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 34

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December/décembre 1981
Ottawa, Canada

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INTRODUCTION

The Canadian Geophysical Bulletin is an annual report of geophysical research, development and services in industry, government, and universities in Canada. Its main purpose is to provide a record, continuous from year to year, of active researchers and their projects and of the current year's publications. Brief mention is made of research results, but the latter are not recorded to any extent since they may be found from the 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 Mrs. J. Breton 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 CNG/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 Mme J. Breton, 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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Ce bulletin est offert à titre gratuit, mais le Comité national du Canada serait heureux de recevoir, en échange, tout rapport de source nationale ou internationale.

D.H. Hall
Rédacteur en chef

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I (A) GEODESY

Compiled by: D.E. Wells

1. Summary

During 1981 work continued on preparations for the North American horizontal networks adjustment, NAD83 (now actually scheduled for 1985). Studies related to the 1988 North American vertical networks adjustment proceeded at an accelerated pace at several institutions.

Canada's only correlation facility for long baseline interferometry (LBI) was shut down in 1981 (mainly due to old age). Alternatives for replacing this facility are under discussion. The Canadian proposal to participate in the NASA Crustal Dynamics Project was accepted. This proposal involves LBI monitoring of strain in Canadian regions. Several institutions are involved.

Investigations of NAVSTAR/Global Positioning System (GPS) techniques and applications were actively pursued at several institutions during 1981.

Refinements in the inertial surveying technique were developed during 1981. The current state of the art in inertial surveying is represented in the proceedings of the Second International Symposium on Inertial Technology for Surveying and Geodesy, organized by the Division of Surveying at the University of Calgary and the Canadian Institute of Surveying, and held in Banff in June. Klaus-Peter Schwarz edited the proceedings.

Banff was also the site of the Canadian Petroleum Association Colloquium III on Petroleum Mapping and Surveys in the 80s, in October. The proceedings, edited by Gerard Lachapelle, reflect recent advances in all areas of surveys and mapping.

Canadian geodetic work was also well reported at the XVI International Congress of the Fédération Internationale des Géomètres, in Montreux, and at the Symposium on Geodetic Networks and Computations, in Munich, both in August.

2. Geodetic Survey of Canada

(a) Horizontal Positioning

The primary horizontal control network in Canada was strengthened and densified by means of satellite Doppler positioning at 57 locations--14 in Newfoundland/Labrador and 43 in northern Québec.

Astronomic observations were made at 5 locations to improve the azimuth in arcs of primary triangulation--4 in Newfoundland and 1 in British Columbia. Observations for latitude and longitude were made at 36 horizontal control stations to determine the deflection of the vertical for geoid studies--6 in Newfoundland, 1 in Nova Scotia, 3 in Quebec, 1 in Manitoba, 4 in Saskatchewan, 11 in Alberta, 9 in British Columbia, and 1 in the Northwest Territories.

Baselines for calibrating electronic distance measuring instruments were measured, or remeasured, to check the stability of the piers, at 5 locations--Burlington and London, Ontario; Fredericton, New Brunswick; Pt. Hawkesbury, Nova Scotia; and St. John's, Newfoundland.

The Inertial Survey System was used to establish second-order control for mapping and for densification in New Brunswick, Quebec, Saskatchewan and Alberta. Minor ISS projects were also undertaken in Ontario and the Northwest Territories. Approximately 11 500 km of ISS traversing was accomplished in 1981 (Babbage, 1981; Webb and Penney, 1981).

(b) Vertical Positioning

Approximately 3 800 km of first-order levelling was completed during 1981. Half of this distance was relevelling for vertical network maintenance and the other half was new levelling for network extension. Special order levelling projects were carried out on Vancouver Island and at LG2 in Quebec. Other levelling projects were located in the Swan Hills area of Alberta, North Battleford and Canora areas in Saskatchewan, Dauphin region of Manitoba, the Hearst, Sault Ste. Marie and Goderich areas of Ontario, and in southeast Quebec. As well, bench mark inspections and/or installations were carried out in British Columbia, Yukon, Alberta, Saskatchewan, Manitoba, Ontario, and Quebec.

Additional control for mapping using the Ground Elevation Meter (GEM) was provided in southern Ontario. Miscellaneous surveys were undertaken in the Arctic Islands, Ontario, Northwest Territories, and Yukon to strengthen existing surveys and to support mapping programmes.

