopic systematics of major lithological units. The data base is now quite extensive and is being used in conjunction with detailed mapping studies to develop models for the evolution of the various domains (with W.D. McRitchie and other geologists of the Manitoba Dept. of Energy and Mines).

Two major plutonic units of diverse age have been investigated from the Molson Lake - Kalliecahoolie Lake area, west of Cross Lake, in the northern Superior province. An older hornblende-biotite monzonite unit gives an errorchron age between 2800 and 2900 Ma. This unit is included with the early plutonic rocks which intrude metavolcanic and metasedimentary rocks in the region. The age is consistent with ages obtained for the earlier plutonic episodes elsewhere in the northwestern Superior province. Small stocks of granite occur throughout the area. These are the youngest granitic rocks in the area and appear to be late kinematic replacement bodies, metasomatically formed. Samples of granite and alaskite collected on a regional scale yield a good isochron age of about 2500 Ma. The initial $^{87}Sr/^{86}Sr$ ratio of about 0.707 suggests that these late granites are mobilizates. Ground gamma ray spectrometer surveys indicate uranium enrichment in these small plutons (with W. Weber, Manitoba Dept. of Energy and Mines).

8. McMaster University - Departments of Geology and Chemistry (R.H. McNutt, H.P. Schwarcz, C.F. Rees, H.G. Thode, L. Heaman, T. Atkins, K. Connare, T.P. Ding)

(a) A study is continuing of Rb/Sr geochronology in Chandos Twp. near the north margin of the Hastings Basin. The Coe Hill granite has been determined to be 1063 Ma, R_i = 0.7040, an age and initial ratio identical to the nearby Loon Lake pluton, suggesting a genetic link. Preliminary work on the Methuen granite indicates an age of 1180 Ma. From work to date there appear to be at least four periods of igneous activity (ca. 1250, 1180, 1100 and 1050 Ma.) in this area. To better understand the Rb/Sr system in high grade metamorphism, i) regional scale, multi-outcrop; ii) single specimen slab studies; and iii) multiple sampling of a single outcrop have been used on the Apsley gneiss, to be augmented with zircon studies (ROM, Toronto). An age of 1290 Ma has been determined on the granulite grade, McKeller orthogneiss, Parry Sound area, Ontario and interpreted as the time of metamorphism. In a joint study with Drs. Fritz and Frappe (Univ. of Waterloo), rock-water samples from Sudbury, Yellowknife and Thompson have shown a total range in $^{87}Sr/^{86}Sr$ value of 0.710 to 0.736. Within a given mine, the range is very narrow. The Sr content can be very high (up to 2000 μgs/ml). In a continuing study with A. Clark (Queen's), Mesozoic and Paleogene samples from N. Chile have shown a range of initial $^{87}Sr/^{86}Sr$ from 0.7035 to 0.7070, similar to our work further south. In contrast, the S. Peru samples give consistent values at 0.7047.

(b) Together with E. Nelson (SFU), we have been using $\delta^{13}C$ and $\delta^{15}N$ variations in collagen from human fossil bones to determine the contributions of various foods to their diet: marine and fresh-water fish, terrestrial herbivores and maize can be recognized as separate components. We are now investigating D/H variations as paleoclimatic indicators.

Host rocks which have been disturbed by groundwater display non-equilibrium ratios of daughter to parent in the decay chains of U-isotopes. This is a means of studying radwaste disposal sites. We are also studying paleomagnetic orientation of the Fe-rich fracture fillings as indicators of time of filling (with M. Gascoyne, A. Latham).

Fluid inclusions in stalagmites are fractionated in H isotopes with respect to solutions from which they grew, possibly due to adsorption effects. After correction for the fractionation, paleotemperatures of calcite growth can be inferred. Also, $\delta^{18}O$ profiles of flowstones from N.W. England show variations of 1.7 per mil that correlate with oxygen isotope stages in deep-sea cores. (with C. Yonge, M. Gascoyne).

In studies of O-isotopes at Sudbury it is found that granophyre is slightly enriched in ^{18}O over norite (7.3% vs. 6.7%) but there is no correlation with SiO_2 content or degree of alteration. Onaping ($\delta^{18}O$ = 8.2%) resembles Archaean gneiss isotopically but not chemically (with T.P. Ding).

$^{230}Th/^{234}U$ dates have been obtained for lower, middle and upper paleolithic sites in England, Wales, France, Israel, Hungary and Morocco.

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.

9. University of Toronto - Department of Physics (R.M. Farquhar, P.E. Smith)

A study of the lead isotope ratios in pyrites and galenas from volcanogenic sulphide deposits of Archean age in the Canadian Shield has begun. It is expected that small time differences in sulphide deposition among Archean deposits will be detectable using high precision isotopic measurements.

The study of precambrian-age stratiform and quartz-vein deposits in the Grenville is continuing. There is a significant variation in lead isotope ratios among the precambrian deposits but it is not clear whether this is a primary (i.e. pre-orogenic) feature or has resulted from processes associated with the Grenville orogeny.

Lead isotope ratio variations among phanerozoic age galenas in sedimentary rocks of the Niagara escarpment suggest that adjacent Grenville rocks were not the dominant source of the lead. The project is being broadened to include a study of lead in the sedimentary rocks themselves.

A survey of lead isotope ratios in galenas from three widely separated deposits of different age in the People's Republic of China, is being undertaken by Cui Cheng-yu. The results of this study represent the first high precision lead isotope ratio measurements made outside mainland China.

10. University of Western Ontario - Department of Geophysics (A. Hayatsu, C.M. Carmichael)

(a) Solubilities and abundances of argon and helium in the primordial atmosphere suggest that the conditions for primordial rare gases to retain their primordial signatures are very favourable for helium but

extremely unfavourable for argon. This explains why there are abundant reports of excess ^{3}He but very scarce low $^{40}Ar/^{36}Ar$ ratios. Therefore, the scarcity of low argon isotope ratios should not be taken as a sign of scarcity of primordial argon in the earth's interior.

(b) The results of K-Ar dating of the Caraquet Dike, New Brunswick are concordant and yielded an age of 198 ± 1.6 Ma.

(c) Fifty-three K-Ar analyses have been made of metamorphosed sedimentary rocks in Scotland in conjunction with a paleomagnetic study.

11. University of Windsor - Department of Geology (A. Turek, P. Smith, W.R. Van Schmus, R.N. Robinson)

(a) Chronostratigraphic studies indicate that the Wawa greenstone belt evolved in at least 53 Ma between 2696 - 2749 Ma ago (extremes of zircon ages). Emplacement of Granitic plutons is generally coeval with episodes of volcanism. There may be a period of plutonism at 2662 - 2675 Ma. The oldest rock dated by U/Pb is 2888 ± 2 Ma. Rb-Sr whole rock ages are not stratigraphically meaningful and probably reflect the Kenoran orogeny at about 2560 Ma.

(b) The Precambrian basement in southern Ontario is being dated by Rb/Sr and U/Pb. Ages obtained so far show that the basement here is an extension of the Grenville province yielding the 950 - 1100 Ma ages. In southwestern Ontario survival ages up to 1860 Ma (Rb/Sr) have been picked up. These rocks belong to the Ontario Gneiss Segment III of the Grenville for which older ages have been reported.

Sampling and mineral separation for a zircon study of the greenstone belt at Island Lake, Manitoba has been started.

12. Queen's University - Department of Geological Sciences (E. Farrar, D.A. Archibald and D.J. Kontak)

(a) The argon fusing system has been rebuilt. It is anticipated that up to 5 argon analyses will be completed per day.

(b) Investigations into the tectonic, magmatic and metallogenic evolution of the Cordillera Carabaya, S.E. Peru 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.

(c) A literature review combined with new K-Ar dates 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.

(d) A study of the geology and geochronology of the southern Kootenay Arc, B.C., is nearing completion. The study comprises conventional K-Ar dating as well as $^{40}Ar/^{39}Ar$, U-Pb (with T. Krough, 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 and surrounding areas.

A study of the K-Ar geochronology and petrography of the 20 intrusive bodies of the Selwyn Mountains, east of Cantung, has been initiated. This project was funded by Union Carbide (Canada) Ltd.

(e) In cooperation with A.H. Clark, a K-Ar study of selected Sn and W mining districts in Korea has been initiated. Preliminary results suggest a complex thermal history for these areas; K-Ar mineral dates range from 80 Ma to 1700 Ma. $^{40}Ar/^{39}Ar$ age spectra will be completed in the near future.

(f) A $^{40}Ar/^{39}Ar$ study (with J. Percival, Queen's University) of the sheared eastern margin of the KSZ is in progress. A study of sheared and unsheared granitic rocks is about to begin in an attempt to resolve the time of brittle deformation.

(g) Continuing from a previous geochronological study of plutons along the Lassiter Coast of the Antarctic Peninsula (with P.D. Rowley, U.S.G.S.), a study of similar intrusives along the Orville Coast has been initiated. Preliminary results indicate that these rocks were intruded during the same extensive Early Cretaceous Magmatic event that has now been well documented for the Lassiter Coast.

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VI METEOROLOGY AND ATMOSPHERIC SCIENCE

Compiled by: E.J. Truhlar

1. Introduction

International and national research activities in meteorology and atmospheric science remain at a high level in spite of the world-wide recession. Canadian scientists participated in two new undertakings during 1982: the Nanticoke II Shoreline Diffusion Experiment (with the United States, Japan and the Commission of the European Communities), and the wind flow experiment at Askervein in the Outer Hebrides (with Denmark, West Germany, New Zealand and the United Kingdom).

The Canadian Climate Program submission to the Federal Treasury Board has been completed and includes a request for support for two research programs on Climate Prediction and CO_2 Research and Impacts. Canada is the first country to publish the 1951-80 climate normals for radiation, temperature, precipitation, degree-days, wind, frost and sunshine.

Acid rain is still a matter of vital concern and intense study. Numerous modelling and experimental studies of air pollutants are continuing in order to evaluate the effects of their transport on climate, weather patterns and environmental quality.

Satellite data are being used increasingly to derive cloud statistics, to determine areas of intense convective activity, especially for short-term weather forecasting (Rainsat) and to measure the low-level winds (Seasat).

The Sixteenth Annual Congress of the Canadian Meteorological and Oceanographic Society was held on 26-28 May at the University of Ottawa on the theme of Sea Ice. Over 400 attended, including 100 members of the CMOS Hydrology Special Interest Group; there were 132 papers and 23 poster presentations. Two new publications are being sponsored by the Society: Chinook, devoted to popular articles mainly on meteorological and atmospheric topics but also on oceanography and the environment; the Climatological

Bulletin, containing research notes, overviews, reviews, news and comments of interest to climatologists, professionals in related disciplines, and users of climate information.

The Society prizes for 1982 were awarded to: Roger Daley, President's Prize; John L. Knox, Dr. Andrew Thomson Prize in Applied Meteorology; Howard G. Westergaard, Brian N. Lea and Donald O. Hodgins, Prize in Applied Oceanography; Len Hubbert, Rube Hornstein Prize in Operational Meteorology; W. Hsieh, Graduate Student Prize. A citation was also awarded to Seaconsult Marine Research Ltd.

2. The University of British Columbia - Department of Geography (T. Oke, D. Steyn, J. Hay)

A data set gathered over a period of three summers and covering a range of synoptic conditions is being analysed with the aim of seeking relationships between commonly measured elements and evapotranspiration. An observational program is in progress to measure water budget components in a suburb of Vancouver. A complete annual budget will be prepared. Three urban energy budget models (Myrup; Ackerman; Carlson) are being run using input conditions consistent with those prevailing during periods of suburban energy balance observations. Their performance will be evaluated using statistical tests. The statistical behaviour of ozone levels in the Vancouver region is being analysed in order to provide a better understanding of the episode nature of pollutant patterns. A mobile unit is being designed and contracted for use as a generalized facility to research air and water quality. These studies continue. Three and one-half years of hourly solar radiation data have been collected for 12 stations in the Vancouver area. Impacts are simulated using numerical models of solar domestic space (active and passive) and hot water heating systems. Observational and modelling studies of the sea-breeze flow in the Vancouver region are being undertaken. Results from this study will improve understanding of the origins of atmospheric oxidants in the region. Other studies are: satellite estimates of solar radiation at the Earth's surface; sky radiance distributions; short-wave irradiance for inclined surfaces.

3. Simon Fraser University - Department of Geography

Research activities entail the study of climatology as it relates to agriculture, snow and ice, and hydrology. (W.G. Bailey and R.B. Sagar)

4. The University of Alberta - Meteorology Division and Institute of Earth and Planetary Physics (K.D. Hage, R. Wong, L.Stovel, P. Hopps, E.P. Lozowski, M. Oleskiw, B. Kochtubadja, G. Strong, Z. Misztal, K. Finstad, R. Charlton, J. Freund, E.R. Reinelt, R. Goodson, D. Phillips, C. Sackiw, J. Roessler)

(a) A two-dimensional numerical model of winds in a V-shaped or flat-bottom valley with pre-specified surface temperature changes and flux-gradient parameterization of turbulent fluxes of momentum and heat was developed (simulating nocturnal drainage flows in the North Saskatchewan River Valley). A numerical model for estimating carbon monoxide concentrations in the central business district of Edmonton from traffic flow data and urban meteorological tower observations was tested.

(b) Preliminary analyses of tornado frequencies in the western Prairie Provinces reveal a secondary maximum in Central Alberta. The year 1982 was a record one in Alberta for the number of tornadoes (27 or 28) and number of tornado days (14 in the period May to September), but not for the number of severe tornadoes.

(c) An inexpensive turbulence data logger accepting up to 5 channels of fast-response turbulence sensor measurements was designed, constructed, and field tested.

(d) A computer simulation of time-dependent rime icing on airfoils, cloud droplet trajectory analyses, investigation of precipitation scavenging, (related to long-range transport of air pollutants), modelling work on the ablation of dry-ice pellets falling through clear and cloudy air, investigation of the effects of synoptic-scale/meso-scale interactions on the development and forecasting of severe thunderstorms, analysis of the data collected during the EPS/AES intensive sulphate study, and field experiments using an aircraft to investigate the role of clouds in the transformation and removal of sulphur dioxide from the atmosphere have been carried out.

(e) Samples of man-made snow, fog and cloud have been collected during the past five winters in the petrochemical district of Edmonton and chemically analyzed in collaboration with the Alberta Research Council.

(f) Routine atmospheric radiation measurements were used to investigate the origin and distribution of Arctic haze. A short period of high aerosol turbidity in spring is followed by an abrupt decrease to low summer values.

(g) The usefulness of high-resolution satellite data for discriminating between precipitating and non-precipitating convective clouds in Central Alberta, airflow over mountains and important class of barrier profiles, and the cohesiveness of upper-air soundings in space and time, by using pressure, temperature and wind data obtained from serial releases of radiosonde balloons are under study. In collaboration with A. Eddy of the University of Oklahoma) evidence has been obtained that seems to support the claim that cloud seeding in North Dakota produces an increase in precipitation during the growing season.

(h) Using finite-element techniques a new algorithm makes it possible to develop a model capable of simulating statistical properties of turbulence, such as energy spectra.

5. Alberta Environment (B.L. Magill)

Alberta Environment continued to support research and monitoring activities related to air quality and meteorology. Studies to assess air quality and to compile acoustic radar data for Calgary and Edmonton were resumed. Field projects to analyse the chemical constituents of rain in the Athabasca Oil Sands area were continued. A study of gas diffusion in two valleys of Moose Mountain was undertaken (including sulfur hexafluoride tracer experiments in drainage flows). Emergency hydrogen sulphide monitoring was carried out during the blowout of a gas well near Lodgepole, Alberta. The Department maintained a high degree of involvement in various LRTAP/Acid Rain Committees represented by Federal/Provincial governments and industry. A sulphur deposition model was completed and used to estimate deposition patterns around selected point sources. Equipment for measuring the dry deposition of sulphur dioxide by means of the concentration gradient was evaluated at the USA-EPA Inter-comparison Study near Champaign, Illinois.

Alberta Environment initiated the formation of the Alberta Climate Advisory Committee and a consultant was contracted to survey the climate data collection activities of provincial government agencies in Alberta to evaluate their collection programs and make recommendations for future coordination. An update of the physical climatology of the Athabasca Oil Sands area was undertaken and the reliability of the climate data base was assessed.

6. Research Council of Alberta (RCA)

(a) Assessment was made, through physical experiments, if cloud seeding can have any significant effect on hailfall and rainfall in central Alberta. The hail experiments involve seeding particular feeder clouds in the new growth zone of hailstorms and then documenting the microphysical processes by means of cloud physics aircraft and radar observations. Similar experiments are conducted on cumulus clouds to assess the effect of seeding on rainfall. In total, 8 cumulus clouds and 5 feeder clouds of hailstorms were seeded. Preliminary analysis suggests there are distinct seeding effects in a few cases. Other projects concentrated on improved forecasting of hailfall parameters and improved measurement of hailfall and rainfall by radar. Theory was developed that allows separating the hail component from the rain component in a radar measurement for an Alberta thunderstorm. Hailstorms were seeded with silver iodide by a fleet of 5 aircraft from June 20 to August 31 south of Red Deer in a semicircular area of radius 80 miles. A contract was let with I.P. Krick Associates of Canada, Ltd. to carry out a ground generator seeding program south and east of Calgary. The Intera/ARC research aircraft flew 23 missions to detect ice nuclei originating from the Krick ground generators. In order to determine if emissions from gas plants affect precipitation processes in central Alberta, rain and hail samples were collected from thunderstorms for chemical analysis. During one week in early September, several research aircraft missions were conducted to document the sulphate and sulphur concentrations in the plume of the Ram River sour gas processing plant. On 10 days in March, research aircraft were flown through cloud systems over the southern Rockies to document ice crystal concentration and liquid water content. Some pockets with significant liquid water content were observed, suggesting a potential for augmenting snowfall by cloud seeding.

(b) A system is being developed to provide the Alberta River Forecast Centre in Edmonton with "real-time" measurements of rainfall derived from the Alberta Research Council's radars located near Red Deer.

(c) Nine storm days with varying convective activity were analysed using synoptic, radar and TIROS-N satellite data to identify the important parameters for predicting short-term weather events. An areal version of the Synoptic Index developed at ARC was shown capable of predicting the location and intensity of convective activity up to 18 h in advance. This index can be used to help interpret satellite data and to locate those areas where storms should be most intense.

(d) Funding was given to Environmental Research and Technology of Massachusetts, in order to provide ERT with consulting services concerning the meteorological applications of the Next Generation of Weather Radar (NEXRAD) for the United States.

7. The University of Calgary - Kananaskis Centre for Environment Research

The formation of peroxyacetyl nitrate (PAN) in the urban atmosphere in Alberta is being studied. PAN concentrations of up to 6.6 ppb have been recorded, with the diurnal maximum occurring concurrently with the afternoon peak in ozone concentrations. The relationship of PAN, nitric acid and particulate nitrate is being investigated in Calgary and Edmonton, and in the Kananaskis valley, 70 km west of Calgary.

8. Western Research & Development

Major projects included: evaluation of wind and air quality data at sour gas processing plants to determine sources of high pollution concentration; analysis of ice fog potential from the operation of a compressor station in the Yukon; operational use of a Gaussian Frequency Distribution Model to

evaluate air quality based on historical hourly meteorological data; and an inventory of climate data collection programs of Alberta Government agencies with recommendations on future coordination.

9. Saskatchewan Research Council

A regional network was established in southern Saskatchewan to quantify the presence of phenoxy herbicides such as 2,4-dichlorophenoxyacetic acid (2,4-D) in the air, during the agricultural spraying season. Preliminary results indicate a considerable improvement in air quality compared with that in a period one decade earlier. Snow pack chemistry accumulation studies continued in the north of the province in order to determine a total acid deposition baseline in a highly sensitive region. Using this baseline future impacts may be addressed. The event collection of precipitation in the Reindeer Lake area of Saskatchewan was studied. Back trajectories for each significant event were produced to illustrate how air mass point of origin can have a significant impact on rain water quality. The emissions monitoring programs were expanded significantly to include trace chemicals emitted to the air by industry. Chemicals such as chlorine, fluorine, mercury and arsenic were added to the SRC routine emissions testing capabilities. Pathways studies of widely used post-emergent agricultural pesticides continued in collaboration with Agriculture Canada. The vapour flux of diclofop was the main object of study.

10. University of Windsor (Dept. of Geography, Dept. of Physics)

The micro-precipitation network set up in Essex county during 1970 is still in operation; work in precipitation chemistry in the Essex region is continuing (Sanderson). Research in Arctic paleoclimates has concentrated on the upper Frobisher Bay area of Baffin Island, and has involved refinement of the post-glacial emergence chronology and, through palynological studies, establishment of the Holocene paleoclimatic record for the area (Jacobs). Various processes involving the interaction of electrons with atmospheric species continue to be studied.

11. The University of Western Ontario - Department of Geography

The long-term instrumental records available for Jasper, Banff, Lake Louise (Alberta) and Valemount (B.C.) are being analysed by B.H. Luckman. As well as providing a summary of changes during this instrumental record period these data will be used to calibrate climate/tree ring relationships for ring width, densitometry and oxygen isotopes (^{18}O). A 600 year + record is available from living trees at the Columbia Icefields and cross-dating with snags could extend the record back to ca. 1300 ^{14}C yr BP.

12. University of Waterloo - Department of Civil Engineering (E.A. McBean, J.F. Sykes, T.E. Unny)

Stochastic variations on the transfer mechanism of acid rain, particularly as they apply to strategy determination, are being investigated. Numerical models for forecasting large-scale sea-ice motion have been developed. Further research on model development and on ice behaviour are continuing. The circulation characteristics of Barrow Strait in the Northwest Passage in the High Arctic were investigated through dynamic models. The numerical simulation results are verified through data from buoys and from remotely sensed images of the motion of floating ice masses.

13. University of Guelph - Department of Land Resource Science (D.M. Brown, T.J. Gillespie, K.M. King, G.W. Thurtell)

The main areas of research are the climatology of dry spells in Southern Ontario and the response of field corn to irrigation under various management alternatives. Other areas are the climatic aspects for assessing land

productivity for land evaluation purposes, and climate effects on the maximum potential of corn yields in Ontario.

14. McMaster University - Department of Geography (J.A. Davies)

Activities include testing numerical models for estimating solar irradiance on a horizontal surface and determining aerosol effects on solar irradiance using spectral and broad-band radiation measurements.