(c) Data Processing and Banking

Work continued on the 1983 North American Datum (NAD83) adjustment. The U.S. target date was changed from 1984 to 1985. A test adjustment of the Canadian horizontal framework was computed on the preliminary 1983 datum that was agreed to with the U.S. National Geodetic Survey. The file of observed data for the test adjustment will form the basis for the continental adjustment. Software for the Helmert block method is being developed with the aid of contracts. Provincial agencies are assuming responsibility for integrating secondary and lower-order networks into the new datum; Geodetic Survey will assume this responsibility for the territories. Evaluation of data by Geodetic Survey has been done for secondary networks amounting to 23 000 stations.

A project group for the 1988 North American vertical adjustment was established, and preparations were made for digitization of primary vertical control data.

Area readjustment of some 1600 secondary horizontal control stations was completed for some networks in the Yukon, Arctic Islands, Quebec and Labrador. Readjustment of about 1650 vertical control points was completed in the Yukon and Arctic Islands.

The positional component of the National Geodetic Data Base was developed to near completion, and 80 percent of the data were loaded from temporary files.

Computer program maintenance continued including modifications to the Doppler and ISS processing packages and the further development of network plotting routines.

(d) Research Activities

The computer program used to adjust EDM calibration baseline lengths observed by Mekometer was modified to allow observation sets from more than one epoch, with different associated Mekometer calibration parameters, to be combined in a single adjustment. This provides better estimates of true inter-pier distances and allows easier detection of movement of any of the piers.

A method of providing azimuth control by position updates prior to commencement of an inertial traverse was investigated with the objective of relieving the ISS from the currently accepted straight-line traverse design constraint (Wilkinson and Wong, 1981). An improved smoothing algorithm has been developed through a contract with the University

of Calgary. The U.S. NGS conducted tests of an inertial survey system near Yuma, Arizona using stations of the very precise (± 1 ppm) trans-continental traverse to provide ground truth. Assistance in the processing and analysis of the test data was provided to NGS.

Refinement of our knowledge of the geoid in Canada continued with the investigation of the isotropy of the gravity anomaly covariance function.

Techniques for modelling the coordinate distortions in horizontal geodetic networks were evaluated (Lachapelle and Mainville, 1981).

A draft version of Guidelines and Specifications for Satellite Doppler Surveys was distributed (Boal, 1980 is an abridged version). Receiving equipment were intercompared (Boal and Vamosi, 1981).

Calibration procedures for invar levelling rods were further refined (Vamosi, 1980), and development of an automatic star transit detector continued.

Motorized levelling equipment including three four-wheel drive vehicles was purchased, and testing is scheduled for the spring of 1982.

Investigation of NAVSTAR/GPS continued with contracts being awarded to Canadian Marconi for the development of detailed GPS geodetic receiving equipment specifications and to the University of New Brunswick for GPS differential positioning pre-analysis software.

3. Earth Physics Branch (Gravity and Geodynamics Division)

(a) Polar Motion Studies

Polar motion observatories near Ottawa and Calgary continued precise monitoring of the earth's rotation and polar motion by means of optical astronomical (PZT) and satellite Doppler (TRANET) observations (Kouba, 1981; Lachapelle and Kouba, 1981). The results have been transmitted regularly to the international time and polar motion services (BIH, IPMS, DPMS). Ottawa TRANET hardware has undergone some modifications: new ELECTRAC receivers were incorporated into the fully automated stations together with a cesium frequency standard.

Development of a geophysical long baseline interferometry (LBI) system continued in cooperation with York University. Experimental results between Algonquin Radio Observatory in Ontario and the Dominion Radio Astrophysical Observatory in British Columbia from April 1980 demonstrated the viability of a commercial satellite communication link for operation of a phase stable LBI (Waltman et al., 1981).

A contract with the University of Toronto was initiated to assemble and test prototype hardware for NAVSTAR/GPS based LBI.

(b) Sea Ice Motion

A final report on LOREX 79 Satellite Doppler results and ice drift analysis was prepared (Popelar et al., 1981). It includes both real time and post processing results as well as strain analysis of ice pack in the vicinity of the North Pole.

(c) NASA Crustal Dynamics Project

A coordinated Canadian proposal to participate in the NASA Crustal Dynamics Project was accepted by NASA. The Canadian experiment involves co-investigators from the Earth Physics Branch (Ottawa), York University, the University of New Brunswick, the Pacific Geoscience Centre, and the Geodetic Survey of Canada. The investigation includes monitoring by long baseline interferometry of strain in the Alaska/Yukon region adjacent to the Pacific/North American plate boundary and within the Canadian Shield.

The selection, monumentation and local stability monitoring of networks has been considered in preparation for the LBI observations to be carried out in 1983.

(d) Cartography (Division of Geomagnetism)

On most small-scale scientific maps of Canada (e.g., the Geological, Tectonic, Mineral Deposits, etc., maps by the Geological Survey of Canada; Bouguer Gravity, Magnetic, etc., maps by the Earth Physics Branch) two projections are used: a Lambert Conformal Conic south of 80°N and a modified polyconic projection north of 80°N. This latter projection has been derived mathematically by Haines (1981); previously, only drafting procedures for the latitude-longitude graticule were available. The analytical formulation of the projection allows computer processing and display of geographical and geophysical information both in the production of maps and for purposes of data comparisons.

4. National Research Council (Division of Physics)

(a) Photogrammetric Research Section

Seasonal and latitudinal variations of astronomical refraction have been investigated on the basis of a new nonsymmetric atmospheric model calculated from global meteorological data.

(b) Time and Frequency Section

Since January 1, 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 first leap second occurred at the end of June 1972, and subsequently at the end of December each year until 1980. In 1980, there was a slight increase in the speed of rotation of the earth, and a leap second was not necessary until 1 July 1981.

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. The format of the CHU broadcast is given in the Time Service Bulletin B-27, and is identical for the three CHU frequencies 3330 kHz, 7335 kHz and 14 670 kHz. A series of bulletins TF-B- announce relevant changes, such as DUT1 and leap seconds, several weeks in advance.

The NRC CsV primary cesium standard of time and frequency has been operating continuously since 1 May 1975, and has demonstrated accuracy and stability of 1 to 2 microseconds per year. 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.

In July 1978 two-way satellite time transfers began between NRC and Observatoire de Paris using the Symphonie satellite, and between NRC/NBS and NRC/USNO using the Hermes satellite. These experiments have shown that precision of a few nanoseconds can be attained in comparing times, and that the frequencies of the time scales can be compared internationally to 1×10^{-14}. The Hermes experiment lasted one year, but the Symphonie time transfer is continuing, and transfers will be made in 1982 at the rate of one per week. The PTB laboratory joined the experiment in February 1980 to give a three way comparison between Canada, France and Germany (FRG). The comparison of the NRC CsV with the PTB standard Cs1 has shown that over periods of six months they maintain a relative stability of 1×10^{-14}. Over the past four years the two standards have agreed in their independent absolute frequencies to 2×10^{-14}, or $\pm$ 1 microsecond in the resulting time scales.

Over the past few years, it has become evident that there are seasonal variations between TAI, or UTC, and the primary time standards NRC CsV and PTB Cs1. Measurements at NRC have shown that the Loran C propagation delay changes by up to 1 microsecond on a daily or seasonal scale when the outside temperature drops below freezing. These results, coupled with the NRC/PTB satellite comparisons, have shown that the seasonal variations are in the international time scale TAI and not in the primary standards of NRC and PTB (Mungall et al., 1981).

5. Bedford Institute of Oceanography (Canadian Hydrographic Service, Atlantic Region)

(a) NAVSTAR/GPS

Between now and 1987 GPS is in a development phase with only 4 to 6 of the eventual 18 satellites available. Sheltech Canada, CHS-BIO, and the University of New Brunswick have set up a joint project to develop an operational marine GPS navigation system for use in the Canadian Arctic during this phase. In order to bridge between the two five-hour periods per day when GPS is available, and in order to provide velocity input for Sheltech's early generation GPS receiver which takes 70 seconds to make measurements on a satellite, the GPS control and fix computation software has been integrated in one computer with the BIO Navigation System (BIONAV). On the first test cruise on BIO's "Hudson" off Newfoundland in November 1981, simultaneous GPS and BIONAV data were collected for analysis and for further program development.

(b) Loran-C Performance

The Arctic Loran-C performance test in the Beaufort Sea, described in the 1980 Bulletin, was successfully completed with winter condition observations in April 1981. These showed conclusively that the arctic permafrost does not adversely affect Loran-C performance, which is at least as good as performance over rocky terrain in southern Canada. However, transmitter towers may require more extensive grounding systems than in the south.

(c) Tides

Tidal measurements continue on the continental shelf. Deep ocean measurements have been taken in the Newfoundland Seamounts area (46°N, 40° to 45°W); the amplitudes observed agree with model predictions, with an M_2 amplitude of about 15 centimetres.

Acoustic telemetry interrogation of tide gauges will be tested in 1982.

(d) Hydrographic Development

Development has continued in microprocessor navigators for sounding launches and in hydrographic data processing on board the mother ship. In 1982 the major push will be toward automated data recording in launches.