15. University of Toronto (R.E. Stewart, R. List, J.V. Iribarne, W.R. Peltier, C.A. Lin, H.-R. Cho, J.R. Drummond)

(a) In the Department of Physics (Meteorology) work includes the following. Development of a new icing tunnel for the simulation of cold rain and hail, ongoing experiments on water drop collisional breakup with and without electric fields; further development of computer models illustrating the effect of breakup on the warm rain process; the analysis of information from radar, aircraft, satellites, and rawinsondes to investigate the mesoscale structure of synoptic-scale storms over Ontario and the North Pacific Ocean; new analyses of the dynamics of non-linear mountain waves focussing upon the interaction of the forced disturbance with the mean flow at a critical level; calculations on the evolution of finite amplitude Kelvin-Helmholtz waves at high Reynolds number; the scale interaction of large-scale atmospheric waves; and the analyses of the stability of planetary waves, and on a model of the atmospheric general circulation; development of a model of the 10^5 year cycle of Pleistocene climatic variability; climate modelling involving calculations with simple energy balance models; studies on cloud-mean flow interactions, and on interactions between cumulus clouds and larger scale weather systems; derivation of a set of first-order equations applicable to weather systems in tropical latitudes; and upper atmosphere composition.

(b) The Institute for Environmental Studies maintains interdisciplinary research programs, particularly with respect to acid deposition, climate impacts, energy, indoor-outdoor air pollution relations, the world carbon cycle and management strategies for snow and ice control.

16. Ontario Ministry of the Environment - Air Resources Branch

A Eulerian model for long-range transport and deposition of acidic pollutants and oxidants, and a mesoscale 3-D wind field model are under development. Meteorological analyses of precipitation chemistry events occurring throughout Ontario were routinely conducted. The analysis and interpretation of an acidic deposition episode at Dorset during August-September 1981 was completed. Air chemistry and atmospheric deposition across Ontario was monitored regularly. A large amount of time was spent on data analysis. Most of the Sudbury Environmental Study data were analysed and results were reported; and some preliminary interpretations of the Acid Rain Network data were made. Air quality monitoring continued in the Nanticoke area, with much of the data being telemetered to Toronto. Considerable efforts were devoted to developing an air quality model for the Nanticoke area.

17. Trent University - Department of Geography, and Watershed Ecosystems Program

Studies of land snowpack, including energy balance work, and of ice and snow on lakes, including aspects of lake light regime, continued. Field-work was conducted in Southern Ontario and in Labrador. Compilations of palaeoclimatic and palaeogeographic data were undertaken in support of theoretical work on the dynamics of ancient climates; this work focussed on the origins and earliest state of the Earth's hydrosphere.

18. Communications Research Centre

Radio climatological studies continued. Precipitation intensity data were used to assess the influence of rain on microwave propagation in all parts of Canada.

19. National Aeronautical Establishment - Flight Research Laboratory (FRL)

The FRL Twin Otter and Beech 18 aircraft were flown approximately 135 hours in projects related to atmospheric studies. The scavenging of airborne pollutants by cloud and precipitation was investigated in cooperation with the Air Quality and Atmospheric Processes Research Branches of the AES (see 1981 CGB). From June 28 to July 28, NAE, AES, and the Ontario Ministry of the Environment cooperated in an extensive study of the role of clouds in producing acid rain in the Algonquin Park area. The DND facilities at North Bay airport were used as the main operations centre and base for two highly instrumented aircraft. Experiments continued on the measurement of the flux of carbon dioxide in the boundary layer above several types of vegetation.

20. McGill University (Depts. of Meteorology and Agricultural Chemistry and Physics)

In the Department of Meteorology the dynamics of atmospheric blocking patterns is being investigated by means of diagnostic calculations using the January 1979 FGGE data. Related investigations deal with the response of a barotropic atmosphere to large-scale orographic forcing when the undisturbed flow is a function of both longitude and latitude; observational studies of the stationary planetary waves; large-scale coherent structures in atmospheric flow and their interaction with the earth's surface. In cloud physics and dynamics, a study was initiated on the effects of cumulus convection on mid-latitude cyclone systems. Radar research continued on rainshower statistics, the prediction of rainfall over various catchment areas, and the development of methods for remotely detecting the thermodynamic phase of precipitation. A study was initiated on the detection and forecasting of severe weather events using GEOS satellite data. Radar data together with the chemical composition of rain collected near cloud base and at the surface during the AES cloud chemistry project in North Bay is being analysed with the view of obtaining several detailed case studies of the wet deposition of sulphur.

In the Department of Agricultural Chemistry and Physics the variability, in space and time, of the boundary-structure near the ground is being studied in the laboratory and in the field in order to assess its effect on micrometeorologically measured fluxes of heat and mass. Aircraft measurements of CO_2 fluxes continued. A study was begun into the minimum number of observations that are required from a temporary climatological station in order to establish a useful correlation with the nearest long-term station.

21. Université de Sherbrooke - Département de géographie et Institut d'aménagement (J.J. Boisvert, G. Bousquet, J.M.M. Dubois, A.M. Valton, B. Lauriol, J.T. Gray, B. Hétu, J. Poi)

(a) Laboratoire de télédétection (traitement numérique d'images des satellites Landsat, HCMM, NOAA et de simulations aéroportées) - Télédétection des propriétés thermiques de la surface terrestre: études, élaboration et application du concept d'inertie thermique pour la mesure de l'humidité des sols et des variations de textures; mesures multispectrales et à l'infrarouge, appliquées aux caractéristiques biophysiques et de croissance des végétaux; régionalisation des données météorologiques sur la températures, localisation des endroits propices aux gelées nocturnes. - Caractéristiques hydrodynamiques de l'estuaire et du golfe du Saint-Laurent: courants, matières en suspension, pollution, rejets thermiques, variations spatio-temporelles. - Études par

télédétection de la couverture neigeuse et des glaces flottantes: cartographie des congères et zones de rétention maximum, corrélation avec des paramètres climatiques et topographiques (Ungava); cartographie et évolution des glaces flottantes de 1975 à 1980 (Nord-est canadien).

(b) Laboratoire de climatologie: climatologie régionale des Cantons de l'Est (1941-1980); les changements historiques du climat dans le sud du Québec; les tempêtes dans le golfe du Saint-Laurent; geothermal modelling of deep drill hole data aimed at reconstruction of Late Quaternary Environments in Northern Québec and Gaspésie.

22. Environnement-Québec - Service de la météorologie

Les projets suivants ont été réalisés: implantation sur le territoire québécois d'un réseau de 45 collecteurs de précipitation pour l'échantillonnage des pluies acides; constitution de 27 banques différentes sur les données obtenues à partir des pluviographes à augets basculeurs et portant sur les périodes mobiles de 5 min à 72 h. Les projets suivants se poursuivents: analyse des méthodes statistiques et stochastiques pour la détermination des pluies maximales probables; modification et réorganisation du réseau météorologique du Québec. Les projets suivants ont été amorcés: analyse du contenu de l'information pluviométrique dans l'optique de la rationalisation du réseau du Québec pour des manifestations rares; climatologie des vents (vents dominants et vitesses moyennes).

23. Agriculture Canada - Agrometeorology Section, Ottawa

The following results were obtained: (1) The software for the Williams' Model (1981) was fully revised to minimize resource costs and used to calculate yields for the four PFRA drought periods (1934 to 1937, 1947 and 1948, 1954 and 1955, and 1958 to 1961) from the data for the entire Manitoba and Saskatchewan station network obtained under the PFRA agreement. (2) The rates of photosynthesis and respiration based on net CO_2 assimilation, and transpiration based on water loss, were measured for a corn crop at several stages of development, using the eddy flux correlation technique. (3) The relationship between estimated biomass production and transpiration under various evaporative conditions was obtained for corn. (4) The change in green biomass and percentage ground cover for four crops was determined from a 4-band ground spectrometer. (5) A data set of 38 years was constructed for Saskatchewan as part of the preliminary assessment of weather on grasshopper population. Observed rural municipality grasshopper population data were associated with geographic locations and used to test software for generating 3-D displays of spatial variations in population. (6) The micro-environment in the spring pertinent to pest and disease persistence for farm weather service needs was studied. (7) A sonar-based snow depth gauge is being developed in cooperation with ESRI. A prototype device will be built for field evaluation in the winter of 1983-84, compatible with the CR-21 data logger. (8) Application of agroclimatic criteria as an integral part of forage crop zonation mapping for the Atlantic Region was begun. (9) Field experiments were carried out to provide data for a water stress-sensitive phenological index and to quantify the significance of osmotic adjustment to production over a growing season. (10) Basal leaf water potential measurements were tested under controlled and field conditions and found to integrate the effects of atmospheric demand and soil water availability. (11) A climatic data file was established for several sites in Manitoba.

24. Canadian Forestry Service

(a) Newfoundland Forest Research Centre, St. John's: Climatic diagrams for Labrador are being prepared for the national map of Canadian ecoregions. Correlation of native red pine tree-ring patterns with climate and fire history in central Newfoundland and study of the relation of the meso- and micro-climates to shelterbelts and energy plantations continue.

(b) Maritimes Forest Research Centre, Fredericton: The program continues as reported in the 1981 CGB.

(c) Laurentian Forest Research Centre, Ste-Foy: Activities are as reported in the 1981 CGB.

(d) Canadian Forestry Service Headquarters, Ottawa: In response to widespread concern over the impact of increasing concentrations of carbon dioxide in the world's atmosphere, the CFS is developing a forestry perspective on the CO_2 issue.

(e) Petawawa National Forestry Institute, Chalk River: The open-area data collection platform (DCP) near Cobden and the wind sensor array on the 43-m permanent forest wind site were operated successfully. Radiation data and temperature and moisture profile data were measured by Queen's University personnel on the same mast as part of an energy budget study contrasting forested and open field conditions. The prediction of monthly area burned by wildfire using components of the Fire Weather Index and raw meteorological data as predictors is nearing completion. The impact of intensive forest management on soil processes affecting fertility is being studied to provide better management of forest soils for sustained productivity.

(f) Great Lakes Forest Research Centre, Sault Ste. Marie: Historical and current weather data are used by the Fire Research Unit for studies of wildfire cases, long-term drought situations, insect outbreaks, and seedling germination, survival and growth.

(g) Forest Pest Management Institute, Sault Ste. Marie: A field program in cooperation with NRC is measuring turbulence at intervals through the forest canopy; different turbulence indices are being compared. A new solar-powered remote weather station under field testing is working effectively in the local climate conditions.

(h) Northern Forest Research Centre, Edmonton: Several studies continue: the effect of microclimate of clear-cut areas on pine and spruce seedling growth; forest hydrology modelling; fire behaviour and management; and air pollution injury to vegetation. Three automated weather stations were installed on the Marmot Creek Watershed to monitor air temperature, relative humidity, wind speed and direction data, recorded by Campbell Scientific CR-21 data loggers. Weather data are used to monitor on-site fire behaviour and to develop past wildfire case histories. Attempts are being made to link pollution deposition modelling generated from meteorological measurements to the deposition to and the impact on lichens in northeastern and west-central Alberta. Available climate data are being incorporated into the on-going Ecological (Biogeoclimatic) Classification of Alberta forests. Climate information has been used in reports on methods of detecting frost injury in conifer seedlings. A study was initiated on the role of ice nucleating agents (INA) that mediate freezing.

(i) Pacific Forest Research Centre, Victoria: The studies reported in the 1981 CGB are still active. New studies include: the climate factors associated with mountain pine beetle dispersal; the spread of a pathogen in a seed orchard. Two studies have been completed on the weather-related effects on the western spruce budworm in British Columbia, one involving an analysis of long-term weather records, and the other the effects of elevation on rate of development.

25. Atmospheric Environment Service

(a) Meteorological Services Research Branch (MSRB): A new version of the hemispheric spectral forecast model was delivered to the Canadian

Meteorological Centre for operational evaluation. A semi-Lagrangian technique for advection has been developed for and thoroughly tested in barotropic models, and is being incorporated into a full three-dimensional atmospheric model. In cooperation with the Ontario Ministry of the Environment and the Federal Republic of Germany, work commenced on a model for calculating the long-range transport of airborne pollutants. Two different statistical procedures for predicting airport winds from numerical forecast model outputs were tested and compared. Both gave short-range forecasts superior to subjectively produced operational forecasts. A third-order closure model using the Wiener-Hermite expansion was developed to calculate the fluxes in the planetary boundary layer. The Ice Dynamics Model for predicting unconsolidated sea ice was implemented at Ice Forecast Central. The Regional Ice Model for winter pack ice was tested using Beaufort Sea data. A digital ice data-base system was developed under contract and implemented at Ice Forecast Central. An automated version of the operational significant wave height forecast procedure was developed. The Donelan spectral wave model for enclosed basins, such as the Great Lakes, was tested for possible operational application. A system to automatically verify aviation terminal forecasts was implemented at all Weather Centres. A similar system for public weather forecasts is being developed. Software was developed to automatically reformat, store and display various kinds of weather information in Telidon format. A prototype system to combine radar and satellite data to delineate areas of rain was developed under contract, and is being evaluated and improved. A prototype system to convert locally received satellite radiance measurements into profiles of atmospheric temperature and humidity has been built. Seven months of data are being studied for operational applications. A complex image analysis software package was developed under contract to enable multi-spectral satellite data to be interpreted in terms of sea-ice extent and thickness, snow cover, air pollution, etc.

Comprehensive re-processing of Seasat scatterometer data was completed to remove errors and redundancies, and to rearrange, geographically register and plot them in order to improve the de-aliasing of wind determinations and to estimate their impact on meteorological and oceanographic forecasts. The wind flow over an instrumented hill in Alberta (Kettles Hill) was simulated in the AES wind tunnel with good agreement of the speed-up observed at the summit of the hill. A second experiment, in cooperation with Denmark, Germany, the U.K. and New Zealand, reached the field phase at Askervein Hill in the Scottish Hebrides. These studies should lead to better calculations of wind energy potential for other candidate hills.

(b) Atmospheric Processes Research Branch (ARPB): Much of the research activity centred on measurements of SO_2 in the Mount St. Helens and El Chichon volcanic clouds, mostly the latter. The SO_2 measurements were made with a spectrophotometer developed by the Division and flown on board various NASA research aircraft to study the evolution of the El Chichon cloud. The new MOPOL (Monitoring of Planetary Ozone Layer) program was commenced and ground-truthing measurements for the Solar Mesospheric Explorer (SME) satellite were conducted.

One scientific balloon flight, to measure trace constituents of importance to the ozone layer in the stratosphere, was successfully launched 22nd September, 1982 from the National Scientific Balloon Facility at Palestine, Texas. This flight was particularly important since it was launched simultaneously with three other payloads also carrying various remote-sensing instruments in the NASA Balloon Intercomparison Experiment (BIC I). Other continuing activities (see 1981 CGB) include: the ozone monitoring program; the UVB monitoring program; radiometric monitoring of long-wave fluxes, and of short-wave

irradiances for solar energy studies; urban turbidity studies (now two years in progress) using the AES/Sonotek sunphotometer; the pyranometer calibration program, in which over 200 instruments were calibrated; and the international pyranometer calibration experiments. Six Mark II ozone spectrophotometers have been delivered, including units for Greece, Sweden and West Germany; four more are under construction. A major field project to study cloud and precipitation scavenging of pollutants was operated out of North Bay, Ontario during July. Two highly instrumented aircraft, surface air and precipitation chemistry sensors, as well as 4 AES weather radars were used (see report in Section 19 by National Aeronautical Establishment). The objectives of the study were to measure the interactions of polluted air with clouds and rain, to determine how the pollutants are converted to acids, and to evaluate the rate at which pollutants are removed and deposited on the ground. In weather radar research, further analysis of coincident radar rainfall and raindrop measurements provided a measure of the reduction in rainfall rate estimate errors when combining a series of contiguous observations. Data on best Z-R relationships and error estimates are being published.

Improvements to the existing sferics direction-finding system provided new data on the phenomena of positive strokes and multiple strokes. Experiments were conducted using Telidon Videotex transmission techniques, and a simple low cost mobile radar display that can be used with a standard telephone receiver was developed. Other activities included further support for the analysis of data from the Precipitation Enhancement Experiment in Spain, the Montana Cooperative Convective Precipitation Experiment and the North Pacific STREX project (see 1981 CGB); cloud physics and chemistry instrumentation development; and the initiation of a LRTAP-related cloud climatology study for Ontario and Quebec.

(c) Air Quality and Inter-Environmental Research Branch (ARQB):

AES efforts in this field are focussed on applying a Lagrangian trajectory model to estimate transboundary flows of sulphur compounds, to determine source-receptor relationships, to assist in data analysis and interpretation, to study non-linear chemical reactions and in-cloud processes and to test and evaluate the forecasting capability of a real-time concentration model. Continuing activities include: preparation and implementation of a more complete and recent pollutant emissions inventory for North America; application of source-receptor transfer matrices to emission control strategies development; further model evaluation and intercomparison studies. The Atmospheric Environment Service, the Ontario Ministry of the Environment and the Federal Republic of Germany are cooperating to develop and implement a multi-level Eulerian Air Pollution Model for North America. The data base and wind-field aspects are being designed under contract by the MEP Company, and the air quality model is being developed by the Environmental Research and Technology Company. A method for evaluating the accuracy of trajectory models was developed and applied to existing models. Theoretical estimates of error were validated against numerical computations. The Air Precipitation Network for sampling air and precipitation every day expanded from 6 to 8 stations on the addition of stations in Newfoundland and Saskatchewan. The 54-station Canadian Network for Sampling Precipitation (CANSAP) samples precipitation on a monthly basis. Data have been published to December 1981 for both networks. The Canadian Arctic Air Sampling Network (CAASN) is continuing to monitor at three Arctic sites.

Methods developed to measure directly the fluxes of gases such as SO_2 and O_3 using an eddy-accumulation technique were tested during the Nanticoke Shoreline Fumigation Experiment, and an international instrument intercomparison in Illinois in June and July. Particulate

flux was also measured by using a laser spectrometer-sonic anemometer system. Instrument development mainly dealt with the measurement of ambient particulate matter, nitric acid and NO_2. Studies of precipitation scavenging processes and the cleansing roles of clouds are continuing (see 1981 CGB). A national inventory of natural sources and emissions of alkaline particulates was prepared under contract. The North American contribution to the chemical composition of the lower troposphere is being studied. Shipboard, coastal and snowpack measurements are being made to determine the Pacific "background" precipitation composition, and an investigation has been initiated to determine the flux of pollutants leaving North America to the east, over the Atlantic Ocean. A helicopter snow-sampling survey of coastal mountains in British Columbia was completed in cooperation with AES Pacific Region. Samples from remote sites show very low acidic pollutant levels, while those close to Vancouver are consistent with the samples from the CANSAP station there.

AES is integrating its air and precipitation monitoring networks into one network known as the Canadian Air and Precipitation Monitoring Network (CAPMoN), which will include the present CANSAP, APN and CAASN monitoring networks together with the stations measuring CO_2 and turbidity for the WMO monitoring program. The CANSAP stations in this network have been assessed; the network in Eastern Canada has been revised, to commence measurements on 1 April, 1983. Since 1976, when the Federal Environmental Contaminants Program was established, AES has investigated the behaviour of inorganic and organic atmospheric contaminants and their interaction with the biosphere. Several sampling stations for toxic chemical monitoring of the atmosphere in Canada have been selected and equipped with air sampling devices to become operational in 1983. An instrument that measures background levels of atmospheric mercury and its inorganic and organic forms has been developed and tested, in cooperation with the Environmental Protection Service and the National Research Council.

Research relating to oxidants continues as reported under (a) to (f) in the 1981 CGB, but also includes studies on the stratospheric injection of ozone, and the preparation of a criteria document on ozone. An ozonesonde was refined to increase its sensitivity, and then utilized in two onshore-flow experiments involving the transport or production of O_3, and potential crop damage.

The physical and chemical reactions of pollutants within clouds and rain leading to the formation of strong acids are being investigated using special instrumentation in aircraft, and air and water samples collected at ground stations. The data are being analysed to determine the contributions of HCl, HNO_3 and H_2SO_4 to the acidity of rain.

In support of the Departmental EIA program and other agencies, several reports were reviewed, dealing with the air quality and meteorological aspects of: the effect of a railway tunnel vent in British Columbia; oil spill contingency plan guidelines; risk analysis associated with the shipping and handling of liquid natural gas (LNG) on both the East and West Coasts; dust from a coal mine operation; dispersal of organic toxic chemicals; particulates and toxics from residential wood burning; a Federal Nuclear Emergency Response Plan; and dispersion models for radionuclide releases. The interactive model air quality package (AQPAC) developed for environmental emergencies was used in a Bruce Nuclear Station accident exercise. Development of the Fay and Rosenzweig analytical long-range transport model continued. It has been run on the AES AS/6 computer, using data from North American SO_2 sources, and for up to 2500 receptor locations. Model results for annual average SO_2 and SO_4 air concentrations are being compared with measured data. Results of work on diffusion in non-idealized conditions yielded a

formulation for effective stratification of plume rise and the analysis of a multi-layered Arctic inversion. A multi-axis Doppler acoustic sounder was purchased as a potential candidate for measuring boundary-layer winds and turbulence during a regional environmental emergency. Continual testing began during the Nanticoke experiment in June. A series of large-scale heavy gas releases by the U.K. Health and Safety Directorate are being sponsored, in part, by AES. The multi-year program is designed to develop knowledge about and environmental assessment capabilities for spills of denser-than-air gas, and in particular LNG. Work continued on implementing the Atmospheric Interactive Modelling System (AIMS). Initially, three point-source models and a user's guide will be available. The AQPAC (Air Quality Package) has been thoroughly tested at AES, Downsview, and used to provide advice during several emergency situations (train derailments in Orillia, Ontario and Vancouver, B.C.; Rochester New York State nuclear reactor accident; and hypothetical accident analysis for Point Lepreau, N.B.). It will be implemented in the AES regional offices for environmental assessment of emergencies.

Boundary-Layer Division staff participated in a multi-agency and multi-disciplinary study of aerial spraying of spruce budworm. Detailed data to spray height, particularly under stable conditions, indicated how complex the flow was; wing-tip generated vortices and their effects have been demonstrated to exist within the canopy. A second field experiment to study flow over an isolated hill was conducted at Kettles Hill, Alberta in February in order to evaluate the performance of a tethered balloon and kites for boundary-layer wind measurements and to test refined surface-wind instrumentation. Acquisition, processing and evaluation of data from three tall towers in the Gulf of St. Lawrence and from one in the Magdalen Islands continued for wind-power potential studies connected with the Aeolus project. Studies of boundary-layer structure over the ocean using the Storm Transfer and Response Experiment (STREX) data are continuing. Radiation and radar STREX data from 1981 are being analysed. It is expected that the albedo of and the rainfall rate over the ocean can be parameterized. A model has been developed for the exchange between the atmosphere and ocean of such gases as CO_2 and O_2, and vaporous organics, at high wind speeds. The principal forcing term, which is the extent of breaking waves, has been examined using a multi-spectral scanner on an aircraft over a wind-driven wave field on Lake Ontario. Requirements for air-sea research in support of a proposed microwave scatterometer on Radarsat have been reviewed and reported to the task force examining such a possibility. Experimental data from the Dundas Island Polynya Experiment of 1981 have been analysed. The effect of wakes and net forces produced by surface-mounted obstacles, such as wind turbines, was examined.

Work is continuing on a computer model of boundary-layer flow over small-scale three-dimensional complex terrain features. The modelling work has been closely tied to field studies at Kettles Hill and Askervein (see above) and wind-tunnel work carried out in the Meteorological Services Research Branch. An alternative model involving finite-differencing in the vertical has been evaluated under contract and shows considerable promise.

AES is involved in international intercomparisons of remote sensing technology for use in air pollution monitoring. The AES is planning for a new cooperative shoreline dispersion study to be held at Fos-Berr, France from 1 to 16 June 1983. The intercomparison will involve Lidar, COSPEC and Brewer spectrophotometer technologies.

In June, fifty scientists and technical personnel participated in the second major shoreline diffusion study at Nanticoke, Ontario, designed to assess the additional impact of two new industries in the

area; and to investigate in greater detail certain components of the meteorological conditions that give rise to shoreline atmospheric circulations. The study involved other teams from the Ontario Ministry of the Environment, Ontario Hydro, The Nanticoke Environment Management Program, The Ontario Centre for Remote Sensing, The Commission of the European Communities (represented by the Netherlands Public Health Institute), Japan Environment Agency, The U.S. Environmental Protection Agency and NASA (represented by a team from the University of South Florida and equipment from CAPITA, Washington University, St. Louis, Mo.) and Unisearch Ltd. of Toronto. Data on the turbulent characteristics of the shoreline boundary layer were obtained by use of a sonic anemometer attached to a large tethered balloon. A second tethersonde, equipment at four minisonde/airsonde stations, and four acoustic sounders were employed to map the shape of the internal boundary layer. Plume shape and concentration were mapped by helicopter, two Lidar systems, three COSPEC units and the surface monitoring network. Comparative measurements of nitric acid and PAN were also made.

The Canadian Arctic Air Pollution Program (CAAPP) is into its fourth year of operation at three sites in the Canadian High Arctic. In addition to routine measurements, the intensive aerosol study mentioned in the 1981 CGB was completed.

One small-scale field study has been completed to examine the main physical processes occurring during the release and dispersion of heavy gases, and further experimental work is planned. A heavy gas dispersion model for hazard analysis is being developed.

A feasibility study is being carried out on the detection of air pollution using satellite imagery. Detection of plumes by a "false-colour" method has been used to identify examples of long-range pollutant transport from volcanoes, forest fires, dust storms and industrial areas.

(d) Canadian Climate Centre: Established in 1981 as a joint AES/DEMR energy project, this program provides information and advice to policy makers and scientists on matters relating to atmospheric CO_2 concentration and its impact on climate and society. The program includes a new library, on-line search capability, an information sheet on CO_2 and climate, and seminars on CO_2 for scientists and policy makers. Regional quality control processing of climatological temperature and precipitation data came into full operation with a subsequent reduction in centralized quality control. Such data are now available in digitized format within two months.

Over four years of work culminated in the publication of 13 volumes of Canadian Climate Normals for the period 1951-80 on radiation, temperature, precipitation, degree-days, wind, frost and sunshine. Climatological data were supplied in response to more than 13,000 requests. Another 500 were received for magnetic tape copy or special computer statistical analyses of digital data retained in the National Climatological Archive. Approximately 7,500 pages of historical data were published in regular periodicals; and another 13,000 pages, in other publications, reports and minutes. Over 350,000 pages of climate documents were microfilmed.

The climatological network needed to monitor monthly temperature and precipitation for evaluating the water resources of the Mackenzie River Basin was assessed. Rainfall intensity-duration frequency graphs and tables were updated for 450 recording rain-gauge sites across Canada. Improvements were made in mapping weekly water-budget applications, and in mapping snow cover from satellite images using a hybrid analogue-digital image analysis and microcomputer system. A marine

statistics computer program was developed that provides tabular and graphical analysis of marine observations over the area of the North Atlantic between 40 and 160°W and north of 40°N. Water temperature maps of the Great Lakes and Scotian Shelf/Bay of Fundy area were regularly prepared bi-weekly from digital infrared satellite data. Research studies focussed on the areal determination of hydrometeorological parameters, particularly snow cover and surface temperature. In cooperation with other scientists, studies were initiated on the use of passive microwave (SMMR) and airborne gamma data and their relation to ground measurements to determine the water equivalent and depth of snow in Saskatchewan. Thermal infrared data were used to monitor surface temperatures for determining areal evaporation from natural surfaces. Two other studies commenced: to intercompare automatic climate stations for hydrometeorological data collection; and to assess sensors for use on hydrometeorological data collection platforms.

Climate applications to agriculture, solar and wind energy, industry, construction and northern development continued. New work included: determination of the trajectories over Eastern North America of ozone gas in concentrations sufficiently high to cause crop damage; study of the climate factors affecting biomass production from hybrid poplar plantations; evaluation of the usefulness of Canadian tree-ring chronologies for reconstructing past climate; assessment of climate factors that would affect the long-term storage of nuclear wastes. A publication on the Climate of Ottawa was completed; it is intended to serve as a prototype of climatologies for other Canadian cities. Work resumed on a regional study of the climate of the Yukon.

In climate prediction research, studies are under way to diagnose the circulation of the atmosphere on seasonal and annual time scales, and to evaluate several forecast tools for monthly prediction. Interannual seasonal circulation statistics of the atmosphere are to be compared with similar statistics derived from general circulation models. In support of climate monitoring research, a project has been initiated to develop objective methods of using satellite data to derive climate statistics. AES will participate in the International Satellite Cloud Climatology Project sponsored by ICSU and WMO. Initially, the research will focus mainly on the development of algorithms for determining cloud statistics, and for archiving GOES-E data (at 8-km resolution) for a period of up to five years.

A version of the Canadian multi-level General Circulation Model (GCM) was "frozen" and used for a five-year annual cycle simulation. Standard diagnostic products were obtained for each month of the annual cycle simulation, and long-term statistics and measures of the natural interannual variability of the model atmosphere were obtained. Sensitivity tests performed with the model considered the effect of a warm equatorial sea-surface temperature anomaly. Work also continued on parameterizing physical processes, including the dynamical and physical effects of cumulus convection on larger scales, and the effects of topographically generated gravity wave drag in the GCM. Numerical experiments were carried out with a two-dimensional time-dependent radiative-photochemical-transport model of the stratosphere to assess the possible effects of increased atmospheric N_2O, CFM perturbations, and solar cycle variations on stratospheric ozone and climate. Other modelling studies involved assessment of the possible influence of increased atmospheric CO_2 and stratospheric volcanic aerosols on the vertical temperature structure of the atmosphere, and on surface climate. Diagnostic analysis of atmospheric behaviour in spectral space included calculation of the stationary and transient energy budget. The resulting picture suggests that the Rhines mechanism for restricting upscale energy cascade is circumvented in the atmosphere.

The entire year of level III-b FGGE data from the European Centre for Medium Range Weather Forecasts has been archived and converted to spherical coefficients. Extensive general circulation statistics in terms of zonal wavenumber have been computed for the FGGE year; kinetic energy/available potential energy calculations in terms of zonal wavenumber and the two-dimensional wavenumber have been carried out.

The Ottawa offices of the Ice Forecasting Central, Ice Climatology and Applications Division, and Ice Research and Development Division were co-located to the Ice Centre in March, with resultant improved coordination and service output. The new international ice symbology was introduced throughout the program in 1982. Beyond the normal level of activity, additional winter-time baseline ice reconnaissance flights were made in the Arctic, and several iceberg flights were carried out in the eastern areas. Downlinking of SLAR imagery from the aircraft to ships was successfully demonstrated, including downlinking to MV ARCTIC during her November trip to Parry Channel. Work on evaluation and implementation of ice drift models and on ice chart digitization continued. Further ground-truth experiments along the St. Lawrence River in the winter and in Mould Bay in July were conducted as part of the Radarsat Program. Under contract, algorithms have been developed so that the brightness temperatures received from the passive microwave radiometer on Nimbus 7 can be converted to sea ice types and the outputs displayed and contoured for ice concentration and for separation of predominantly old ice areas from first-year ice. Holdings of historical ice information were increased during the year, and analysis of existing laser profilometer data continued. A start was made on accumulating an iceberg data base for the Newfoundland-Labrador area. Work continued on additional ice climatological publications and updating of ice atlases.

The Field Service Directorate role of providing weather information and service to the public is supported by studies that it conducts to improve its operational products and their application. Current and recent studies include: evaluation of satellite atmospheric soundings, and application of satellite images to precipitation and cloud studies; socio-economic impacts of winter storms; forecasting aircraft icing; and techniques and potential for obtaining rawindsonde data from commercial vessels crossing the North Pacific Ocean.

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Brasnett, B. 1982. A study of forced Rossby waves.

Cherna, E. 1982. Concentration of lightning, in location and time.

Keen, K.J. 1982. Radar-derived statistics of summer rainshowers.

Macpherson, S. 1982. A three-dimensional numerical simulation of a hailstorm.

Ph.D. Theses

Ibrahim, M. 1982. The effect of weak non-linearity on vertically propagating internal gravity waves in the atmosphere.

Massambani, O. 1982. Radar as a remote sensor of regions of supercooled cloud water.

Mitchell, H.L. 1982. Resonance of stationary waves in a model atmosphere.

Ritchie, C.H. 1982. Forced Rossby waves in the presence of a nonlinear critical layer.

Tsonis, A. 1982. The evaluation of extrapolation schemes for the growth or decay of rain area and applications.

Turpeinen, O. 1982. Application of a three-dimensional cloud model to the study of GATE showers.

(i) Université de Sherbrooke - Département de géographie

Lévesque, J. 1982. Essai d'utilisation de la thermographie aérienne nocturne en cartographie microclimatique: applications aux problèmes des gelées. Mémoire de M.Sc., p. 144.

VII OCEANOGRAPHY

Compiled by G.T. Needler

1. Introduction

This report consists of the separate summaries of activities of thirteen different government and university organizations. While the bulk of the work reported deals with Canada's coastal and inshore waters and the oceanic waters which surround us on the east, north, and west, Canadian oceanographers also report work on the Eurasian Basin of the Arctic Ocean, the Norwegian and Greenland Seas, the equatorial Pacific and McMurdo Sound, Antarctica. Many of the programs reported are cooperative between two or more organizations reflecting on the good degree of communication within the oceanographic community. Many of these cooperative programs are international since the science, like the water itself, knows nothing of the international boundaries which we draw on our charts. With the development of offshore oil and gas activity on the eastern seaboard and in the Arctic there is an increasing amount of oceanographic data being collected in support of this work. This work has only been reported within this compilation when it has been carried out in cooperation with one or more of the university or government organizations.

The programs reported here study phenomena with space scales from centimeters to thousands of kilometers; time scales of seconds to centuries. They concern processes occurring within the ocean itself, and at the boundaries of the ocean with the shore, the terrestrial runoff, the atmosphere, the ocean bottom and with sea and glacial ice. Not only do they include trying to understand the ocean's dynamics and thermodynamics but also the dynamics of various chemical species and dissolved gases and the dynamics of sediments. With such a large range of activities, a summary of the year's activities in oceanography is best got by reading the summaries of each Laboratory's activities.

2. Memorial University

(a) The Ice Properties Group is focused on the investigation and measurement of ice conditions, stresses, strengths, and the energy transfer from turbulent seas. A field program to test some initial ideas for the rapid measurement of the engineering properties of sea ice was mounted in February, 1982, at Pond Inlet, Baffin Island. Another series of experiments was undertaken in the Strait of Belle Isle during May.

A skywave HF Doppler radar program in collaboration with the Communications Research Centre has produced wind vector plots for the Labrador Sea and is nearing completion. The technology transfer of a U.S. designed groundwave HF Doppler radar (CODAR) for the measurement of surface currents and other ocean variables is continuing, supported by Supply and Services, Canada. HF propagation over sea ice has been examined in the Arctic. A low-cost analog video processor, for use with standard radar, has been developed for enhanced real time analysis of small targets in the presence of sea clutter and is under evaluation.

In the summer of 1982 the Seabed Group collected approximately 30 gravity cores from the southeast Baffin Island Continental Shelf. These are being examined to determine the fluctuations of the sea level in this region for the past 10,000 years.

(b) The Newfoundland Institute for Cold Ocean Science is responsible for the coordination and encouragement of basic oceanographic research within the Faculty of Science.

Of primary physical oceanographic interest are the dynamics of mixing as related to topography and the formation of bottom water in the deep holes along the southern Newfoundland coast. There are two potential sources for deep water, one from the cold but fresh Labrador Current and the other from warm but salty modified Slope Water. Physical oceanographic studies have focused on currents under ice and on the refinement of an iceberg trajectory model. The experimental physical oceanographic program emphasizes the application of acoustic remote sensing techniques to the study of internal waves and sediment transport processes. Projects include: (1) a multi-disciplinary study of the sedimentology of Arctic fjords; (2) a study of internal solitary waves in the Davis Strait; and (3) an analysis of physical oceanographic data collected in 1980 and 1981 in the vicinity of Carson Canyon on the edge of the Grand Bank. Systematic gravity mapping around the Avalon Peninsula and westward along the continental shelf has shown that terrestrial features can be traced offshore. This work contributes to an understanding of Precambrian controls on subsequent sedimentation patterns. Marine geothermal measurements on the continental shelf and slope are used to reconstruct the thermal history of offshore sedimentary sections. This allows evaluation of the maturation state with regard to petroleum potential. Geological studies of sediment transport in the near shore, and the distribution and geochemistry of ophiolites are continuing as well. These last are particularly important in understanding the nature and movements of the oceanic crust.

3. Dalhousie University

Research interests in physical oceanography cover a broad range, mainly in nearshore and continental shelf processes but with increasing interest in the open sea, particularly in ocean mixing. Graham Symonds, Tony Bowen, and David Huntley continued their investigation of the role of wave breaking in the generation of low-frequency forced waves. Theoretical ideas have been extended to consider a beach profile with an offshore sand bar. Analysis of low-frequency velocities from a barred beach on PEI shows agreement with the theoretical predictions.

Research continues on sea bed stress and sediment dynamics on the Continental Shelf. Terry Chriss and David Huntley have field tested apparatus to make detailed velocity measurements from about 1 m above the seabed down to within a few millimeters of the seabed. Liz Bedell is analyzing data from a coastal bay, to study boundary layer stresses under the combined influence of waves and currents. In deeper waters, Mike Stacey has been investigating the dynamics of turbidity currents with particular interest in the vertical structure and the role of the settling sediment. This has led to a close look

at the concept of autosuspension. Data from an extensive survey of Navy Fan off Southwestern California is being used by Tony Bowen and David Piper (BIO) to try to reconstruct the history of particular turbidity currents.

Keith Thompson has shown, using extensive meteorological and tide gauge data, how monthly mean changes in coastal sea level in the eastern Atlantic are related to changes in Sverdrup transport for the whole ocean. Thompson, Wright, and Marsden have investigated the relationships between monthly mean geostrophic winds and surface wind stress.

Barry Ruddick has been working on some practical and theoretical aspects of interpreting fine structure C.T.D. data. In September he went along as "scientific advisor" on C.S.S. Dawson cruise 82-033, in which several Batfish tow sections were taken in the frontal regions of a Gulf Stream meander. He plans to work with Andrew Bennett and Charles Tang on the data, testing ideas about interleaving at fronts.

Bechara Toulany and Chris Garrett (with Brian Petrie at BIO) are completing their study of low frequency flow fluctuations in Belle Isle Strait. Chris Garrett applied some of the ideas to the Mediterranean and has studied some problems of mixing in the ocean interior, and has also developed simple models for the prediction of the concentration of pollutants from deep-sea dump sites.

4. Bedford Institute of Oceanography

(a) Our recent work on the heat budget of arctic polynyas has been successfully completed with the publication of results. An international study of humidity flux over the open sea, HEXOS, is now planned for 1986 with appropriate pilot projects to be undertaken in advance. An in-depth review of the bulk formulae for radiation has shown unacceptably large errors to result in calculations of large-scale oceanic heat budgets such as proposed for CAGE (a CCCO-sponsored program). Additional data from weatherships have been obtained and employed to improve upon the radiation formula. We are continuing with an experimental program to develop a free drifting buoy which is capable of measuring surface wave growth at offshore locations. The existing iceberg drift model has been refined based on additional data from oil rigs. A program of sea ice dynamics and climatology for the Gulf of St. Lawrence and Labrador Coast has been initiated. This program will concentrate on identifying the physical processes important to the observed large-scale, annual, and multi-year variations in ice and iceberg volumes. Existing data on sea ice and icebergs are being edited to prepare a scientific data archive.

Our study of oceanic microstructure continues to emphasize the relationship between mixing and spectral levels. The major deep sea field program for the year was a March expedition to the Norwegian-Greenland Sea in cooperation with scientists from Scripps Institute of Oceanography. On the return trip from Europe, the Hudson completed a trans-ocean baseline hydrographic section. Analysis of Labrador Sea circulation data and the development of a diagnostic model continues. A local study in the Labrador Sea, the Polar Front Experiment, was initiated with the completion of its first field program. The long-term current monitoring program on the Labrador Shelf near Hamilton Bank continues to show significant multi-year variance and will be maintained. The analysis of data from moorings placed in the vicinity of the Gulf Stream south of Nova Scotia continues as part of a program to improve our knowledge of coherence scales and dynamics of the region. This work is conducted in association with the similar deep ocean programs of WHOI. A theoretical and analytical study of deep sea vertical profiles of geochemical tracers was initiated to provide new insights into diffusion models, a joint project with WHOI.

There are a number of programs concerned with continental shelf dynamics. The Flemish Cap experiment, a joint program with Fisheries in Newfoundland, has a reduced field program, and the data analysis is continuing. Theoretical studies of the circulation and dynamics of Georges Bank will be completed. Work on tidal rectification over submarine topography continues with a critical examination of flow observed on southwestern Scotian Shelf. A study of the occurrence of intense internal waves and solitons on the continental shelves has been expanded with additional effort given to theoretical models and the collection of experimental data. A successful field program in the Gulf of St. Lawrence is expected to provide the necessary experimental data for critical evaluation of the estuarine numerical model presently under development.

(b) A wave climate for Canadian Atlantic waters based on 11 years of visual observations has been completed including the Sable Island region, Hibernia and the Labrador Shelf. Current measurements from the Hibernia area have been examined to determine extreme currents, tides, and important forcing mechanisms for engineering applications.

Joint work with Dalhousie oceanographers has continued on the dynamics of flows in straits, using current observations from the Strait of Belle Isle that provide a basis on which to test models of the spatial and temporal structure of the flow. Deep current measurements in the Laurential Channel of the Gulf of St. Lawrence have shown variability associated with meteorological forcing. Results derived from a numerical model of the low-frequency wind-driven circulation of the Gulf are being compared to these data. Based on the Kurdistan spill, an evaluation of models used to predict oil movement in the open ocean is nearing completion. Field activities this past year have included a cooperative program with U.S. scientists to map the detailed temperature and salinity structure of a warm Gulf Stream ring using Batfish. Satellite-tracked drifters were deployed to measure the near surface circulation and satellite imagery is being used to examine the evolution of the ring over longer time scales.

The program to monitor temperature at sites of important invertebrate fisheries has continued to expand.

Data from the Scotian Shelf Break experiment have been analyzed to determine seasonal variability and the low-frequency circulations driven by wind and offshore currents. A model for the barotropic radiation of topographic Rossby waves by Gulf Stream rings has been developed and work on modelling baroclinic effects continues.

A non-linear 2-D numerical model has been used to estimate the M_2 tidal residual and seasonal wind-driven circulation in the Gulf of Maine and Bay of Fundy. Also, in conjunction with a local diagnostic model, these results have been used to interpret long-term mooring measurements off Cape Sable, Nova Scotia. Tidal rectification and longshore density and pressure gradients are the dominant driving terms for the mean and seasonal circulation. Plans are being developed for a joint fisheries and oceanographic experiment on Browns Bank that will make use of the Cape Sable array and include physical measurements on the Bank over the next two years.

(c) Anemometers and thermistor chains for long-term, unattended operation on drifting buoys are being developed. Fast CTD sensors and a dissolved oxygen sensor are being evaluated. Substantial activity continues on biological sensor development including a second generation profiling pump, an optical zooplankton sensor and a moored biological monitoring system.

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 are being developed. Acoustic positioning methodology is being used to study the behaviour of various oceanographic devices such as draglines.

Current meter mooring technology continues to be studied with the objective of increasing longevity while reducing mooring motion and cost. Methods of improving the deployment of instrument packages on electro-mechanical cables are being investigated.

Efforts to make the BIO electric rock core drill an operational research tool to 3000 m are continuing and the power transmission technology, which is a by-product, is being used in the development of a deep ocean in-situ particulate matter sampling system.

(d) The physical oceanography group in the Marine Ecology Laboratory is small but has a broad range of interests.

This spring Edward Horne and Marlon Lewis in cooperation with Neil Oakey of the Ocean Circulation Division conducted an experiment in Bedford Basin to make simultaneous measurements of the photoadaptive properties of phytoplankton and turbulence (dissipation).

Work is also continuing on ice-induced upwelling. Physical and biological data collected in a glaciated fjord in the Canadian Arctic in 1980 shows evidence for upwelling next to the ice face. In addition the nutrient data shows evidence of a downwelling region about 0.5 km farther away from the ice. This was unexpected and is currently thought to be driven by caballing.

In addition, a major cruise to Hudson Strait and Hudson Bay was undertaken in August by Ken Drinkwater in cooperation with the Chemical Oceanography Division. The object of this cruise was to study the mixing and transport mechanisms operative in Hudson Strait during the summer months since examination of limited historic data suggested that the physical mechanisms operative in the area may be important in supplying nutrients into the euphotic zone, and subsequently to enhanced production southward along the Labrador and Northeast Newfoundland Shelf.

Other research topics include (1) a study of the residual current patterns on the Canadian Atlantic continental shelf as revealed by drift bottles and sea bed drifters by Dr. Trites and (2) a study of the circulation of St. Georges Bay, which includes a numerical model, to support the biological measurements taken there.

5. Institut National de la Recherche Scientifique-Océanologie, Rimouski, Québec

Les activités du programme II: Milieu physique côtier portent principalement sur les points suivants: 1) Étude des transports sédimentaires en zones littorales et infra-littorales sous l'action des houles et des courants, formation de barres sableuses, limite d'action des vagues sur les sédiments, formation et déplacement des figures sédimentaires, stabilité des littoraux. 2) Étude des estuaires sub-boréaux, mécanismes d'évolution naturelle des estuaires sub-boréaux, évolution géomorphologique des estuaires après harnachement hydro-électrique des rivières et impact sur les avant-côtes adjacentes. 3) Étude des transports sédimentaires par traçage radio-actif. Les principaux lieux d'intervention sont présentement la Côte-Nord du golfe du Saint-Laurent et les Îles-de-la-Madeleine.