6. Canadian Hydrographic Service

(a) Tides, Currents and Water Levels Division

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. Off-shore 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) Nautical Geodesy Section

The horizontal control adjustment programme, designed to facilitate the transition from the 1927 NAD to the 1985 geocentric datum, has advanced with the completion of the Maritime Provinces control networks. All adjusted stations are utilized to update the horizontal control data bank and List of Lights data file. An adjustment programme is presently being structured for the area from Cornwall to Brockville, Ontario, as a first step to addressing problems concerned with the charting of common boundary areas between Canada and the U.S.A.

Nautical Geodesy participated in several Loran-C calibration exercises, assisting in collecting and analyzing the data, and providing parameters for navigational charts.

7. Université Laval (Département de Géodésie et Cartographie)

(a) Nivellement

- L'étude sur la théorie du nivellement se continue. Les définitions fondamentales sont révisées à la lumière de la géométrie différentielle des espaces Reimanniens.

- Une étude a été amorcée sur l'utilisation du bilan énergétique de l'atmosphère pour le calcul des principaux paramètres météorologiques pour évaluer la réfraction (Leclerc, 1981b).

- Le programme de mesure de nivellement de précision supporté par la Direction de la Physique du Globe EMR, s'est poursuivi à l'oservatoire géophysique de Charlevoix.

- Le projet sur le développement d'une méthode de nivellement hydrostatique en utilisant des senseurs de grande précision se poursuit.

- Le projet sur l'automatisation de la cueillette de données et des calculs de nivellement de premier ordre se poursuit.

- Un projet sur le développement d'un inclinomètre pour l'étude de la stabilité des repères est en cours.

(b) Positionnement Doppler

- Un projet a été poursuivi avec la collaboration de la Direction de la Physique du Globe EMR et l'Observatoire Royal de Belgique en vue d'analyser les variations des coordonnées Doppler (stations TRANET) en fonction du temps.

- Un projet a également été entrepris en vue d'étudier les possibilités qu'offrent les techniques d'intégration numérique pour le calcul d'éphémérides améliorées à partir des éphémérides transmisés.

- Le système de calcul développé a l'Observatoire Royal de Belgique a été amélioré et implanté sur l'ordinateur CDC de l'Université du Québec.

(c) Autres Travaux

- Le projet sur le développement de méthodes d'observation expédiées pour les déterminations astronomiques s'est poursuivi (Sanchez, 1980).

- Une étude a été conduite sur l'existence de points minimax dans la fonction T du potentiel perturbateur.

- Une étude a été faite sur l'utilisation de la collocation dans l'étude des marées terrestres (Hmam et al., 1981).

- Un travail sur la géométrie des ellipsoides confocaux à trois axes a été complété (Mazaachi, 1981; Leclerc, 1981a).

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

Studies continued into applications of NAVSTAR/GPS to navigation and geodesy (Wells et al., 1981; Wells and Lachapelle, 1981). A GPS receiver was successfully interfaced to the BIONAV integrated navigation system and tested at sea as part of a joint UNB/BIO/Sheltech experiment.

Work began on projects involving development of microprocessor-based integrated navigation systems, a general navigation algorithm, and modelling of phase lag for radiopositioning. Local variations of sea surface topography in eastern Canada were studied (Merry and Vanicek, 1981).

Investigation of techniques for geoid evaluation has continued with the development of rigorous formulae for combining satellite data with terrestrial gravity data. A technique for local evaluation of the geoid from gravity data was developed (Najafi-Alamdari, 1981).

A diagrammatic approach to the formulation of adjustment equations was described (Mohammad-Karim, 1981).

The accumulated tilt data from previous years collected at the UNB tiltmetric station have been thoroughly analyzed. The results show a very good agreement (better than 1% for the M_2 frequency) between observations and theoretical models. A new analytical approach to the study of tilt response to various forcing phenomena was developed (Steeves, 1981).

Strain applications to horizontal geodetic networks (phase one) have been described (Vanicek et al., 1981).

Collaboration with colleagues at the Massachusetts Institute of Technology on the study of variations in the rotation of the earth has begun. Changes in angular momentum of the global atmosphere are being compared to changes in the length of day. A particularly high degree of correlation between the two observation types has been found in the period range of 40 to 60 days (Langley et al., 1981).

Investigations are continuing in the application of long baseline interferometry (LBI) to geodesy and geodynamics. This work is being carried out in collaboration with investigators at York University and the federal Department of Energy, Mines and Resources. Efforts include studies of the tidal loading effect on LBI observations, participation in the Canadian contribution to the NASA Crustal Dynamics Project and work associated with the Canadian Long Baseline Array proposal.