6. Centre Champlain des Sciences de la Mer, Pêches et Océans, Québec

(a) De mars à mai 1982, un projet d'étude sur l'influence des processus dynamiques sur la production primaire dans la glace et dans les eaux sous-jacentes a débuté à rivière Grande-Baleine, au sud-est de la baie d'Hudson. Ce projet se poursuivra en mars 1983 et est réalisé en collaboration avec la Division d'océanographie biologique et les universités Laval et McGill. La Division participe présentement à un programme de surveillance, ayant pour but de mesurer l'efficacité des méthodes utilisées pour changer l'eau de ballast des navires qui viennent aux Iles-de-la-Madeleine effectuer des chargements de sel. L'objectif de ce programme est de diminuer au maximum le risque de contamination des eaux côtières des Iles-de-la-Madeleine et des ressources halieutiques importantes de cette région, en vertu de la loi sur la protection de l'habitat du poisson.

(b) Les travaux sur la distribution et le comportement du mercure dans le fjord du Saguenay, l'estuaire et le golfe du Saint-Laurent se sont poursuivis. Dans le cadre de SCOPE, la Région a participé à un programme international de mesure des flux de matière organique arrivant à l'océan par les grands fleuves du monde. En septembre 1982, D. Cossa a participé à une intercalibration portant sur les méthodes de prélèvement et de dosage des éléments en traces dans l'eau de mer. Cet exercice était organisé par le Conseil international pour l'Exploration de la Mer (CIEM).

7. McGill University: Institute of Oceanography

(a) In the spring of 1982, a major field program was completed in the Great Whale region of Hudson Bay. 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.

Previously reported studies of circulation in the Eastmain River (James Bay), the St. Lawrence estuary and the Avalon Channel region were continued this past year. Emphasis was placed on analysis of existing data sets. A small field program in the Eastmain was completed this past summer.

A field program directed toward ice research in Barrow Strait (Arctic) was completed in spring 1982. Data were collected using moored and profiling current meters and a CTD and turbulence probe.

(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. GIROQ - Groupe Interuniversitaire de Recherches Océanographiques du Québec

Le GIROQ regroupe des chercheurs des universités McGill, Laval et de Montréal. En 1982 les activities du GIROQ en sciences physiques se sont déroulées dans le cadre des études menées dans l'estuaire du Saint-Laurent et dans les baies de James et d'Hudson.

(a) Estuaire 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); etude de la dynamique des fronts à petite échelle (R.G. Ingram, McGill); etude de la

variabilité de la circulation hydrodynamique dans l'Estuaire moyen supérieur (Y. Ouellet, Laval); etude des mécanismes de transport de sédiment dans la couche suprabenthique dans l'Estuaire moyen (J.P. Savard et B. d'Anglejan, McGill); etude 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 particulaire et les sediments (M. Lucotte et B. d'Anglejan, McGill).

(b) Baie de James: etude 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, S. Lepage, McGill); etude du régime sédimentaire de l'estuaire de la Rivière Eastmain (B. d'Anglejan et J. Basmadjian, McGill).

(c) Baie d'Hudson: etude 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).

9. Oceanographic Division, Bayfield Laboratory for Marine Science and Surveys (formerly Ocean Science and Surveys, Central Region)

(a) The second of a five-year multi-disciplinary oceanographic study in Barrow Strait in the Northwest Passage was undertaken in March and April 1982. Data collected on the vertical structure of currents, density, and nutrients showed that a much deeper surface mixed-layer existed as compared to previous years showing yearly variation in oceanographic properties. Numerical modelling of the flow in Barrow Strait is being carried out at the University of Waterloo. Work was completed on a two-layer numerical model of freshwater plume dispersion under an ice cover in James Bay (PhD thesis University of Waterloo), which showed that the post-project La Grande River plume would cover a much larger area of northeastern James Bay inhibiting the spring phytoplankton bloom. A year-long current meter array 100 miles northeast of Churchill on Hudson Bay provided data during the ice formation and breakup periods and a data set to examine the effect of an ice cover on tidal flow constituents. Contract work is nearing completion on a vertically one-dimensional numerical model of sea-ice growth and ablation, including an ocean mixed-layer component. Work continued on the record of internal tides in the middle estuary of the St. Lawrence River and on the dynamic estimation of water levels and transport in tidal channels. Assistance was given to the Delft Hydraulics Laboratory on the mathematics of real-time prediction of tides and storm surges in the Eastern Scheldt Estuary.

A program of study on sea-ice in relation to ocean conditions in Arctic channels and Hudson/James Bay is being developed.

(b) Ocean Technology

The geoscopically-referenced, unmanned current profiling system was repackaged to reduce weight and operated for periods of 8-10 days from the ice cover in Barrow Strait. One of two bottom-referenced, fixed orientation current meter moorings designed to operate in the vicinity of the north magnetic pole was recovered this spring.

An experiment was carried out at the Borden Peninsula radar site to investigate multi-path interference effects on the detection of low-lying ice targets. Laboratory measurements of dielectric properties of both freshwater and sea-ice have been started.

10. National Water Research Institute, Burlington

Physical limnology research at the National Water Research Institute concentrated on several areas during the past year. The physical limnology of large systems has been studied with particular emphasis on better quantitative understanding of physical processes and the development of hydro-dynamic and transport numerical models. Work has continued on the physical limnology of special lake systems such as deep fjord lakes, shallow Prairie lakes and reservoirs. The coastal and shore dynamics of nearshore waves, currents, diffusion, sediment movements, and shore evolution have been studied. Studies of air/water interaction including the generation, propagation, and dissipation of wind-waves, and interfacial transfers have continued. Specialized instrumentation for use in physical limnology and meteorology, including a vertical profiling system and systems to measure bottom stress, wind stress, and pressure gradient are being developed. The optical properties of natural waters are being investigated and models developed for the application of sensors for water quality determinations.

11. Fisheries and Oceans, Ottawa, Marine Sciences and Information Directorate

The Marine Sciences and Information Directorate carries out its national and international mandate through three branches: Ocean Sciences Affairs Branch (OSAB), Marine Environmental Data Service (MEDS), and the Scientific Information and Publications Branch (SIPB). OSAB provides a focus for various national and international matters.

MEDS is Canada's national marine data centre, archiving oceanographic data collected around Canada, including the northeast Pacific, Arctic, and northwest Atlantic oceans.

As part of the overall data management, CAMDI (Canadian Main Data Inventory) has been designed and developed. The inventory includes data holdings from the national and regional archives and tracks all oceanographic data sets of interest to Canada, whether Canadian or foreign.

12. University of British Columbia: Department of Oceanography (W.J. Emery, K. Thomson, L. Royer, L.A. Mysak, M. Ikeda, G. Mertz, G. Swaters, P.H. Leblond, J. Cherniawski, P. Cummins, S. Pond, T. Yao, A.J. Webb, W.G. Large, R. Marsden, R. Ninnis, S.E. Calvert, R. Francois, C.J. Jones, A. Losher, T.F. Pederson)

(a) The study of large-scale oceanic properties and variability has continued. An atlas of TS, SZ, and TZ curves for the North Atlantic and North Pacific oceans has been published. Multiship XBT surveys (with D. Krauel of Royal Roads) are documenting the properties of mesoscale phenomena across the North Atlantic (2 cruises between England and Halifax) and the Pacific (6 Honolulu-Esquimalt, one New Zealand-Esquimalt cruise). Two years of surface salinity data have been collected across the Strait of Georgia, from instruments mounted on B.C. Ferries; the analysis is now being extended to compare the data with the prediction of available models of the Fraser River Plume. A study of circulation in the Alaskan Gyre is continuing and five satellite-tracked buoys have now been drifting in that area for over a year. A four-layer non-linear model of baroclinic instability in a coastal current has been developed. The most rapidly growing perturbation, about 150 km in wavelength, has been successfully compared with satellite imagery from the B.C. coast. A theory of Rossby-wave-driven-mean flows along non-zonal barriers, with application to the Hawaiian ridge has been developed. The response of a three-layer model of the Somali Current to 50-day wind oscillations has been developed. Eddies produced by flow over topographic features in the Gulf of Alaska have been studied. A study of a series of satellite images of the seaward ice margin on the Labrador coast has been completed, showing presence of travelling long-period oscillations in the

Labrador Current. Infra-red and visual views of the mouth of Hudson Strait are being interpreted in terms of the circulation and of mixing processes in that area. Theoretical modelling of the circulation of a T-junction, with application to the above strait and to the mouth of Lancaster Sound is also under development. Large amplitude internal wave data from Davis Strait are being compared with theoretical models. A review of the oceanography of the Strait of Georgia has recently been completed. Three cyclesondes (internally recording profiling current meter/CTD systems) were deployed in the central Strait of Georgia from September 1981 to June 1982 (a fourth instrument was added in February 1982). They were also deployed in Observatory Inlet for 8 days in August. Observations with two instruments will be made in Indian Arm from December 1982 to May 1983. Work is in progress on interpretation.

Turbulence measurements (using an airfoil probe) from a freely falling vehicle were made in the Pacific Equatorial Region as a part of the Pacific Equatorial Ocean Dynamics Experiment and in the Kuroshio Extension Current, the first of this type to be made below 1,200 m. Development of a Laser Doppler Anemometer capable of measuring 1-D cross-stream turbulent velocity spectra continued. Work includes designing the electronics necessary for zero mean-flow measurements. Both cylinder wakes and grid turbulence are to be used to calibrate the high wave-number response of the shear probes.

(b) Studies of the geochemistry of the sediments of B.C. coastal inlets, the relationship between trace metals and organic material in anoxic fjords, trace metals in anoxic and oxic fjords, and the geochemistry of modern uncontaminated sediments, and the tailings from a molybdenum mine in Alice Arm are continuing. Studies (in collaboration with D.Z. Piper, U.S. Geological Survey and D.J. Huntley, Simon Fraser University) of the chemistry and mineralogy of ferromanganese nodules and associated sediments from two DOMES (Deep Ocean Mining Environment Study) sites in the northern tropical Pacific are continuing. A development of an α-scintillation method is being used to obtain sediment accumulation rates. Investigation continues of the geochemical behaviour of metals and halogens in marine sediments and interstitial waters in three diverse environments: (i) the Panama and Guatemala basins in the eastern equatorial Pacific Ocean, (ii) in British Columbia, Rupert Inlet, where a study of diagenesis in a marine Cu-Mo mine tailings deposit is nearing completion, (iii) Powell Lake, a meromictic former fjord containing permanently anoxic bacteria - and sulphide-rich saline water. Aspects of this work were being carried out in collaboration with Dr. C.I. Measures (M.I.T.). Geochemical variation in eastern Pacific sediments as a function of climatic change is being investigated with Dr. N.J. Shackleton (Cambridge). Analytical work is underway on a Carnegie Ridge core which record 400,000 years of continuous deposition and has excellent $\delta^{18}O$ chronostratigraphy.

13. Royal Roads Military College - Coastal Marine Science Laboratory (D.P. Krauel, F. Millinazzo, W.W. Wolfe, H.J. Duffus, J.S. Collins, M.J. Press, P.J. Schurer, W.T. MacFarlane, J.M. Gilliland, J.W. Madill)

(a) Dynamical oceanography studies are concerned with the dynamics of estuaries and harbours, with emphasis on the relative importance of various forcing mechanisms. A computer model of circulation in Sooke Harbour and Basin is being developed based on new data. Coliform data from the Royal Roads outfall have been used to refine a statistical model of dispersion from marine outfalls. A detailed study of coastal erosion in the vicinity of CFB Comox has been completed with the aid of wave hindcast models, and historical aerial photographs. Acoustic studies of pulse smearing and of near horizontal acoustic links for video data from unmanned submersibles are underway.

(b) An acoustic bottom survey has been carried out in the Victoria/Esquimalt Harbour approaches, leading to the discovery of acoustic masks, a field of sand waves, and a set of reflectors that are being cored. Ninety magnetic profiles roughly perpendicular to the seaward extension of the Leech River Fault have been obtained using a towed total-field magnetometer. The seaward extension of the fault has been defined, and several offsets in the magnetic pattern perpendicular to the fault's trend have been identified with topographic features. The fine structure of the interaction between the Leech River and Survey Mountain Fault systems, which converge off Brotchie Ledge, is under investigation. Novel anchoring techniques and bottom strengths are being studied.

(c) Lapse rate photography of the Mt. Helmcken ship control 3 cm radar screen is being used to study tidal currents and fronts, internal waves, and radar sea clutter statistics in the Strait of Juan de Fuca, using digital image analysis techniques.

14. Institute of Ocean Sciences, Sidney, B.C.

(a) A total of eight cruises along Line P and two other lines, between the West Coast and Station P were made during August 1981 through November 1982 to complement the 22 years of time-series measurements made along Line P and to determine the relationship between the water properties. Data collected in the Gulf of Alaska during 1947-1975 have revealed a well-developed, anti-cyclonic, baroclinic eddy that frequently recurs a few hundred kilometres west of Sitka, Alaska apparently as a result of atmospheric forcing and topographic interaction. Measurements of temperature and salinity taken in a 40 km triangle around Ocean Station P since 1978 are being examined. The advective velocity determined from the scalar field and the time-integrated atmospheric stress field are being compared with the results of time-dependent baroclinic adjustment theory. A study of the response of the upper ocean to extratropical storms in the North Pacific is being continued. A theoretical description of finite amplitude interactions among internal waves and geostrophic motions and of their relation to smaller scale, stably-stratified turbulence is being sought; the efficiency of mesoscale eddies in producing parapycnal transport, including effect of planetary wave propagation and of underlying topography is being examined, as is the use of decision theory in geophysical forecasting. A study of Rossby wave propagation in a barotropic atmosphere of finite equivalent depth has been completed leading to further understanding of the predictability of the atmosphere.

(b) The interpretation of data taken during the Coastal Ocean Dynamics Experiment off the West Coast of Vancouver Island has lead to studies of baroclinic and barotropic semi-diurnal tidal currents, baroclinic and barotropic models of diurnal period continental shelf waves, the temporal variability of near-inertial current oscillations and their importance to mixing, low-frequency variability of offshore currents, and the possible existence of topographic waves and seasonally-forced, baroclinic waves. Inverse techniques are being applied to diurnal shelf waves. Satellite-derived sea-surface temperatures for 1980 through 1982 are being used to delineate detailed circulation off the coast of B.C. For example, the January 1979 data indicated the presence of a jet of cool water southward, while the January 1980 data showed a well-defined warm jet northward. In cooperation with several Australian groups, the physical oceanography of the Australian continental shelf in the area of the Great Barrier Reef was compared with conditions on the B.C. shelf.

(c) Data collected on the southern Vancouver Island Continental Shelf in conjunction with the Ocean Ecologists is being analyzed using an internally consistent set of covariance functions that will facilitate

the mapping of the oceanographic fields. Moorings at five locations along the coast of B.C. should yield a description of disturbances propagating along the coast. Analysis suggests that currents off southern Vancouver Island are highly coherent with those off Crescent City, N. California, but incoherent with those off northern Vancouver Island and the Queen Charlotte Islands.

Preparations are continuing for the Australian Coastal Experiment involving scientists from IOS. The experiment is cooperative between Oregon State University and CSIRO, Cronulla. The experiment is to provide observations of freely propagating continental shelf waves in a simple linear regime and examine whether they can carry signals over any significant distance. In ocean acoustics, Doppler and correlation techniques are being explored. In Alice Arm techniques provided a detailed description of sill flows. The first tests of the echometer, a device designed for remote measurement of temperature profiles in the atmosphere, yielded accurate and continuous measurement of wind speed, and the first unambiguous use of ambient noise as a measurement of precipitation, separable by virtue of its unique spectral signature. The acoustics programme includes graduate students of the physics department at the University of Victoria. Work on ocean mixing processes has continued with an analysis of the composite spectrum of vertical shear and its relation to the boundary between waves and turbulence in a stratified fluid, direct measurements of salt fingers in the Central Waters of the North Pacific and a study of the PISCES submersible as a vehicle for small-scale turbulence measurements. The analysis of isotropy of the dissipation-scale velocity field of the space and time scales in the ocean relevant to biologists continues.

A review of the physical oceanography of fjords and analysis of shear flow instabilities in the vicinity of sills is being prepared. Field efforts shifted from Knight to Observatory Inlet and Alice Arm due to concern over mine tailing. Little relationship between local run-off and winds and the fresh water content or upper layer thickness is seen in Alice Arm and forcing of all layers seems to be from outside the fjord. The internal resonant response of Alice Arm to tidal forcing is being investigated. Intermediate water exchanges between Alberni Inlet and the adjacent coastal sea have been shown to dominate the circulation of Alberni Inlet during the winter months and are partly explained by wind-induced upwelling offshore and fluctuations in the coastal current. Deep water renewal of Alberni Inlet occurs during the summer but has not been related to forcing mechanisms.

(d) Arctic Ocean studies include the interpretation of EUBEX data collected north of Svalbard in March/April 1981, the installation of tide gauges around the edges of the Arctic Ocean Basin to monitor water height variations at long non-tidal periods in cooperation with the University of Washington and planning of a water mass experiment north of Ellesmere Island. This work will be integrated with the CESAR program. A large continuing physical oceanography program in the Canadian Arctic Archipelago emphasizes the Northwest Passage. During 1982 an intensive field program was conducted in Prince of Wales Strait, M'Clure Strait, the Sverdrup Basin, Amundsen Sound, M'Clintock Channel, Prince Regent Inlet, and Lancaster Sound. This program was coordinated with that in Barrow Strait being conducted by the Bayfield Laboratory. The interaction of the mixed layer of the Arctic Ocean with the shelf and sea ice growth continues including laboratory experiments to elucidate the convection due to sea ice growth in shelf regions. An investigation of underwater ice formation is being undertaken in McMurdo Sound, Antarctica, in cooperation with Lamont Doherty Geological Observatory.

(e) Three-dimensional model studies, in cooperation with the University of Hamburg, have reproduced gross features of the mixed tidal regime, the

tidal residual and density driven circulation, complex stratified system of straits and passages between Vancouver Island and the mainland. Velocity vectors obtained from surface drogues (2 m depths) together with concomitant boat and helicopter STD survey, are being used in the development of a buoyant spreading upper layer tidal numerical model of the Fraser river plume. Irregular triangular grid models for the Dixon Entrance, Hecate Strait, and Queen Charlotte Sound for tides and storm surges are being developed. The modelling of tides in the Bay, requested by the World Meteorological Organization, is completed. Some synoptic studies on explosive development of extra-tropical cyclones in the northeast part of the Pacific Ocean were completed.

(f) Following work on remote measurement of chlorophyll fluorescence, a fluorescence line imager is now being constructed with joint DFO and ICS (Interdepartmental Committee on Space) support. The instrument, to be ready in 1983, will be used to evaluate the possibility of chlorophyll fluorescence mapping from space. Water colour data from existing U.S. satellite and airborne equipment is being analyzed and a Canada/German field experiment provided remote and in-situ measurements of chlorophyll fluorescence in the North Sea and Baltic. An image processing system (IKONAS interactive display with OVAAC-8 and University of Miami software on a PDP 11/34) was installed at IOS in October for analysis of satellite data and is also finding use with data from numerical models and acoustic sounding.

(g) Tidal currents were measured in Queen Charlotte Sound along the edges of the banks and on the banks themselves and in Chatham Sound along the deep-sea ship approaches to Prince Rupert Harbour. Surface current observations in Strait of Georgia were completed and have been incorporated into the Current Atlas of Juan de Fuca/Strait of Georgia, to be published in 1983.

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VIII GLACIER STUDIES

Compiled by: R.M Koerner

1. Introduction

The year saw the continuing measurement of all the mass balances from as far south as the Barnes Ice Cap on central Baffin Island up to St. Patricks Bay on Northern Ellesmere.

There is a continuing shift from government to university centres. This is partly due to the loss of the glacier study programs of DRB a couple of years ago and a continuing emphasis on hydrology rather than glaciology in the Snow and Ice Division of NHRI of Environment Canada. Private companies pursuing glacier studies appear to be particularly badly hit by the present recession. The main areas of work continue to be: ice radar, glacier surging, ice core/climate studies, iceberg research and routine mass balance measurement.

2. Energy, Mines & Resources Canada - Polar Continental Shelf Project

(R.M. Koerner, D. Fisher, B. Alt, M. Parnandi, J. Bourgeois)

(a) Reduction of filter samples to slides for pollen analysis of a 100,000 year time series from the Agassiz ice cap in Northern Ellesmere was completed. The methodology of this procedure is now considered satisfactory but pertinent only to ice core/pollen studies.

An optical microscope study of the variation in morphology and mineralogy of microparticles in our ice cores was begun. Differences between type, number and size distribution of microparticles between ice deposited during the last glacial period and since have been recognized.

Studies of the relationship between oxygen isotope time series from ice cores and the glacial geology record have been undertaken. That on the Devon isotope record has been completed and the other on the Northern Ellesmere record (with J. England) should be completed in 1983. Investigations on the moisture cycle of precipitation from source to ice cap have been made to improve our understanding of the oxygen isotope climate relationship. Calculation of the lag response of a northern Ellesmere ice sheet to a change of mass balance nears completion. Synoptic analogues (developed from the study of extreme mass balance seasons) were applied to fluctuations of various parameters on a paleoclimatic time scale. Parameters such as oxygen isotopes, melt percentage, and pollen concentrations in the core were considered.

(b) Mass balance profiles on the Meighen, Melville, Devon (NW side) and Agassiz (Northern Ellesmere) ice caps were measured. Balances were more

negative than the long period mean. Down borehole photography, and borehole tilt and diameter measurements of the two surface-to-bedrock Agassiz ice cap boreholes were made. Bulk samples were collected on the top of 10 ice caps by us and by others from 3 widely separated locations on the Arctic Ocean. These samples are being analysed for pollen concentration and type. Mass balance poles set up by DRB 25 years ago were located on Gilman Glacier and remeasured.

3. Environment Canada - National Hydrology Research Institute (NHRI) (D.H. Lennox, C.S.L. Ommanney, J.W. Clarkson, G. Holdsworth, O. Mokievsky-Zubok, D.K. McKay, S. Fogarasi, J. Power)

(a) The inventory of the Stikine River basin was undertaken in 1982. Some 6,500 glaciers were inventoried and the data, including that compiled in 1981 for the Iskut River basin, keypunched; it includes the area of ice cover within 100 m elevation bands for each glacier. Bibliographies on Ellesmere Island glaciers and ice shelves and on ice islands in the Arctic Ocean were published.

(b) Mass balance measurements were continued on Peyto Glacier, Alberta, by Ottawa University students under a contract given to Prof. P.G. Johnson. These form part of an overall data collection and analysis program aimed at an improved understanding of climate-mass balance-runoff relationships.

(c) Ice core site reconnaissances were carried out on Flint Ice Cap (NWT) and icefields at the head of Donjek Glacier (YT). Shallow cores, 11-16 m deep, were obtained for stratigraphic and oxygen isotope analyses. Temperatures at 10 m depth ranged from near temperate to -6°C and total ice depths from 270-500 m.

The electro-mechanical drill has now been tested to over 200 m depth and some modifications will be made. An electro-thermal drill is being constructed for use below the firn/ice transition to core in warm ice to depths of about 450 m.

The following analyses of the Mt. Logan ice core are proceeding: oxygen isotopes by R. Krouse, University of Calgary, chemical by R. Delmas, gross β-activity by M. Pourchet, and total gas content and CO_2 content by D. Raynaud (all of CNRS, Grenoble, France).

(d) Mass balance measurements were continued on several B.C. glaciers, all showing specific negative net balances for the balance year ending in 1982. In g cm^2 y^{-1} the balances were as follows: in the Iskut River Basin, the Yuri, Alexander and Andrei Glaciers, -0.96, -1.18, -1.09 respectively; Tiedemann and Bench Glaciers, -1.33 and -0.89; Bridge River area (with S. Fogarasi), Bridge and Sykora glaciers combined balance -0.30 and Zavisha -0.52; in the S.W. Coast Mountains of B.C., Place and Helm glaciers -0.64 and -0.34. Sentinel Glacier was the only one measured with a positive balance (0.86 g cm^{-2}). However, since 1979 this glacier has retreated 24 m. Some of these studies are related to stream discharge, glacier-dammed lakes and run-off forecast models.

A site survey of Cathedral Glacier has been made for Parks Canada. The glacier causes the formation of mudslides which damage railway tracks and the Trans Canada Highway.

4. Karl E. Ricker, West Vancouver, B.C. - (W.A. Tupper, BCIT, K. Ricker, K.R. Ltd., Alpine Club of Canada)

(a) Final production of the 1:10,000 map of Wedgemount Glacier, N. Garibaldi Park, B.C. is underway with contouring at 20 m intervals on an orthophoto base. There was less ablation at the snout than usual. There

has been a very slight advance in the southern snout margins and retreat on the northern. A 10% velocity decrease suggests the recent recorded glacier advance is coming to an end. A velocity profile has been set up at the equilibrium line to enable flux calculations to be made.

(b) Snout positions of the Tchaikazan and Friendly Glaciers (Coast Mountains, B.C.), first surveyed in 1951 and 1975 respectively, were resurveyed; recession of both glaciers continues. Recent glacier advances appear restricted to maritime glaciers in contrast to substantial recession of continental-facing glaciers.

5. University of British Columbia - Department of Geophysics & Astronomy (G.K.C. Clarke, M.G. Maxwell, B.B. Narod, B.T. Prager, R.D. Russell, E.D. Waddington)

Laboratory Investigations and Field Work in Yukon Territory and Alaska

Flow and temperature modelling of Agassiz ice cap from ice core data of the Polar Continental Shelf Project is being undertaken using finite-difference and finite element methods. A fully-automated isotope analysis and data reduction system has been developed and over 400 ice samples from the Yukon and B.C. analysed. Isotopic fractionation processes due to glacier bed processes are being studied. A 1981 series of digitized radio-echo sounding results are being computer analysed using techniques adapted from seismic signal processing.

A wave-like bulge was found in Trapridge Glacier (YT) propagating down glacier at 25 m a^{-1} at the boundary between warm-based (upstream) and cold-based (downstream) ice. An airborne radio-echo sounding survey was flown over the ice-filled caldera of Mount Wrangell. Reflecting horizons were found possibly due to volcanically deposited horizons in the ice.

6. Memorial University of Newfoundland - Department of Geography (R. Rogerson)

Torngat Mountain Glaciers and Yoho Park, B.C. The 1982 summer was warm and caused a negative mass balance of about -100 g cm^{-2} for the 1981/82 balance year on the 4 cirque glaciers studied in the Torngats. Emerald Glacier in Yoho Park, B.C. advanced about 1.5 - 2 m over the 1981-1982 period.

7. Memorial University of Newfoundland - Ocean Engineering Research Group (T.R. Chari, Chairman)

Seven main research projects are being conducted by 21 researchers. These projects include the stability of icebergs, iceberg drift and its prediction, iceberg-snow model development, iceberg melting (theoretical, observational and experimental), Monte Carlo simulation of iceberg shapes and impact probabilities, and ice friction and mechanics.

8. University of Ottawa - Department of Geography (P.G. Johnson)

The long-term photographic record of changes in the Donjek Glacier terminus, Yukon Territory was continued; little change was apparent for 1982. The role of low frequency, high magnitude events in the formation of rock glaciers with a variety of trigger mechanisms is becoming apparent in the St. Elias Mountains and Ruby Range, Yukon Territory.

9. Hokkaido University and GeoTechs Inc., Japan (A. Takahashi)

Tests of a thermal drill designed by GeoTechs Inc. for use by the Japanese Antarctic ice cap Research Expedition (JARE) were made on

Southern Ellesmere Island between 13 and 17 August, 1982. Drilling terminated at 13 m depth after the cable slipped out of the drill head. The tests are considered satisfactory as they allow modifications to be made for the main drilling in the Antarctic over the Austral winter of 1983.

10. University of Calgary - Department of Geography - (M.O. Jeffries, H. Serson)

In April and May 76 m of 7.6 cm diameter ice cores were drilled from 7 locations including the Ward Hunt Ice Shelf, Ayles Fiord and the Milne Ice Shelf. These samples will be analysed for ice density, texture, fabric, chemistry and oxygen isotopes in an attempt to improve our understanding of Arctic ice shelf evolution. The mass balance networks set up in the early 1960's on Ward Hunt Ice Shelf and Island were remeasured.

11. University of Minnesota - Department of Geology and Geophysics (R. Hooke)

In early May a trilateration line set up 12 years ago by Holdsworth was resurveyed and extended 4 km further out. Present and past base lines were tied in to allow measurement of change in the ice cap profile from edge to top of South Dome over the last ten years.

12. University of Massachusetts - Department of Geology and Geography (R.S. Bradley)

In June and July mass balance measurements of a small ice cap in St. Patrick Bay begun by the Defence Research Board over 10 years ago were made and the stake network redrilled. Winter snow balance was also measured. The balance for 1981/2 was estimated to be slightly positive. Since measurements began the ice cap has shown a slight negative balance.

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IX HYDROLOGY

Compiled by: G.J. Young

1. Introduction

As in previous years, hydrological aspects of glacier studies and hydrometeorological studies are reported on separately in other sections of this volume. A bibliography has been included this year and has been limited to 1982 titles; those titles in press at the time of compilation will appear in next year's listing.

2. Federal Departments

Many federal departments have been involved in water management activities during the past year. Some of the more important are Environment Canada, Fisheries and Oceans, Regional Economic Expansion, Indian and Northern Affairs, Transport, National Health and Welfare, External Affairs, Public Works (CMHC) and Energy, Mines and Resources. Space limitations do not permit comprehensive reporting of all water related work undertaken during the past year by these departments. The principal department from the freshwater point of view is ENVIRONMENT CANADA with its Environmental Conservation Service, Environmental Protection Service and Atmospheric Environmental Service.

I. Environment Canada

(a) Inland Waters Directorate (IWD)

The IWD conducts its day to day programs under the Canada Water Act and the International Rivers 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, planning for, and participating 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 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 and the National Water Research Institute.

(i) National Hydrology Research Institute (NHRI)

NHRI is based in Ottawa with subsidiary offices in Calgary and Vancouver. Most of the research conducted by NHRI forms part of Environment Canada's Water Management Research Program. Organizationally, NHRI is made up of three Water Divisions:

a) 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 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, dynamics of ice jamming and sediment in the Liard and Mackenzie Rivers. This group also is conducting hydrologic studies of four watersheds along the proposed route of the Inuvik-Tuktoyaktuk Highway. Modelling activities include the development of a regional evaporation model and of a physically based model of water flow in snow-covered terrain, the statistical analysis of precipitation and runoff in mathematical basin models, a new method of developing baseflow recession curves, and the operational testing of a modified UBC precipitation-runoff model that takes into account the contributions made by meltwater from glacierized areas. This division also conducts a range of remote-sensing studies, including the application of gamma ray, thermal infrared and synthetic aperture radar techniques to snow-pack observation and measurement, and use of time-domain reflectometry to observe movement of a melting or freezing front through the soil. An important new initiative in 1982-83 will be in the form of a new research project on land drainage. 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.

b) 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. The Division is also heavily involved in studies of contaminant transport in subsurface waters and the geochemical controls that influence this transport; it contributes to national programs on the Long Range Transport of Airborne Pollutants and Toxic Chemicals; and it is responsible for the hydrogeological research package that forms part of the AECL-sponsored Nuclear Fuel Waste Management Program. A very important element in this last group of studies is the attempt to gain an understanding of fractured-rock systems and the possible contribution of ground water flow through fractures to migration of radionuclides away from a repository site. During 1981-82 the Division carried out the preliminary evaluation that led to recommendations for the Agricultural Land Drainage Project and will continue to contribute substantially to this project. The Division is providing expertise for field studies of streamflow losses in the Milk River system of southern Alberta and of subsurface transport of agricultural chemicals in the Osoyoos area of southern British Columbia.

The Division also undertakes reviews of the ground water aspects of environmental assessments and other operational ground water matters.

c) The Snow and Ice Division is conducting evaluations of the mass, energy and water balances for selected glaciers in the Coast Mountains; it continues to work on an inventory of Canadian glaciers, the priorities of which are now being linked to operational needs - particularly the requirement to assess the potential hazards posed by glacier-dammed lakes and surging glaciers; it conducts research into the physical properties of ice and sand-ice mixtures in order to gain a better understanding of frozen-ground phenomena in northern regions and to help in the development of a sound theoretical basis for the application of geophysical techniques in ice studies; and it has initiated a study to collect glacier ice cores for analysis for evidence of climatic changes over periods of several hundred years.

(ii) National Water Research Institute

Located at the Canada Centre for Inland Waters at Burlington, this institute has regional offices at Vancouver and Winnipeg. The following are the activities for 1982/83: survey and data activities in accordance with the Great Lakes International Surveillance Program; dissemination of surveillance data for trends, data summary, description and interpretation, including a descriptive atlas for Lake Ontario; radionuclide trends and status in the Great Lakes; calibration of hydrometric equipment; bimonthly inter-regional Quality Assurance studies (major ions and nutrients) for DOE's Water Quality Branch; Water Quality Branch specification studies for Methods Manual; Report on Trace Metals by inductively coupled argon plasma emission spectrometry; test D.O. - Temperature-Conductivity System; field test of sampler for electrochemical concentration of trace metals; bacterial water quality report for Lake Ontario; report on Legionella occurrence; identification and quantification of the important processes affecting the trophic state of lakes and streams including: field experiments in St. George, Jack and Yellow Lakes and in Canagagique Creek - development of N^{15} method for measuring nitrification rates - NH^3 model for polluted streams - report on Lake Erie N cycle - 12 field surveys in Lake Ontario - nepheloid layer in Lake Ontario - OECD eutrophication data base elevation - presence of organic contaminants established in the colloidal fraction of Lake Ontario water; dynamics of coastal wetlands for environmental impact of hydro, offshore oil and pipeline construction and as wildlife habitat; establish the relation of aquatic macrophytes to nutrient release from sediments, H_2S content in sediment mechanical harvesting, the mobilization of heavy metals, and use of herbicides; determination of the effect of urbanization on water quantity and water quality including the loading of contaminants in urban runoff; techniques to incorporate ice effects (jams, salinity, frazil) into flood level estimations; dynamics of flow and sediment transport in ice-covered and open water conditions; reliability of wave direction and height measurements using buoys; modelling and synthesis of physical and bio-chemical data for Lake Erie (GLWQA) including a report detailing hydrodynamical/nutrient/dissolved oxygen; predictive models for coastal currents and dispersion; model of vertical mass exchanges in lakes and oceans (Canadian Climate Program) including a report on coupling of an upper ocean model and atmospheric circulation model by March 1983; water quality criteria based on optical properties; identification of contaminants in the Niagara River and its tributaries and examine their transport and fate in Lake Ontario;

identification of contaminants at the Uniroyal site and examine their transport and fate in Canagagique River; for selected old and new organic contaminants, determine toxicity of fungi, algae, bacteria and fish biodegradation rates and products lipid surface layer and sediment water partition coefficients, including the conduct of laboratory tests of toxicity of chlorophenols, chlorobenzenes, PCBs to and their degradation by fungi, bacteria and algae. Work on analytical methods will include the extention of the 2, 3, 7, 8-TCDD method to other isomers, the toxaphene method, GC/HPLC comparison report and a PCB report; high resolution GC/MS techniques for toxics including the evaluation of source performance of PICI and the application of CI GC/MS; national and inter-regional quality assurance studies for persistent toxics; deterministic models of lake and watershed acidification: monitoring program for water quality (LRTAP) for the Atlantic and Quebec regions; Cation Denudation Rate Model; assessment of trace metal mobilization by acidification including the development of a dialysis technique for sampling of sediment pore water; assessment of effects of acidification on cycling of organic matter and microbial populations; LRTAP pollution history including a complete analysis of Pb-210 data, heavy metal studies report and the interpretation of diatom fossil data; quality assurance program for LRTAP; geochemical response of a specific drainage basin to acid precipitation.

(b) Water Survey of Canada - Water Management Data Program

The Water Survey of Canada, a division of the Water Resources Branch of Environment Canada is the agency responsible for the collection of water quantity data from over 2600 sites in Canada. To oversee such a large network, the Water Resources Branch has eight regional offices and employs more than 300 engineers and technicians to maintain the gauging stations and assemble the data. The regional offices of Dartmouth, Longueuil, Guelph, Winnipeg, Regina, Calgary, Yellowknife and Vancouver 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 cooperative 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 the design of reservoirs or similar structures and for water quality purposes. Companies and commissions operating hydroelectric stations also collect water data related to the operation of those 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.

(c) Atmospheric Environment Service, Hydrometeorology Division

The data collection phase and initial data analysis of the Lake Okanagan Evaporation Study were completed. The study showed the usefulness of thermal imagery for mapping lake surface temperatures and its use in estimating lake evaporation. Continuing snowfall-snowpack studies included: measurement of the water equivalent of fresh snowfall at climate stations; development of the Nipher-type shield for recording

precipitation gauges; metrication and standardization of snow samplers; and measurement of snowfall in low precipitation regions of Canada such as the Prairies and Arctic. Research studies began on the use of both active (SAR) and a passive (SMMR) microwave data for the determination of snow cover properties. An investigation began into hydrometeorological sensors for data collection platforms, portable hydrometeorological data acquisition systems and the development of standards for sensors used on such systems.

Studies continued on the drought project for the Prairies. Streamflow and meteorological data were analyzed to identify, define and rank historical droughts. A study of a statistical technique to indicate monthly precipitation trends was completed. Maps of water budget components were produced each week in near real-time for all of Canada.

Short duration rainfall intensity-duration-frequency statistics have been analyzed for 450 Canadian stations including those from automatic recording gauges in remote areas. Maps of means and standard deviations were prepared for rainfall amounts with durations of five minutes to twenty-four hours for the various regions across Canada. A probable maximum precipitation study was completed for the north western area of Newfoundland (Cat Arm River area). Analyses of twelve significant rain storms were published in the series "Storm Rainfall in Canada", for events occurring in Ontario, Quebec and the Maritime Provinces from 1968 to 1976.

Radar data from five SCEPTRE sites continue to be received and archived. Approximately 800 magnetic tapes have been quality controlled and archived to date. Analyses of rainfall accumulation and intensity have been carried out for private and other government agencies.

Satellite-derived maps of snow cover in the Saint John River Basin were provided to the New Brunswick flood forecast centre. The technique is based on the computer analysis of digital satellite data with percent snow cover given to the sub-basin level.

A grid point climatology of geostrophic winds was developed for the northwest Atlantic and comparisons made with observed surface winds. A review of the climate of the northwest Atlantic and impacts during the 1970's was prepared. Development of statistics began of the freezing spray potential based on ships observations. Water surface temperature maps of the Great Lakes and Scotian Shelf/Bay of Fundy area were prepared bi-weekly from digital infra-red satellite data.

(d) The Environmental Protection Service

This Service develops regulations for specific industrial waste discharges, administers nutrient controls, regulates production of environmental contaminants, and monitors environmental aspects of federal facilities and activities.

(e) Canadian Wildlife Service

This Service carries on activities to preserve endangered waterfowl habitat, research into effects of water-borne and other pollutants on wildlife, and research on aquatic ecology and limnology in national parks.

(f) Parks Canada

Parks Canada manages water resources of national parks, including water supply, fish protection and pollution prevention; administers ARC Agreements, including historic canals, and is presently preparing a proposal to establish a national heritage rivers protection system.

(g) Flood Damage Reduction Program

This program is carried out under agreements with the provinces. Its aim is to identify flood risk areas on maps and discourage future flood vulnerable developments in those areas. This is accomplished by formally designating the mapped areas and bringing into effect policies aimed at discouraging inappropriate development. These policies include commitments by both senior levels of government not to build or support any future flood-vulnerable developments there nor to give disaster assistance to anything constructed in the area after it has been designated. The program was initiated in 1975 and since then over 150 communities across the country have been designated.

(h) Canadian Forestry Service

This department 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. Activities in the latter three are as follows:

(i) Great Lakes Forest Research Centre

Acid rain--Twenty small catchments (12-70 ha) in the Algoma district of Ontario are being monitored for precipitation, throughfall, stemflow, forest floor percolates, soil percolates at four levels and the small leader streamflows. The purpose is to look at both terrestrial and aquatic aspects with respect to acid rain; Forest harvesting effects--Eight small catchments in the experimental lakes area near Kenora are being monitored for flow and water chemistry. The effects of forest harvesting upon these variables are being investigated.

(ii) Northern Forest Research Centre

Pilot Project--Alberta Forestry and Environment are seeking a 125-250 km^2 area in which to conduct a large scale pilot evaluation of forest cutting techniques to improve water yield in the South Saskatchewan River. Techniques researched by the CFS will be applied; Mountain Pine Beetle--this insect has attacked lodgepole pine stands in Southern Alberta. Water users in the area have expressed concern over the effects of control measures on streamflow. The Forestry Service is using the US Forest Service WRENs procedure to predict possible effects.

(iii) Pacific Forest Research Centre

Carnation Creek Project--primary work involves a slope hydrology study of soil water or groundwater behaviour processes and logging-induced changes. Field work is mostly completed and emphasis is now on data analysis and report writing. A case study of two small landslides will be undertaken this year; Fertilization--snow project--the hydrology component is being studied to determine the fate of fertilizer (mainly urea) applied on snow. This includes measurements of meteorological parameters, snow accumulation and melt, soil water and surface runoff. Plot studies in interior and coastal B.C. have been conducted with potential plans for a third study area next year; Rain-on-snow--this topic has been identified as a high priority item by B.C. forest hydrologists. The potential impact of harvesting on rain/snow peak flows is of concern to forest managers in that increased peaks could be detrimental to aquatic habitat in coastal streams where fisheries values are high. The implication is that rate-of-harvest in any given watershed could be restricted if significant flow changes are expected.

II. Agriculture Canada

A workshop was sponsored to prepare Recommendations for Research on Water in Agriculture. Some 60 specialists representing federal and provincial agencies, universities and the Department of Agriculture met for 2-1/2 days. Five programs were given highest priority and as needing much increased support: research directed to "increase water use efficiency" i.e. maximize the efficient use of existing water supply to crops by precipitation; research to improve the efficiency of delivery and use of irrigation water for crop production; research aimed at control and management of soil salinity; research on water management on wet soils; research to provide economic assessment of expanded irrigation, land drainage and dryland production.

Agriculture Canada's Regina Research Station is the centre for weed control research in Canada. Its function is to develop and improve weed control methods through research on: chemical control of weeds; transport, persistence, and metabolism of herbicides in the environment; and ecological and biological characteristics of weeds, including economics of weed control, and biological control of weeds.

The Environmental Chemistry of Herbicides Section is concerned with the study of the behaviour of herbicides in the soil, plant, air, and water components of the environment, including improvement of application techniques and exposure hazards during application. The soil aspects include: factors affecting the availability, leaching, and volatility of herbicides; and residues, degradation and persistence of herbicides in soils. The air and water components include: transport of herbicides in air, including air monitoring; residues of herbicides in irrigation and dug-out waters; and the transport of herbicides in irrigation and surface run-off waters.

Analytical technology involves the development of methods for sampling and analysis of herbicides in various components of the environment.

III. Indian Affairs and Northern Development

In the Northwest Territories the department has been monitoring peak discharges on about twenty-five small watersheds crossed by southwest NWT highways and a summary report for 1978 to 1982 activities is planned for early 1983. The collection of basic climate data (snow accumulation, summer rainfall rates and amounts, and air temperatures) continued at ten Water Survey of Canada (WSC)/DIAND hydrometric stations at remote locations across the NWT. A summary report for 1979 to 1982 is planned for early 1983. Snow surveying will continue at some thirty stations in the NWT by DIAND staff this winter. Approximately twenty are hydro-power related and are to be sampled in later winter, while ten will be sampled monthly and published along with results from Atmospheric Environment Service (AES) stations, in a monthly snow bulletin. Data from all snow courses will be used in the early summer regional fire hazard indexes for the southwestern Northwest Territories.

In the Yukon, activities include the operation of a small stream network, co-operation with the WSC and the AES in network operations, and a modelling study of Marsh Lake.

IV. Energy, Mines and Resources

Geological Survey of Canada (GSC)

The GSC is working on an airborne gamma ray snow survey of Saskatchewan as part of a US/Canada multi-stage remote sensing snow cover

experiment, and on an airborne gamma ray snow survey of Trent Severn district for Parks Canada.

V. Fisheries and Oceans

Freshwater Institute

The Institute at Winnipeg is involved in water budget studies for small precambrian basins, erosion and sedimentation in permafrost affected shorelines and in stream behaviour and aquatic habitat studies in mobile bed streams.

VI. Other Significant Water Management Activities

The governments of Canada, Alberta, Saskatchewan, British Columbia and the Yukon and Northwest Territories issued the final report on the $1.6 million, 3-year water resource study of the Mackenzie River Basin in February 1982. The aim of the study is to provide a base for the environmental assessment of the impact of future development in the basin. A report on the economic and technical feasibility of tidal power generation in the Bay of Fundy was tabled in the Nova Scotia legislature in late March 1982. The report, prepared by Shawinigan Engineering for the Nova Scotia Tidal Power Corporation suggests that a five mile tidal barrier containing 128 turbines capable of producing 4864 megawatts of power, could be built in the Minas Basin between Economy Point and Cape Tenny and could be economically feasible. Project costs in 1985 dollars are between 21 and 23 billion dollars.

The creation of Quebec's largest lake commenced in late October 1981. As part of the giant James Bay hydroelectric scheme, the Caniapiscau River was shut off to create a huge reservoir which will divert the flow from its usual course, which led towards the Bay of Ungava, into the Grand River to power the hydroelectric dams LG 2, 3, and 4 and thence into James Bay. The reservoir, to be known as Lake Caniapiscau, will take 2 years to fill and will have a surface area of 4,275 km^2 - more than twice that of Quebec's largest natural lake, lac Mistassini and 4-1/2 times the area of Lac St. Jean. A draft management plan for the Fraser River Estuary Study has been released to the public by the federal and British Columbia governments. The plan, which is designed to protect the estuary as a natural resource while recognizing development needs, is the result of a 4-year $580,000 study.

Following several extensions to the 1976 Agreement between Canada and Ontario on Great Lakes Water Quality, a new Agreement was signed in July 1982, renewing existing obligations outlined in the 1976 Agreement. The new Agreement is also directed at the control of toxic substances and pollution from sources such as urban and agricultural runoff. It formalizes a Canadian federal government grant of $65 million over a three-year period to assist in the construction of municipal sewage facilities to meet the requirements of the 1978 Canada-U.S. agreement.

3. Newfoundland

Climatological studies at the Memorial University of Newfoundland will include radar and raingauge observations of orographic rain over the N.E. Avalon Peninsula, Newfoundland. A network of fourteen autographic gauge sites will be set up in an area which includes coastlines of the Atlantic Ocean and Conception Bay as well as St. John's. The study is expected to assist in drainage system design for St. John's and district. A glacier mass balance program was initiated in summer 1981 to study four cirque glaciers south of Nachval fiord, which is within the Torngat mountains of northern Labrador. Measurements and observations will continue over several field seasons. The

Centre for Cold Oceans Resources Engineering (C-CORE) is continuing its study of sea ice. Investigations have turned to new approaches to 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. At the present time, remote sensing work at C-Core is concentrating on high frequency systems for measuring surface current and winds, with a further objective of applying this existing technology to pack ice and iceberg detection. In addition to research in the Atlantic Ocean, the Newfoundland Institute for Cold Ocean Science also conducts estuarial and land water studies as follows; a) Analyses of trophic structure according to size in a series of lakes on the Avalon Peninsula. This data is being gathered for comparison with size structure phenomena observed in other experimental lake regions. b) Primary production in the waters of the proposed Cat Arm reservoir in western Newfoundland. This work is a part of a study looking at the effects of large impoundments on fish populations, and is being done in cooperation with Newfoundland hydro. c) The response of aquatic insects and periphyton to spruce budworm spray. Studies have continued with Newfoundland and Labrador Hydro on the economic scheduling of integrated hydro and thermal power generation. The environmental aspects of peat mining operations in central Newfoundland (water balance, water quality, vegetation changes, etc.) are under investigation. A second site on the Avalon Peninsula will soon be monitored. Construction for the NRC Arctic Vessel and Marine Research Institute on the University Campus has begun.

4. Prince Edward Island

The PEI Department of Community Affairs will be undertaking a joint 5 year study with the federal DOE and the City of Charlottetown, of the water resources of the Winter River basin. The study will involve 3 main components; a 3 dimensional numerical model, isotopic geochemistry studies, and tracer tests. The capacity of present well fields, the location of future well fields, the impact of groundwater withdrawal on streamflow, and water quality protection and contaminant migration will be studied, culminating in a basin management plan. The computer data bank of information obtained from well drillers' reports is operational. Nine thousand well records are now on file and the final 2,000 records are being edited. The data is accessible by hard copy file or by interrogation through computer terminal. Data from a province wide network of 10 groundwater observation wells is being analysed, and maximum, minimum and mean monthly water levels for the ten to fifteen years of records are being calculated. Other projects include municipal landfill site selection and post disposal monitoring, and abandoned waste disposal site evaluation. Recently three sets of guidelines were approved by various government agencies; Guidelines for Small Dam Construction, Guidelines for Highway Construction, and Guidelines for Forestry Operations. These guidelines will be extremely beneficial in maintaining the water quality and fish habitat of the P.E.I. streams and rivers. Petroleum and nitrate contaminations continue to be the major groundwater contamination problems in P.E.I.

5. New Brunswick

The University of New Brunswick Department of Civil Engineering was evaluating sediment production from stream banks, studying changes in a channelized river reach with time and studying flow in laboratory and natural channel bends.

6. Nova Scotia

Under its Halifax urban watersheds program, the Technical University of Nova Scotia's Department of Civil Engineering is contributing to the development of effective methodologies for management of watersheds and lakes in urban and urbanizing areas. A study involving four major lakes and two watersheds is providing a unique opportunity to study water quality and

quantity implications in areas exposed to varying degrees of urbanization and development pressures. Studies are also underway into the hydrologic and water quality factors affecting the use of rainwater as an alternative water supply in Nova Scotia. The Department of Agricultural engineering has been evaluating, under laboratory conditions, land application of manure disposal. NSERC sponsored the construction and use of a 10' x 3' bed laboratory rainfall simulator. The air and water pollution, and economics of manure storage and disposal on site, have been studied under the project 'Environmental assessment of swine manure management in northern New Brunswick'. The Department of Applied Mathematics has been active in research on wave forces on offshore structures due to the offshore oil and gas recovery program from the sea-bed off the coast of Newfoundland and Nova Scotia. At the same time, proposed construction of the 4000 megawatt Fundy tidal project has already created a great deal of interest among scientists and engineers in eastern Canada. The Department is currently interested in the research on the extraction of hydraulic power throughout the Bay of Fundy.

7. Quebec

The Quebec Ministry of the Environment reports that real time data collection has become an indispensable operational tool and that it is moving toward the automation of all of its hydrometric and climatological stations in New Quebec. In southern Quebec the acquisition of real time data is primarily used for hydrometeorological forecasting and the daily management of hydroelectric works. The network presently consists of 110 stations, 60 of which transmit via satellite. A reexamination of the hydrometeorologic network operations in 1981 for New Quebec has resulted in modifications involving both technical and managerial aspects. The hydrometeorologic network consists of 1100 stations. The professional and technical personnel previously involved separately in hydrometric and meteorologic studies have now been combined and will undertake both atmospheric and hydrologic studies. Forty-nine hydrometric and 50 meteorologic stations will be discontinued in 1982-83. Studies during 1982 have been investigating the quality of climate and surface water data and reviewing the objectives of the program. The Environment Ministry accords much importance to the acid rain issue and attempts are being made to assess the extent of the problem in Quebec. The Meteorological Service has set up a network of 45 stations in support of studies on the impact on the water environment. The Groundwater Service has undertaken a ground water inventory on the south bank of the St. Lawrence River, to determine permeable and impermeable regions and to identify users of subsurface water within a 2000 km^2 area. A detailed hydrogeologic study has been carried out on the Farnham - St. Césaire region to evaluate groundwater availability and quality in a region of 1000 km^2. A network of 200 piezometers is being monitored for water level data, and 18 of these are monitored for groundwater quality. A groundwater pollution study was undertaken in the town of Mercier following a hydrocarbon spill of 45,000 litres. Available flow maps were prepared for hydrogeologic data.

The University of Quebec (INRS - Eau) is involved in statistical distribution for flood flow analysis, acid rain and the analysis of water quality data. The University of Quebec at Chicoutimi (UQAC) continued its research on stochastic characterization of precipitation for planning, design and operation of water resources systems. During the past year the following work has been completed: a) a proposal for a general stochastic approach to characterization of rainfall time distribution; b) the development of a probability distribution function for total amount of daily precipitation during a wet period; c) the development of a stochastic model for characterizing temporal patterns of hourly rainfall. The model can take into account some probabilistic characteristics of an actual rainfall process, e.g., persistence of rainfall occurrences and correlation structure of successive rainfall depths. A research project has been initiated to study the application of short-term flow forecasting in the optimum operation of a hydroelectric system. UQAC continued to collaborate with l'Ecole

Polytechnique on a research project entitled "Study of rainfall - runoff phenomena in the Montreal region". Hydro Quebec's Meteorology Division has been working on spring flood peaks and volume distribution, the relationship between the snowpack and snowfall, the influence of a network of meteorological stations on forecasting, and the relationship between infiltration and surface water flow. The Resource Regulation Division has been involved in filtering historical (and real time) daily inflows estimated from the water budget of single-gauge reservoirs, in determining the optimal number and location of gauges to measure storage of large reservoirs, and in determining the optimal scheduling of releases of multi-reservoir, multi-objective water resource systems. Alcan Smelters and Chemicals Ltd's Power Operations Division has been working on a hydrometeorological information system for the operational management of a hydroelectric system, on a real time daily hydrological forecasting system, on an interactive seasonal hydrological forecasting system, on a multi-site seasonal time series analysis, and on optimization models for reservoir operation. The SNC Group, Energy and Heavy Civil Works has undertaken the following activities: regional hydrology of the Sussex area flood plain, N.B.; flood study of a watershed in Melville Island (Arctic Ocean); evaluation of long-term monthly flows and flood study for the Maquatua River (James Bay); evaluation of long-term monthly flows and preliminary flood study, Ross Canyon (Yukon); hydrological study of three small watersheds near Cadillac in northwest Quebec; ice observation study to determine the maximum winter ice build-up at Muskrat Falls (Labrador) and its effects on the surroundings. R. Charbonneau of Quebec has been addressing the problems associated with the modelling of high mountain drainage with predominant snow yields, involved in mathematical simulation modelling for drainage basins, and studying the application of principal components to detect homogeneity errors in hydrometeorological time series. J.C. Rassam of Montreal has been involved in the filtering of historical and real time daily inflows estimated from the water budget of single gauge reservoirs, has been studying the optimal number and location of gauges to measure the storage of large reservoirs and has undertaken studies on the optimal scheduling of releases from multi-reservoir multi-objective water resource systems.

8. Ontario

The Ontario Ministry of the Environment moored current meters in the Toronto waterfront nearshore area of Lake Ontario to study the flow structure, dispersal properties and the upwelling phenomenon to assess the effects of municipal discharge on a nearby water intake. The Trent-Severn Waterway Authority controls flows and levels in 45 lakes, including 125 dams involving watershed areas of 18,600 km^2. Navigation, recreation and power interests involve 18 plants totalling 61,000 Kw max. capacity. New studies involve the rating of radial gates in situ and of vertical lift gates using a suspended current meter upstream of the open dam, visible and operable from the dam deck. The Halton Region Conservation Authority (HRCA) is working on the development of a computerized hydrologic data acquisition and flood warning system including streamflow and reservoir levels, precipitation, swamp levels, piezometric levels, snow densities, etc.; the development of an automated hydrologic data acquisition network; the optimization of reservoir operations; the development of a comprehensive streamflow forecast system for the HRCA watersheds; and recommendations for the design of shoreline erosion protection of Lake Ontario. The main areas of activity of the Ausable-Bayfield Conservation Authority concern soil erosion and water quality studies. Studies in progress include the Bayfield River gross soil erosion study, the assessment of potential water quality problems resulting from agricultural manure handling systems and the establishment of a water quality inventory for the Ausable River. The Niagara Peninsula Conservation Authority has conducted an environmental impact study on Shiners Creek storm drainage.

Major topics of research at McMaster University include the hydrology of snow, lake ice and permafrost, evaporation, wetland hydrology, urban

hydrology, stochastic analysis of floods, and the modelling of water quality involving biological parameters. The main thrust in the last decade concerns northern hydrology. Recognizing the fact that a large part of Canada is underlain by permafrost, the McMaster hydrologists are attempting to understand the effects of extreme and prolonged cold on various components of the hydrologic cycle. Currently, several lines of study are being actively pursued: Snow Hydrology - the Arctic snowpack is very cold and persistent, and this leads to great differences from the temperate latitude snowpacks in terms of accumulation, distribution and ablation processes. Studies are focusing upon the processes of snow metamorphism and melt, the modelling of meltwater movement through cold snowpacks, the effects of spatially uneven snow cover on basin water yield, and the floods generated by snow jams which are uniquely prevalent in the Arctic Islands. Permafrost Hydrology - the presence of frozen ground provides a cold and impermeable substrate which affects both the energy and water balances of the active layer. Research continues to determine the relative significance of surface vs subsurface flows on arctic slopes, and the evaporative and ground heat fluxes in continuous and discontinuous permafrost environments. Wetland Hydrology - while the impermeable permafrost enhances wetland formation, the movement of meltwater and rainwater helps to thaw the active layer. Research programs have been initiated in the subarctic to examine the relationship between frozen grounds and wetlands, the various components of the water balance of arctic wetlands, and the hydrologic regimes of these water-logged tundra areas. McMaster's efforts in studying the hydrology of cold regions is joined by hydrologists and climatologists in several neighbouring universities. Examples include glacier studies at the University of Toronto, and the snow and lake ice studies of Trent University. There are exchanges of ideas and information among these researchers through meetings, occasional visits and recruitment of each other's students. Other projects at McMaster concern the statistical analysis of high flows in Western Canada and stormwater modelling. A major component of Trent University's graduate facility is the Watershed Ecosystems Program which takes advantage of the university's location on the Kawartha Lakes and on the Trent Waterway to develop, in Geography and Biology students, an interdisciplinary specialisation in water. The main thrusts of the program have been in small basin hydrograph studies in rural and urban environments and in studies of snow and ice in lake and land situations. The University of Toronto has been involved in hydroclimatological processes in wetlands, specifically the Beverly Swamp and the Holland Marsh. The main areas of interest concern evaporation and the soil water budget. New ventures will focus upon the influence of vegetation and water movement in the unsaturated zone. The University of Western Ontario is involved in the assessment of regional flood frequency analysis in Ontario, basic studies of overflow and underflow currents in shallow water, and in analytical and physical modelling of heated discharge in shallow receiving water. Queen's University has been active in real time flood forecasting using combined stochastic deterministic models, in urban runoff quantity and quality simulation, and in the development of urban design storms. Laurentian University's Department of Systems Design Engineering is involved in forecasting geophysical time series, the identification of stochastic models to fit hydrological time series, modelling seasonal environmental time series with many missing data points, stochastic modelling in reservoir operation, and in intervention analysis. Ottawa University's Geography Department has been studying hydrologic processes associated with the formation of seasonal frost mounds in the interior Northern Yukon, with particular interest in pressures associated with mound formation, and glacier hydrology formation, and glacier hydrology studies have concerned suspended sediment and solute load discharge variations of Peyto Glacier, Alberta. The University of Waterloo's Department of Systems Design has been involved in the forecasting of monthly river flows, transfer-function modelling and intervention analysis.

The Niagara Falls office of Acres Consulting Services undertook the following Canadian hydrologic activities during 1981-82: Northwest Territories Water Resources Study Update - regional hydrology analyses -

update of earlier (1976) Acres study. Keating Channel Environmental Assessment - flood frequency analysis for an urbanizing watershed. Muskoka River Watershed Study - development of techniques for estimating future time period net basin runoff for input to a basin operation model. Little Jackfish Hydroelectric Project, Ontario - (1982-83) probable maximum flood studies. M.M. Dillon Ltd. of Toronto has been involved in storm water management, urban hydrology, erosion control and flood studies. Kresin Engineering and Planning Ltd. of Sault Ste. Marie has undertaken hydrological assessments of the Magpie River in the Algoma district and the Blanche River in the Temiskaming district.

9. Manitoba

In Manitoba, work is progressing on Phase one of the five year Agreement Respecting Flood Forecasting which was signed on March 31, 1981 by the governments of Canada and Manitoba. A review of numerous runoff simulation models is being conducted by the Water Resources Branch to determine which would be most applicable to runoff forecasting in Manitoba. Four devices for collecting and transmitting real-time hydrometric and precipitation data have been purchased and will be installed this summer. Two of these devices are satellite data collection platforms and two are land line DATS devices.

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.

Experimental Watersheds - An intensive program of monitoring a variety of meteorological and hydrological parameters in the 22 km^2 headwaters of Wilson Creek in western Manitoba was terminated in September, 1982. The program had been initiated in 1958 and over the 25 year study period much research has been done using the collected data. The primary purpose of the study was to determine the effect of escarpmental runoff on flooding, silting and erosion of the agricultural lands below the escarpment and to determine what steps could be taken to alleviate the problems. Two erosion control weirs have been constructed on the Creek at the base of the escarpment in an effort to trap sediment during major runoff events. The channel above and below each structure will be surveyed annually to determine the effectiveness of such structures.

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. Investigations underway are aimed at developing adequate aquifer monitoring installations in a surficial sand and gravel aquifer and establishing a transfer mechanism from a surface water course to the aquifer.

A relief well system to reduce the pressure in confined aquifers where agricultural drainage systems are adversely affected by excessive discharge of groundwater in the form of springs and blowouts in the bottom of drainage channels, has been put in place on the Ross Creek Drain just north of Winnipeg, and another is under construction on the south Lateral Drain southeast of Winnipeg. The Ross Creek relief well system has been in operation for two years and has functioned very satisfactorily.

Investigations are also underway to assess the feasibility of controlling groundwater levels in unconfined surficial sand aquifers using a combination of buried tile and open channel drains. A major concern in the development of

drainage systems for wet sandy soil is the depletion of the water supply capability of the aquifers.

P.F.R.A. 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.

The University of Manitoba, Department of Civil Engineering, in co-operation with the Water Survey of Canada, has undertaken a statistical analysis of existing hydrometric networks to determine criteria for future network design, especially in the North. The Department has also investigated rainfall events along the Manitoba Escarpment and on Wilson Creek experimental watershed in particular, applied the Sacramento Watershed Model to Wilson Creek watershed to investigate parameter sensitivity, investigated the variation of flood level with urbanization, and investigated the distribution of flood peaks on the Red River.

10. Saskatchewan

Saskatchewan Environment reports that Phase I of the Drought Proofing studies under the Can/Sask Interim Subsidiary Agreement on Water (SAW) are going well and are scheduled to be completed by the end of 1982. A 2-year extension to SAW has been requested and has so far been approved by the province. The Phase I report of the Regina - Moose Jaw Water Supply Study consisting of the compilation of existing information, the identification and evaluation of a range of alternatives and the selection of preferred systems was released February 26, 1982. Phase II of the work will extend to 1984 and consist of a detailed evaluation of the alternatives selected from Phase I. The study will conclude with the selection and recommendation of a long-term water supply system. Personnel from each of the member agencies of the Prairie Provinces Water Board met on February 9, 10 and 11, 1982 in Lloydminister, Alberta to exchange ideas on current practices and problems in hydrological analysis related to assessing impact of agricultural drainage, determining evaporation and evapotranspiration, generating historical streamflow data and determining the role of snow accumulation and snowmelt in streamflow forecasting. The Canada-Saskatchewan Consultative Committee on Water met on March 10 to discuss interprovincial basin activities, federal-provincial initiatives, international basin activities and monitoring programs. Proposed terms of reference for a study of Battle and Lodge Creek basins are under study by a PFRA/DOE(IWD)/Sask. Env. task force. The PPWB Committee on Water Demand is preparing a report for publishing in late 1982. The report documents historical and current water uses in the Saskatchewan - Nelson Basin.

The University of Saskatchewan Department of Agricultural Engineering commenced work on two research projects: ground water recharge, and the monitoring of the effect on the ground water hydrological regime and soil salinity alterations of irrigation with groundwater. The Department of Geography has been involved in the statistical analysis of flood characteristics using both annual flood and partial duration series. Magnitude, timing and duration of high flow events have been successfully modelled in British Columbia and Northern Ontario. The Department of Civil Engineering has been studying the influence of agricultural practices on prairie-parkland hydrologic response, has been modelling saturated flow at the base of a snowpack, and has studied local erosion around bridge piers.

11. Alberta

Alberta Environment reports that the use of hydrological models to estimate runoff from ungauged basins is a continuing area of interest. The Hydrology Branch of the Department evaluated the applicability of the model HYMO for a selected basin in the Peace River region of Alberta and intends to do the same thing for several other basins throughout the Province. A computer model has been developed for using multiple outflow rating curves in studies of lake regulation schemes. The continuing question of how to select the most appropriate statistical technique for analyses of floods is being thoroughly investigated - current studies should lead to an objective mathematical method for making a selection from the several alternatives. A method for calculating lake evaporation developed by F. Morton has been applied at 23 locations in Alberta to develop monthly evaporation estimates for the period 1912 to 1980. A method for evaluating the variation in effective drainage area, based upon the use of Morton's mathematical model for determining aerial evapotranspiration to determine the storage conditions of the basin, has been developed for a research basin in Alberta and the expectation is that this method can be extended to other basins. The Earth Sciences Division is undertaking a seismic study in the Cold Lake area to establish background seismicity levels and determine the influence, if any, of in situ oil recovery. This study, in cooperation with the Geophysical Department of the University of Alberta, was started in 1981 and will continue until 1986. A study of the influence of wastewater injection in Alberta on groundwater in both Saskatchewan and Alberta is being conducted by a consultant in cooperation with Alberta Environment and the Saskatchewan Government. The study will make recommendations for monitoring of injections and will identify possible influences of injection in Alberta. A bibliography of all Alberta groundwater reports available to the general public, has been completed and will be ready for distribution September 1982. Over 3,000 reports have been included in the bibliography and are sorted by author and map sheet. The use of melt rates calculated from snow pillow data has been found to consistently give better results than that obtained from other methods. The Alberta River Forecast Centre uses this information in conjunction with the SSARR computer hydrologic model for real time forecasting. Data collection platforms operating on the GOES system have proven to be very successful in the collection and transmission of hydrologic data from remote areas for use in flow forecasting. In 1981, 98.7% of all expected data was actually received by the Alberta River Forecast Centre. Twelve DCP's are currently operating and 22 will be operating as of fall 1982. At the Alberta Research Council work is continuing on the development and testing of the data processing routines required to convert information gathered by weather radar into a readily useable form of precipitation data. Final testing of this system and the transfer of the system to the Alberta River Forecast Centre will take place by fall 1983. Moneco Consultants Limited of Calgary have been involved in flood risk mapping, flood studies for mine and reservoirs, a drought study, environmental impact assessments and water resources evaluation.

12. British Columbia

The B.C. Ministry of Environment continued activities on the regionalization of peak flows with a view to developing a procedure for estimating extreme peak flows from ungauged watersheds. Strategic plans are being developed outlining management priorities for environmental resources. This involves hydrologic input such as estimates of peak and low flows for various return periods for gauged and ungauged sites and a review of B.C.'s hydrometric network. An in-depth hydrometric network review and planning project was completed for the Okanagan Basin. Estimates of dependable water supply for various drought durations and return periods are routinely provided for irrigation projects. A new procedure has been developed which analyses hydrologic time-series and generates synthetic runoff sequences which are

routed through the system of storages and diversions. Under the Dam Safety Program the adequacy of spillway capacity and of existing dams was investigated and flood inundation studies were undertaken using the National Weather Service DAMBRK computer program. A future activity will concern probable maximum precipitation for small and medium drainage basins. J. Keng of the Research Station at Agassiz is involved in geohydrological studies in the Fraser Valley, soil hydrological properties as affected by cultivation and drainage, and ground water table measurement and prediction. The Kamloops Forest Region has developed a 5 year hydrology research program (82-87). The Upper Penticton Creek Experimental Watershed Study has been initiated to evaluate the effects of logging on annual water yield, peak and low flows and nutrient and sediment concentrations. The Pacific Forest Research Centre was involved in the investigation of the effects of forest harvesting on the hydrologic regime at Carnation Creek experimental watershed, the monitoring of snowmelt and soil water as part of a study into the fate of urea fertilizer applied on snow, and in a preliminary study of the differences between rain-on-snow runoff from a forested and an open area on Vancouver Island. The University of British Columbia Faculty of Forestry undertook research into snowmelt in coastal B.C. during rain-on-snow events, investigated the effects of logging in the Nelson B.C. area using isotopes of oxygen to determine the separation of ground and surface waters, continued with its work at Garrison Creek experimental watershed to determine the effects of logging in Vancouver municipal catchments, and prepared recommendations for forest harvesting to protect the water quantity and quality on the Graystokes Plateau near Kelowna, B.C. The UBC Department of Geography is continuing its field studies on the long term response of rivers to hydrologic regime changes; undertook a field study on the effects on river channel morphology of logging practices in the Queen Charlotte Islands (as a contribution to the fed./prov. Fish/Forestry Interaction Program); identified runoff and solute sources in alpine basins; estimated nutrient load in the Okanagan Valley; designed data collection and monitoring networks to evaluate point source contamination of groundwater; studied coupled heat flow - fluid flow in groundwater basins, stochastic modelling of mass transport in fractured rock, fractured rock hydrology of Cascade geothermal systems, and continued research on the seepage face prediction on heterogenous hillslopes and on time-space tradeoffs in rainfall-runoff models. The Bio-Resource Engineering Department is studying the effects of precipitation and evapotranspiration on groundwater fluctuations on agricultural lands with and without drainage systems; is using field data to verify the predicted water table positions generated from a hydrologic water balance computer drainage model; and has investigated the impact of agriculture drainage on the peak runoff of a watershed and on watershed hydrology in general. The Department of Civil Engineering was involved in the evaluation of SCEPTRE precipitation radar data, the design of monitoring networks, the development of environmental sensors and data logging instruments and the optimization of the operation of hydroelectric systems. An annual informal meeting between B.C. and University of Washington hydrologists was held in March. The success of these meetings suggests that such should perhaps be determinedly pursued in other sectors of the hydrological community. B.C. Hydro sponsored a Simon Fraser University study into the detection of snowpack ripeness by means of spectral analysis using light aircraft equipped with small format cameras. B.C. Hydro and the National Hydrology Research Institute incorporated glacier runoff into the operational runoff model FLOCAST. Kerr, Priestman and Associates of Vancouver are involved in drainage studies for Victoria and North Cowichan and hydrologic studies associated with Quinsam Coal operations. Klohn Leonoff Ltd. of Richmond, B.C. were involved in probable maximum precipitation and probable maximum flood studies, hydrologic modelling for spillway design floods and diversion flows, baseline hydrologic data collection and analysis of mine drainage and sedimentation ponds, snow and sedimentation studies on the Thompson River, and hydrology studies to evaluate small hydroelectric power potential. I. Hutchinson of Colorado undertook a water balance study for mill tailings impoundment on Queen Charlotte Islands.

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Projet assainissement diagnose du lac des Sables (ND-03599)
Projet assainissement diagnose du lac Gale (ND-03600)
Projet assainissement diagnose du lac Brome (ND-03601)
Projet assainissement diagnose du lac Bromont (ND-03602)
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Projet assainissement diagnose du lac Saint Charles (ND-03607)
Projet assainissement diagnose du lac Selby (ND-03605)
Projet assainissement diagnose du lac Trousers (ND-03606)
Projet assainissement diagnose du lac Aylmer (ND-03617)
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Rapport de la diagnose écologique - lac Arcand (ND-03626)
Rapport de la diagnose écologique - lac des Trente et un Milles (ND-03627)

Abbreviations:
CCIW - Canada Centre for Inland Waters
NHRI - National Hydrology Research Institute
NWRI - National Water Research Institute
IWD - Inland Waters Directorate

CHS:82 - Proceedings of the Canadian Hydrology Symposium '82, Hydrological Processes of Forested Areas, NRCC, Fredericton, N.B.

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X MINING GEOPHYSICS

Compiled by: Norman R. Paterson

1. Introduction

Thirty organizations reported research in mining geophysics in 1982. Several more indicated that they were doing research but did not have time to complete a report. Relatively few of those reporting were able to indicate

either man-years or dollar expenditures. The following estimates are derived partly by extrapolation and partly on the basis of telephone conversations with research managers.

Despite drastically reduced business revenues in 1982, industry appears to have increased its research effort by almost 100 per cent over 1981. The number of scientist-years increased from 110 to an estimated 198. Expenditure rose from approximately $4.0 million to an estimated $7.9 million, of which $4.0 million was spent by three companies: Scintrex, Huntec and Phoenix Geophysics. Geoterrex and Questor Surveys reported in excess of $700,000 each.

Approximately $1.0 million of the industry-reported funding came from the ETDF program of the Ontario Ministry of Natural Resources. Presumably an equivalent or greater sum was the result of federal government funding. Substantial funding in 1982 came from senior mining and petroleum companies, particularly in the areas of induced polarization and electromagnetics.

Level of effort in the government and university sectors cannot be estimated reliably but appears to be roughly the same as in 1981. IREM-MERI/ Ecole Polytechnique, in conjunction with the University of Montreal and McGill University, reported 14 scientist-years and $500,000 in mining geophysics research, including subcontracts.

Unlike 1981, funding agencies were flooded with applications and a number of worthwhile projects had to be postponed. Undoubtedly this is a direct result of the decrease in industrial activity.

Effort in 1982 seems to have been about evenly divided between new field apparatus/methods, on the one hand, and improved processing and interpretation hardware/software on the other. The trend is accelerating toward increased use of microcomputers in field (and post-field) processing and interpretation of data. Two successful workshops were held in 1982 on this subject.

INDUSTRY

2. Barringer Magenta Limited, Rexdale, Ontario

Development of the COTRAN airborne EM system continued throughout 1982. Final development stages included airborne surveys over the Cavendish and other areas in southern Ontario. Emphasis has been placed on testing hardware and software improvements, monitoring system reliability under routine operating conditions and the development of transfer functions to improve the data processing algorithm. A major post-time software breakthrough has been achieved enabling removal of the primary field with high accuracy, removal of aircraft transient field, effects of topography and altitude changes.

Development also continued on the TIVAC system for oil and gas exploration. This project, carried out in conjunction with the National Research Council, PetroCanada Exploration Inc. and Barringer has resulted in the successful testing of a ground prototype of the system.

Investigation was initiated into the application of light reflectance in the visible and near infrared range to mineral exploration using the Barringer Hand Held Radiometer (HHRR) and Reflectance Spectrometer (REFSPEC). Studies included an examination of hydrothermal alteration patterns associated with gold mineralization at the Kerr Addison mine and several gold prospects in Ontario. Research continues into the application of this methodology in exploration for uranium and oil-gas deposits. The company employed a full-time research staff of 23, including 12 geoscientists.

3. Dighem Limited, Toronto, Ontario

Design and construction work were carried out on the DIGHEM helicopter EM system comprising: a coaxial coil-pair operating at 900 Hz; a coplanar coil-pair operating at 900 Hz; and a coplanar coil-pair operating at 7200 Hz. A staff of six people was employed on these and other activities, led by D.C. Fraser.

4. Exploranium/Geometrics, EG & G Canada Ltd., Toronto, Ontario

All research reported by this organization appears to have been carried out by the US parent.

5. GEM Systems, Inc., Toronto, Ontario (I. Hrvoic, J. Myzyk, M. Bloore, P. Halbersma, V. Odorcic)

GEM Systems, Inc., of Toronto have completed the development of a high sensitivity airborne Overhauser magnetometer for the Geological Survey of Canada. Ground tests of two prototypes have shown a resolution of $\pm$0.01 nT for 1 sec. reading intervals. The magnetometers generate a steady proton precession signal via the Overhauser effect. Precession frequency is measured by either a commercially available counter or a 16 bit computer. The development continues with major goals of integrating the frequency determining computer with the basic magnetometer. Over $100,000 was spent on this development in 1982.

Two versions of intelligent portable proton magnetometers (classical and Overhauser) have been under development in co-operation with Lamontagne Geophysics of Toronto. The Overhauser high sensitivity (0.1 nT) magnetometer Model GSM-10 is being supported by an ETDF grant of the Ontario Ministry of Natural Resources. Programming is now in final stages. Nearly $100,000 has been spent on these developments. A solar powered 1 or 0.5 nT Overhauser magnetometer Model GSM-9 was completed in 1982. The development cost is about $20,000. Budget for 1983 is likely to be lower than for 1982.

6. Geophysical Surveys Inc., Parc Jean-Talon Nord, Québec

The company, in conjunction with IREM-MERI, developed a portable instrument which is capable of recording the total magnetic field and the VLF-EM field simultaneously from three stations. The data are automatically recorded on an analogue chart and a mini-cassette at the time or distance interval chosen by the operator.

7. Geotech Ltd., Markham, Ontario

Development work was completed on the EMEX-1, the first commercial four frequency helicopter EM system. The system consists of: 380 and 870 Hz coplanar coil pairs, and 918 and 5000 Hz coaxial coil pairs. Extensive model studies were carried out at the University of Toronto's scale modelling facility. The work was supported by an ETDF grant of the Ontario Ministry of Natural Resources.

8. Geoterrex Limited, Ottawa, Ontario (S. Thomson, M. O'Connell, A. Jackson, J. van Gulik, B. Bolivar, P. Millette, D. Wagg, W. Finney, T. Whiting)

Work continued on the development of forward interpretation routines for ground transient EM using data acquired from the Alfred/Hawkesbury test site near Ottawa for layered earth EM sounding data. Notably these routines will be resident on either the in-house Perkin Elmer computer or the Lamontagne field computer. Inversion routines for simple layered earth models have also been completed. In cooperation with Barringer Research and Société National Elf-Aquitaine (Production) the company continued its contribution toward development of the interpretation of the Cotran data, in addition to supplying

the airborne platform. Substantial work was carried out during 1982 on development of automatic inversion routines for layered earth and vertical plate model data for airborne transient EM. In addition considerable forward modelling has been performed resulting in a better understanding of the INPUT system response under particularly demanding geological conditions.

New digital surface approximation techniques are being used in conjunction with the "prism" technique of gravity terrain correction to provide more consistent automatic terrain corrections. Research has been carried out to determine the time dependent behaviour of the Inertial Navigation System. Closely controlled flight testing followed by computer analysis has yielded a predictive solution to the "Schuler frequency effect".

During 1982, 20 scientists were involved in development projects with a 1982 R&D budget of $720,000.

9. Huntec ('70) Limited, Scarborough, Ontario

Under leadership of Engineering Manager Jack Dodds, work continued on the development of GeoPort, a portable geophysical computer which incorporates data management software. This software is a numerical data base system with general input/output, editing, processing and graphic capabilities. It is designed to aid data reduction and interpretation for IP, EM, gravity, magnetic and other geophysical surveys. Development was supported by an ETDF grant from the Ontario Ministry of Natural Resources. The company also undertook limited development of a new line of microprocessor-based induced polarization equipment. Mapping tools developed through the Seabed 2 Program (see Engineering Geophysics section) will be applicable to ocean mining.

Huntec employs a full-time R&D staff of approximately 30.

10. Instrumentation GDD Inc., Ste-Foy, Québec

A new version of the company's electronic level was developed, incorporating internal computer-checks of instrument performance and data integrity. Improvements were made in the Beep Carpet method of locating conductive boulders. Towed by a vehicle or horse this instrument has located, on the average, one conductive boulder every 10 km. Improvements in sensitivity are expected to increase this figure to one boulder every 1 km.

11. Kenting Earth Sciences Limited, Ottawa, Ontario (J. Irvine, O. Cepella, R. Coates, B. Berrigan, J. Wilson)

Development work continued on a twin-boom airborne magnetic gradiometer, under a contract with the Ontario Ministry of Natural Resources. During the year the sensing head orientation system and software-controlled Larmor frequency counter were completed. Software development, testing and evaluation of a new doppler system by Canadian Marconi were carried out. New compilation and interpretation methods for magnetic gradient data have been developed.

12. Lamontagne Geophysics Ltd., Toronto, Ontario (Y. Lamontagne, A. Wieckowski, R. Cockburn, L. Hrvoic, A. McNae)

Work continued on scale model and mainframe computer model studies and compilation, and development of software for field interpretation of EM data (quasi-plate, thin sheet, half space, layered earth models). Inversion routines to be used with surface and/or borehole data are under study. Research in field-portable micro-computers was conducted. With recent advances in computing technology, such as single board array processors, it appears feasible to place mainframe computing power in the field economically.

A borehole UTEM system is being developed using fibre optic data link technology to achieve backpackable portability with 2 km depth capability and eliminate all potential ground loop and pickup problems associated with long conductive wires. To further increase signal/noise, research is underway on an 800V at 16A/400v at 32A transmitter. Prewhitening research has led to signal to noise improvements from 3:1 to 6:1 without any increase in transmitter power. Microprocessor reprogramming permitted operation of up to 32 selectable time channels for sounding applications.

In conjunction with GEM Systems, Inc. an intelligent, fully labelled, lightweight magnetometer is being developed to enable memory use by virtually any operator.

During 1982, Lamontagne Geophysics employed 5 (full time equivalent) staff on research.

13. Phoenix Geophysics Limited, Toronto, Ontario (J. Klein, P. Hallof, J. Sevenhuysen)

The main research effort has been on a major, industry-sponsored project to evaluate the use of spectral IP for hydrocarbon exploration. The results of Phase 1 (1981-1982) have been encouraging. Field studies have revealed a significant percentage of fields with genuine anomalous response. Theoretical studies have allowed prediction of the complete spectral response of multiple well casings. Drilling has provided an indication of the source of the observed anomalies, which appears to be related to geochemical alteration in the rocks overlying the hydrocarbons. Phase II (1983) will concentrate heavily on the geochemical aspects and origins of the anomalies, with additional field surveys being used to clearly define drilling targets.

A project, partially funded by the Ontario Ministry of Natural Resources, is directed towards defining the electrical properties of various types of metallic mineralization in the Province of Ontario. A large number of spectral IP measurements have been made, using the IPV-3 6-channel receiver, in graphite, magnetite, nickel sulphide and massive sulphide mineralization. In nearly every case the observed volume percent and texture appear to be properties which most effect the response. Geologic descriptions for the various test sites are being prepared under the direction of R. Hutchinson at the University of Western Ontario.

An ongoing industry-sponsored project was carried out to further develop the spectral IP technique. In 1982, this project concentrated mainly on field surveys and tests. Broad-band measurements were completed over a massive sulfide body in California. Surveys were made in the basin-and-range province of the U.S., using a newly developed 100KW transmitter, and measurements were made in sites in a lead mine in Missouri. An additional component of this project has been development of a medium power (15KW) high frequency (4096 Hz) transmitter.

Approximately $1,294,000 was spent on research in 1982.

14. Paterson, Grant & Watson Limited, Toronto, Ontario (N. Paterson, S.W. Reford, F.S. Grant, I. MacLeod, P. Walker, J. Pannar)

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.N. Edwards (University of Toronto) a fast two-layer, 1-D inversion method was developed for multi-channel airborne EM. The program, using eigenvector decomposition, provides a continuous measure of both goodness-of-fit and how well each of the earth parameters is determined by the EM data. The program has been used successfully on more than 3000 line km of helicopter EM data. Interpretation

aids for vertical magnetic gradient data were developed. The company's MAGMOD model-fitting program was extended to include vertical gradient data for 2-, 2 1/2- and 3-D bodies. Work was carried out on a space domain susceptibility mapping program which allows a different value of depth to be assigned to each grid point. With this technique it will be possible to generate high-resolution, accurate maps of basement susceptibility under a transparent surface layer from a drape-flown airborne survey using either total field or vertical gradient data. It will also permit the field, or any of its derivatives, to be computed at any level, plane or irregular, above the magnetic sources. In conjunction with V. Gupta and others of the Ontario Geological Survey, a space domain gravity inversion program was developed for obtaining depth to a density interface beneath a layer whose density is allowed to vary laterally.

15. Questor Surveys Limited, Mississauga, Ontario (J. Lazenby, T. Peacock, H. Jantsch)

After two years of development work the company succeeded in adapting its Mark VI fixed wing INPUT system to rotary-wing (helicopter) operation. This development was completed in the first half of the year, and the equipment has now seen six months of commercial survey use. The design and installation of a large moment (about 2.5 x 10^5 MKS peak) "button-on" transmitter loop was successfully certified for a Bell 205 helicopter and final field tests were successfully carried out over a number of known conductors. Because the new system has a higher power transmitter and uses a wider (2 ms.) primary pulse than its fixed wing counterpart it exhibits a very high signal to noise ratio while taking advantage of the unique adaptability of a helicopter system to rugged terrain which cannot be mastered by conventional aircraft. The helicopter coil configuration is of necessity different from that normally employed. Here the vertical axis receiver is close coupled to the transmitter at the end of a 250-foot cable. The resulting anomalies show a high degree of resolution between adjacent conductors and an improved sensitivity to conductor dip.

Using its own high sensitivity helium vapour magnetometers Questor Surveys has developed a high performance aeromagnetic gradiometer. This instrument consists of two magnetometers mounted vertically one above the other on a nose boom extension adapted to a Britten-Norman Trislander aircraft. The vertical separation between the two total field magnetometers is 3.05 m (10 feet), resulting in an unprecedented basic sensitivity of about five milligammas/m. This equipment has been successfully tested in Saskatchewan. At this time over 10,000 line km of data are being compiled in preparation for interpretation.

In order to improve on the quality of its airborne electromagnetic survey capabilities the company initiated, in 1980, a program of fundamental research on AEM principles and practice. A DC-3 aircraft was fully dedicated to this program to obtain the required experimental data. The aircraft is equipped with a large loop, a high power pulse transmitter and an auxiliary power unit. This equipment is capable of providing a peak dipole moment of 4 x 10^5 MKS. The aircraft is also equipped with a hatch that permits in-flight experimentation with the towed receiver unit. Signals are digitally recorded on magnetic tape via a microprocessor-controlled high speed data acquisition unit. To date much useful information has been gained on noise sources in AEM instrumentation as well as on the effects of coil configuration on system response.

16. Scintrex Limited, Concord, Ontario

During 1982, Scintrex carried out development of geophysical methodology and instrumentation in the following technical areas: a) Use of time and spectral resolved mineral photoluminescence (Luminex) as an airborne and ground method for exploration for a variety of deposits of tungsten, tin,

molybdenum, gold and zinc, etc.; b) Development of handheld instrumentation for Luminex use; c) Refinement of airborne instrumentation for Luminex use and software programs for aerial data processing; d) Development of microprocessor-based instrumentation for magnetic and electromagnetic ground instrumentation, both hardware and software; e) Improvements in high power IP transmitters for time and frequency domain surveys; f) Improvements in dual-frequency comparator ground EM system (GENIE); g) Development of software programs for processing of ground geophysical data.

17. Sonotek Limited, Mississauga, Ontario (Y. Khvalov, P. Macak)

An Automatic Aeromagnetic Digital Compensator (AADC) for active, real-time software-controlled compensation of high-sensitivity aeromagnetic and vertical gradient measurement is under development. The project is based on earlier work at National Aeronautical Establishment, Ottawa (C.D. Hardwick et al.) and sponsored by National Research Council of Canada through their PILP program. Earlier in 1982 the company was active in the development of novel digital methods for gamma-ray spectra processing, such as real-time smoothing and background removal.

Research staff in 1982 was 8, down from 17 in 1981, with similar budget reduction.

18. Urtec Limited, Markham, Ontario (B. Pavlik, D. Owen, A. Marsalowski)

Hardware developments include portable scintillometers/spectrometers, data acquisition system, and navigational interface (ARINC). Software development proceeded in real-time data acquisition, spectrometer calibration, data processing, and navigation. The goal of the present and future development is to marry together the high information throughput on systems operating with software written in the assembler language and high level of controls and flexibility generally available in a system operating under some software control (Unix, CP/M etc.) and high level language (basic, pascal, fortran, etc.).

The company spends approximately $100,000 per year on R&D.

GOVERNMENT

19. Geophysics/Geochemistry Section, Ontario Geological Survey, Ontario Ministry of Natural Resources

During the 1982 summer season, survey and research activity continued on the Night Hawk geophysical test range located near Timmins, Ontario. The test range program was initiated with the objective of developing site-specific areas, which are representative of exploration targets in Ontario, into ranges for testing newly-developed exploration technology. The Night Hawk test range is the first in a series of planned testing sites and was specifically chosen as a site suitable for experimentation with inductive prospecting techniques.

The grid system, which was developed in the northeast corner of Thomas Township, covers an area underlain by approximately 90 meters of glacial-fluvial sediments and several graphite horizons in the underlying bedrock.

In addition to the electromagnetic, magnetic gradiometer and gravity survey data obtained by Section staff, researchers with the Geological Survey of Canada, the University of Toronto, and eight geophysical manufacturing and contracting companies have carried out experiments using airborne and ground electromagnetic, audiofrequency magnetotelluric and seismic reflection and refraction techniques.

The gravity interpretation project, initiated in 1981, was continued this year and is based on data collected over the past four years in the Cobalt Embayment-Grenville Front area. As an aid to interpreting this gravity data, eighteen Federal-Provincial aeromagnetic maps have been digitized and processed. Several computer interpretation algorithms, including an interactive 2 1/2-D modelling routine, and an apparent density mapping routine, have been developed and used to interpret the residual Bouguer gravity anomalies after regional effects from deep-seated sources were removed. The study is scheduled for publication early in 1984.

A contract to develop and test-fly a commercial aeromagnetic gradiometer system in 1983 has been awarded to Kenting Earth Services Limited of Ottawa, Ontario. The project is being funded equally by the Federal Department of Regional Economic Expansion (DREE) and the Ontario Ministry of Natural Resources under the Minerals Program of the Eastern Ontario Subsidiary Agreement. The aeromagnetic gradiometer system features a novel retractable boom assembly which is tail-mounted on a twin-engined Piper PA-31 Navajo aircraft. Two cesium vapour magnetometer sensing heads will have a separation of approximately 2 m in the survey mode, and the lower boom will retract for runway manoeuvres. Currently, the development work has centred on the digital acquisition system and the construction of a lightweight self-orienting sensor assembly (Item 11 above).

Currently, the Section consists of three research geophysicists with an annual budget of $350,000. An additional amount of $1,000,000 annually is received from the Ontario Board of Industrial Leadership and Development (BILD) to support the development of exploration technology with Ontario companies specializing in research and development, (ETDF grant program).

20. Resource Geophysics and Geochemistry Division, Geological Survey of Canada, Department of Energy, Mines and Resources (P.B. Holman, K.A. Richardson, Y.T. Maurice, B.W. Charbonneau, K.L. Ford, S.B. Ballantyne, C.R. Bernius, R.L. Grasty, G.W. Cameron, Q. Bristow, P.G. Killeen, C.J. Mwenifumbo, A.V. Dyck, A.K. Sinha, L. Stevens)

In the summer of 1982, high sensitivity airborne gamma-ray spectrometric surveys were flown on the south coast of Newfoundland, and over granitic areas in southern Nova Scotia, under the Canada-Newfoundland Co-operative Mineral Program 1982-84, and the Canada-Nova Scotia Mineral Agreement 1981-84, respectively. A reconnaissance survey was flown on the North Shore of Lake Superior to tie together blocks of existing coverage flown previously under the Federal-Provincial Uranium Reconnaissance Program 1975-1978, and small detailed surveys were flown in Southeastern Saskatchewan to investigate radioactive haloes associated with oil/gas fields.

Field work was carried out on radiometric variations in granites in the Sheet Harbour area of Nova Scotia and in the Surprise Lake mineralized granite of Northern B.C. This latter granite is enriched in a wide range of metals including Sn. The highly radioactive granites in the Nueltin Lake area, District of Keewatin, N.W.T. were studied, as were radioactive granites along the Mid-Continent gravity low in Northern Saskatchewan and Southern District of Mackenzie, N.W.T.

Analysis of multi-channel airborne gamma-ray spectra showed that significant increases in accuracy could be obtained for the measurement of uranium and thorium compared to the standard 3-window technique. This technique also showed potential for measuring in-flight atmospheric background from decay products of radon.

Primary gamma-ray laboratory standards have been developed and were used to analyse the U.S. New Brunswick Laboratory (NBL) uranium and thorium reference standards. Considerable disagreement was found between the G.S.C. results and some of the NBL quoted values. Analysis of the radium content of

four Canada Centre for Mineral and Energy Technology (CANMET) uranium reference standards showed them to be effectively in radioactive equilibrium.

A new R&D logging truck was acquired and outfitted. Instrumentation has been installed in shock-mounted racks which double as shipping containers when removed from the truck. The newly configured system was successfully tested and logging operations were conducted at Bells Corners, Bancroft, Larder Lake and Pointe Fortune. Gammaray spectral logs, temperature logs, and I.P. logs (along with resistivity and self-potential) were recorded.

A new digital I.P. borehole logging system has been developed and data processing and interpretation techniques are underway.

Apparent resistivities, S.P., I.P. decay rates and any number of desired chargeability windows are computed and displayed as borehole logs from the I.P. probe.

A coal logging project was initiated, with the first objective being the establishment of models for density logging calibration. The model design is novel and flexible in its application. Besides being useful for gamma-gamma density it may also be used for electrical and acoustic modelling.

An I.P. probe using non-polarizable electrodes has been designed and constructed for use in applied potential measurements. The mise-a-la-masse electrical technique was used successfully to trace fracture zones from hole to hole in the Bells Corners test holes.

The waterborne version of the resistivity/induced polarization methods was successfully applied to the problem of mapping a portion of the Archaean-Aphebian contact beneath Wollaston Lake, Saskatchewan. The method appears to be widely applicable for mineral exploration in lake-covered regions.

Borehole electromagnetic studies are continuing with the development of upgraded data acquisition facilities and modelling on complex test sites. A theoretical study was completed to show the value of measuring 3 orthogonal magnetic components in order to stimulate the development of the appropriate downhole hardware.

Deep sounding EM surveys were conducted with Maxiprobe and Geonics EM-37 at Lynn Lake, Manitoba and Buchans, Newfoundland to determine effectiveness of the equipment in these environments for detecting disseminated and small massive sulphide bodies at depths up to 500 m below surface.

UNIVERSITIES

21. Department of Geophysics and Astronomy, University of British Columbia

Research on the use of power harmonics is being continued by L. Fisk under the direction of T. Watanabe and W. Slawson.

22. Department of Geology and Geophysics, University of Calgary (K. Duckworth, A.E. Kay, A.R. Bays)

Development was completed of a scale modelling facility capable of simulating continuous wave and transient EM systems using large fixed loop transmitters. A study was made of the effect of permafrost on electrical properties of lead zinc ores.

23. Department of Geological Sciences, University of Saskatchewan (Z. Hajnal, M.R. Stauffer, D. Genzwill, A. Szczpanuk, B. Pandit)

Petro-physical analysis of the Athabasca sandstone in the Midwest Lake area of the Athabasca Basin has begun. The rock-mechanic and acoustic

characteristics of several sets of borehole samples are being determined by laboratory measurements. These results are being correlated to very detailed geological features of the same samples. Synthetic seismograms computed from the above information will establish the seismic behaviour of the Athabasca sandstone over commercial uranium deposits.

Digitally controlled recording with an array of geophones over the Cory Potash Mine near Saskatoon has recorded a number of microseismic events with magnitudes ranging from -0.5 to 2.4. Analysis of the data has shown that the events are located in the rocks above the mine level. The mine is at a depth of almost 1000 meters. The larger earthquakes near the Cory mine are due to subsidence and failure in the competent carbonate rocks above the mine. Mechanical, elastic, and acoustic properties of rocks from the mine have been determined for some 50 water-saturated samples at various confining pressures. The rocks show high strengths which are strongly correlated with their porosity. Surface seismic surveys have been repeated at yearly intervals over an area of the mine. Computer processing of these data, under the direction of D. Gendzwill, using the technique of SEISLOG, has shown that the effects of mining can be recognized. The objective of the research is to determine whether seismic data can be used to estimate the stress condition in the rocks around the mine.

24. Department of Earth Sciences, University of Manitoba (W. Moon, D. Messfin, J. Owusu)

A study of seismic reflectivity of Precambrian Shield rocks and a detailed seismic modelling study is being carried out for the geological setting of the Sudbury basin. Several seismic configurations are being tested to improve the application of seismic methods in mineral exploration. Tests are being made of the vertical seismic profiling (VSP) method in the Precambrian Shield environment, for possible application in mining geophysics.

25. Department of Geophysics, University of Western Ontario (L. Mansinha, B.G. James, S.M. MacRitchie, W. Ravenhurst, D.A. Wilkinson)

The following studies were made: (a) a re-interpretation of the most recent gravity data in the Kapuskasing area, using computer modelling and all available geological information; (b) a test of the resolution limits of the interpretation of MAXIPROBE EMR 16 electromagnetic sounding data with field data from an area near Ottawa; (c) interpretation of borehole pulse EM data, using field results from the Timmins area; (d) the quantitative analysis of gravity data over the New Liskeard gravity high using a new regional-residual filtering technique based on the statistical trend surface method.

26. Geophysics Laboratory, Department of Physics, University of Toronto (G. West, J.S. Holladay, R.N. Edwards, E. Gomez-Trevino, J. Wong, P. Hurley)

(a) Work has continued on designing an improved prototype instrument for EM sounding in the 0.1-5kHz band using a grounded wire source. Electric fields will be measured as well as magnetic fields. Test survey data from sites on the Paleozoic section of S.W. Ontario, where only magnetic field receivers were employed, were carefully analysed using generalized linear inverse methods. The results indicate that even a complicated section of alternating resistive and conductive formations can be reliably traced from site to site. Magnetotelluric surveys have now also been carried out on the same test sites by the group from Edinburgh University (A. Jones, R. Hutton), but data analysis is still in progress.

(b) A very extensive set of model experiments was carried out in the U. of T. EM scale model laboratory by Lamontagne Geophysics (q.v. re UTEM system). Other model studies of pulse EM were conducted by personnel from Crone Geophysics.

(c) An experimental, high-frequency, seismic system for borehole to borehole studies in crystallines rocks has been constructed and tested. The probes operate in the 1-10 kHz range with transmission to distances of several hundred meters depending on rock attenuation properties. Detailed crosshole surveys have been carried out at two sites: Bell's Corners near Ottawa and Pinawa, Manitoba. P velocity and attenuation in the interborehole area are derived by tomographic techniques. An interpretation of the Bell's Corners data agrees with the known geology. Analysis of the Pinawa data is currently in progress. It is expected that the system will be valuable for engineering studies of rock quality, and possibly also for detailed basemetal exploration.

(d) There has been much recent interest in using high-power, large-scale, resistivity - IP field methods in petroleum exploration, and numerous test surveys have been done over developed oil fields. An unsettled question is the effectiveness of oil well casing in producing resistivity and IP anomalies. A set of computer programs has been produced for modelling the effect of one or more vertical, electrically-isolated pipes in a conductive half space. The results of modelling studies suggest that well casings can certainly be an important cause of anomalies in some cases. Work is continuing on adapting the analysis to more complex and realistic situations.

27. Department of Geology, University of Toronto (D.W. Strangway, J. Wong, J.D. Redman, A. Vyas, M. Ilkisik, D.C. Hsu, M. Mahan, W.E.S. Urquhart, Sun-Yunsheng, R.C. Bailey, T. Urbanic, R. Groom)

(a) The complex conductivity spectra of disseminated ores containing elongated particles have been studied. Results from a two-component model containing prolate spheroidal particles showed good agreement with experimental data.

(b) Research continued in various aspects of the AMT method. A prototype digital tensor AMT system was completed and tested at several sites in Northern Ontario. Scalar AMT data were collected over a larger number of sites for the purpose of studying the application of AMT to overburden and bedrock mapping in various conductivity environments. Anisotropic responses were noted in some cases and tests will be repeated with the tensor equipment. Studies were made of the frequency-dependence of conductivity in clays from Northern Ontario. Interpretations were carried out using several 1-D multi-layer inversion techniques.

(c) Regional and high-resolution aeromagnetic data from several areas in Northern Ontario and Québec were studied. The apparent susceptibility map was found to be a useful technique for distinguishing most rock types. Ground truth and petrographic/chemical work is being used to establish the relationships with magnetic properties. Similar studies are being carried out on data from Mainland China.

(d) The detectability of gold mineralization was examined using the effects of associated mineralization on gamma, resistivity, IP and thermal logs. This is a joint project with the Geological Survey of Canada who are logging a number of holes through gold-bearing rocks near Larder Lake, Ontario.

(e) A method for modelling the EM responses of two and three dimensional electrical conductivity anomalies is being developed. This is closely related to the Madden-Swift method, but offers the prospect of faster performance through coarser gridding without loss of accuracy.

28. Department of Mining and Metallurgical Engineering, McGill University (O.G. Jensen, E. Baranyi, P.T. Lafleche)

Theoretical solutions have been obtained to the electromagnetic wave, induction and conduction problems which hold for linear-isotropic halfspaces having frequency-dependent, complex-valued conductivity, permitivity and permeability. Particular solutions for the wide variety of antenna configurations and electrode arrays used in geophysical prospecting can be constructed. In demonstration of the very significant effects of realistic levels of reactive conductivity, dielectric hysteresis and magnetic relaxation, modified Cole-Cole models have been employed for the three electromgnetic material properties. It is expected that the results of this research will be of practical use to geophysicists in resolving which electrical or magnetic material properties are most important in their geophysical measurements using very-high and ultra-high frequency electromagnetic systems.

An EM system has been designed which provides for 30W of highly directed 445 MHz continuous wave signal. The system, which can be employed in either a transmission or reflection mode, is licensed for experimental operation underground. Noranda Exploration is cooperating in the testing of this system in mines in the Abitibi region. The particular prototype system is designed for in-situ measurements of the absorption of UHF-EM waves in very-highly resistive rhyolite zones associated with base-metal mineralization. Geotomographic inversion is expected to allow an interpretation of measurements in terms of a distributed absorber model delineating small fluid-filled cracks and mineralization stringers between stopes and drifts. Preliminary underground surveys are scheduled for the Big Nickel Mine in early March.

29. Ecole Polytechnique/IREM-MERI, Montréal (R. Bazinet, E. Kisak, J. Legault, M. Vallee, M. St-Amant, D. Couture, C.W. Faessler, P. Lorraine, E. Schwarz)

Techniques and interpretation methods are being developed for MT prospecting over multidimensional targets. This includes work to increase upward the frequency range usable in MT surveys and the testing of the MTCH, a phase and coherence measuring MT set. Also being completed is an interpretation method for borehole VLF surveys and other uniform field EM methods using a microcomputer.

Under development are: A new seismic interpretation program for microcomputers and new mechanisms suitable to the construction of a rugged low cost field gravimeter. The deep crustal structure of the Abitibi belt using seismic and gravity methods is also being studied.

Apart from salaries of professors, IREM-MERI estimates that $2.3 million was spent in 1981-82 on mineral exploration research. This was divided approximately $1.6 million in grants and $0.7 million in contracts with contributions from industry (80%) and federal and provincial governments (20%). Staff (including McGill, Ecole Polytechnique and University of Montréal) totalled 90 professors and graduate students. About $500,000 of the above expenditure and 14 staff were devoted to applied geophysical research.

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XI ENGINEERING GEOPHYSICS

Compiled by: J.A. Hunter

1. Introduction

Research in engineering geophysics in Canada appears to be closely tied to the economic climate and, as can be seen by the following report, the overall level is lower in 1982 than in the previous year. A number of industry respondents reported no research carried out.

2. Huntec ('70) Ltd.

With an expanded full-time R & D staff of approximately 30, Huntec is continuing work on the Seabed II Project under the leadership of Dr. J.M. Ross. Seabed II is a joint research and development effort involving several Federal Canadian Government agencies, with Huntec as prime contractor.

The objective of Seabed II is to continue the development of quantitative acoustic remote sensing technology, which began with the 1974-1981 Seabed Project. Current efforts are directed toward development of new digital hardware and software for quantitative high-resolution sub-bottom profiling and long-range side-scan sonar mapping. This new equipment will be deployed in a two-stage towed body at towing depths to 2000 metres. First sea trials of the system are scheduled for the summer of 1983.

The new system will include multi-sensor towfish positioning and motion-compensation equipment, described further in the Geodesy section.

Related studies are being carried out at Huntec by Dr. Shuying Zhang, a professor at the Institute of Acoustics in Shanghai, and Canada's first Industrial Visiting Scholar from the People's Republic of China. Dr. Zhang is developing a theoretical background for remote measurement of sound velocities in near-seabed sediment layers, through the use of a hydrophone streamer in conjunction with the Seabed II seismic profiler acoustic source.

A 1000-Joule version of the boomer seismic source has been developed at Huntec and tested in a deep-towed sub-bottom profiler system off Canada's east coast. With twice the energy output of the original boomer, it provides improved performance over hard-bottom regions.

This high-energy boomer has also been incorporated into a surface-towed seismic profiler, which permits high-resolution profiling in water as shallow as 20 metres. The system can be deployed from small vessels, and requires a single operator.

3. Saskatchewan Research Council (A. Schneider)

One project was carried out in 1982 which involved the application of resistivity and electromagnetic methods to mapping brine contamination in groundwater beneath and around a tailings disposal basin at a Saskatchewan potash mine.

4. McQuest Marine Research & Development Company Ltd. (J.W. Prior)

McQuest Marine Research & Development Company Limited and associated companies have continued the development of their side scan sonar systems with improvements to its signal processing system, display and standardization of its magnetic tape recording of data and playback; these developments result in replayed records of far superior quality to the original field record. These systems are also modified to operate in a rotary mode through a hole in the ice; the system has been operating successfully in shallow water in the Arctic.

The full suite of conventional marine geophysical and positioning systems continue to be used for routine offshore site investigations.

The engineering geophysics on land has seen the introduction of the shallow reflection seismic techniques developed by Geological Survey of Canada introduced into McQuest capability. An induced polarization method to locate clay-filled cavities was used successfully.

5. Laval University Permafrost Studies (M.K. Seguin and M. Allard)

The studies of physical and geophysical nature were concentrated in 3 regions during the 1982 field season: Poste-de-la-Baleine, Clearwater Lake and Nastapoka River. These three sites are located in northern Quebec. Permanent geothermal probes including a series of 20 cm spaced thermistors were installed at the three sites. The temperature measurements were obtained at irregular and discontinuous time intervals for the probes installed at Poste-de-la-Baleine and Nastapoka River. At Clearwater Lake, a first automatic geothermal probe was installed; the continuous recording is on magnetic tape.

At Nastapoka River, electrical resistivity and geothermal soundings were carried out. The resistivity soundings were conducted in specific environments originally classified on a pre-established geomorphological basis. Lateral and vertical extension of discontinuous permafrost zones were determined with these two geophysical methods. Electrical resistivity increases rapidly in materials which are porous and contain a specific water content near the freezing point.

Some 60 geothermal and electrical resistivity soundings were carried out on representative geomorphological environments. Approximately 30% of the sites are characterized by the absence of permafrost. The mean thickness of the permafrost layers detected is approximately 20 m. Additional information included electrical conductivity and salinity of interstitial water as well as repartition and nature of the ice in permafrost. Similar studies were also conducted in running waters and more or less turbated waters in thermokarsted regions. Relationships between the electrical conductivities and the presence of elements such as Na, Ca, Mg, K, and Fe were also established.

Laboratory studies and data interpretation are presently under way.

6. Paterson, Grant & Watson Ltd. (N. Paterson)

In 1982 the company continued as prime consultants and managers of the AECL Master Contract for geophysical research on the nuclear fuel waste management program. The high-resolution reflection seismic studies were completed at Lac du Bonnet and reported on under a subcontract with Petrel Consultants Limited. This program, consisting of closely-spaced buried charges and geophones, is believed to be the most detailed and comprehensive of its kind carried out in Canada. Results are being given detailed analysis and interpretation by the Seismology Division of the Earth Physics Branch, Ottawa.

Also in connection with the above contract, airborne and ground surveys were conducted at East Bull Lake, Ontario, partially to evaluate the hydrogeological and geotechnical characteristics of the near-surface materials. To this end computer inversion methods were developed to model multichannel airborne electromagnetic responses to a two-layer ground. Pseudo-depth contours were obtained for a conductive overburden layer over the entire study area. Structural analysis was also performed.

7. AECL Nuclear Waste Management Program (L.S. Collett)

In many respects geophysical studies of crystalline plutons as possible repository sites are an unconventional use of geophysics. Usually geophysicists look for anomalies indicating metallic sulphide conductors. However, the physical description of a pluton is characterized by major linear discontinuities ranging from faults and fracture zones to regions that contain relatively few fractures. During the past five years, research has been aimed at better defining the capabilities and limitations of existing geophysical methods and improving these methods for the specific needs of the mapping geologist in describing the anatomy of granite plutons.

(a) The VLF-EM method has been found to be a prime surface technique for the detection of fractures, lineaments and fault zones. It has been found that the plane wave field couples or energizes zones striking at $\pm 45°$ to the direction of propagation of the EM field. To survey an area adequately, the signals from two VLF stations should be chosen such that the directions of propagation are approximately orthogonal. Often this situation is not possible. A portable local VLF transmitter has been designed and tested by the GSC (Hayles and Sinha, 1982). Field tests have demonstrated a remarkable similarity between survey results obtained using this transmitter and distant naval VLF transmitters. Ideally, geologists would like VLF surveys done on a 100 x 100 m grid. The VLF technique is capable of determining fracture strike, whether it is a major or minor fracture and can provide an indication of dip. The surface VLF method is not useful for the detection of horizontal fractures at depth.

Subpenetrating radar (50 - 500 MHz) has been used to map properties of overburden, eg., thickness or depth to bedrock, layering, boulders, and water table. The electrical parameter to which these frequencies respond is dielectric constant. Course grained material and bedrock are relatively transparent to these frequencies while clay is a good absorber.

(b) The seismic "tube" wave method provides a rapid technique for locating fracture and permeable zones intersecting a borehole. The technique involves small explosive charges detonated in a hole at surface while a string of hydrophones is successively lowered in the borehole. Tube wave events have been reliably correlated with TV logging, geological core logging and standard geophysical logging techniques to guide hydrogeology studies (Huang and Hunter, 1981).

The VLF borehole method is capable of detecting fracture zones intersected by the borehole. The method looks very promising in extrapolating geological and other information away from the borehole, thus providing information necessary to complement the tube wave method. A continuous log is produced very rapidly.

Standard geophysical logs have been run under contract in all the boreholes on all AECL test sites at White Lake, Chalk River, Atikokan, Pinawa and URL. These contracted logs are self potential, single point resistance, resistivity (16" and 32" normal), focused beam resistivity, natural gamma, gamma-gamma (density), neutron-neutron (porosity), conductivity, thermal, acoustic and caliper. Other logs that would be useful are magnetic susceptibility and gamma ray spectrometer. Each log

has something to offer in describing the rock and in the detection of fractures and cracks in the immediate vicinity of the borehole. Studies have commenced on the correlation and interpretation of these logs.

A borehole radar log has been tested to a depth of 150 m at Chalk River. The tests have demonstrated that cracks and fractures can be detected, which makes the method look promising.

8. Geological Survey of Canada, Terrain Geophysics Section (J.A. Hunter and A.K. Sinha)

Shallow seismic reflection techniques, for mapping the overburden-bedrock interface, were tested at several sites in Canada. A technique called "optimum offset" profiling was developed and was shown to offer potentially good resolution on infra-overburden structures.

Deep electromagnetic soundings were carried out over several locations in the Mackenzie Delta, N.W.T., to test the abilities of two EM systems, (a) Maxi-Probe multifrequency EM system, (b) Geonics EM-37 transient EM system, to detect and map conductive structures within the permafrost layers including the detection of the base of the permafrost. The last locations were selected over existing deep oil or gas wells which had been logged previously. The results with the Maxi-Probe surveys were very encouraging since it was able to detect conductive features at depths up to 700 m from the surface. The depth penetration was somewhat less for the EM-37 system.

9. Bibliography

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