Work on the analysis of deformation surveys continued. A systematic approach to the strain analysis of tectonic deformations has been elaborated and tested on the example of repeated micro-geodetic surveys (Huaytapallana network) in Peru (Chrzanowski, 1981a; Chrzanowski et al., 1981). Research has started on the use of the finite element method in the deformation studies.

A telemetry system for monitoring ground tilts has been developed, constructed and installed in a mining area in British Columbia. The system utilizes an array of tiltmeters with radio transmission and automatic recording of the tilt signals (Chrzanowski et al., 1980).

A comparison of different approaches to statistical testing and "screening" of geodetic observations has been completed (Chrzanowski, 1981b).

9. University of Toronto (Erindale Campus)

P. Vanicek, while serving as visiting professor at the University of Stuttgart, started research into covariance analysis of geodetic levelling data of Swiss and German provenance. This research is continuing with the goal in mind of applying the technique to Canadian data.

Investigation of application of strain analysis to the strength of horizontal geodetic networks (Vanicek et al., 1981) is being carried out under the sponsorship of Geodetic Survey of Canada. Effect of crustal movements and temporal variations of the sea level on heights obtained from levelling is being studied.

P. Steeves is currently working on applications of micro-computers in geodetic control. A programme package including EDM calibration, horizontal control adjustment and computation of apparent places of fundamental stars, is being assembled.

10. Sheltech Canada

The application of satellite Doppler and inertial positioning techniques for the establishment of multi-purpose control points in various parts of the world was continued (Hittel et al., 1981; Hagglund and Crago, 1981).

Research and development concentrated on inertial and NAVSTAR/GPS positioning. The utilization of Sheltech's Ferranti inertial systems for offshore exploration was investigated (Hagglund, 1981; Hittel, 1981a). Results obtained with Sheltech's STI (Stanford Telecommunications Inc.) Model 5010 GPS geodetic receiver indicated that an instantaneous absolute positioning accuracy of 10 to 15 m is already achievable when four satellites in a reasonably good geometry are simultaneously available. An ocean trial to test the use of the GPS receiver at sea and its integration with the BIONAV navigation system of the Canadian Hydrographic Service (CHS) was conducted in November in cooperation with CHS and the University of New Brunswick (Wells and Lachapelle, 1981).

Other research activities dealt with the monitoring of Arctic ice movements with satellite Doppler techniques (Hittel, 1981b), the least squares prediction of horizontal coordinate distortions in Canada (Lachapelle and Mainville, 1981), and the isotropy of the empirical free air gravity anomaly covariance function.

11. University of Calgary (Surveying Engineering Division)

Research on the use of inertial technology in geodesy and surveying was especially active in three problem areas: (a) the comparison of the error models used in the available inertial survey systems (Schwarz, 1981a; 1981b); (b) the development of post-mission smoothing software for the Litton autosurveyor (Schwarz and Gonthier 1981a; 1981b; Wilkinson and Wong, 1981); (c) the design of an efficient Kalman filter for the Ferranti FILS-system (Wong, 1981).

Studies of the accurate determination of the geoid continued. Schwarz (1981c) investigated the feasibility of using a combination of gradiometry and precise satellite altimetry for the determination of sea surface topography. Previous studies on the accurate determination of the anomalous gravity field in mountainous areas were continued.

The Kananaskis test and calibration network was extended in two ways during 1981 (a) by extending the ground surveys, and (b) by establishing partial aerial coverage in cooperation with the Canada Centre for Remote Sensing using an RC-10 aerial camera and the Litton LTN-51 INS. The main objective of the aerial coverage is to use a photogrammetric block to provide the spatial geometric information necessary for a comprehensive analysis of the data provided by other airborne systems.

Research continued on the design of geodetic networks using interactive computer graphics. A software package has been written in standard FORTRAN IV (Mepham and Krakiwsky, 1981). Work on optimization of surveying and mapping this year concentrated on a review of the theory and applications of operations research techniques, and their applicability, feasibility, and usefulness has been documented (Stoliker and Anderson, 1981). Kriging estimation methods have been studied from the theoretical point of view and their relationships to other least squares methods clarified. Geodetic and photogrammetric applications of Kriging prediction methods are being investigated.

Work began on an experimental investigation of some types of systematic effects in precise levelling. A 4 km base line with permanent turning points at 25 m intervals has been established near Kananaskis. A Zeiss NI 002 reversible compensator level has been obtained. Initial independent trial experiments indicate that sinking of rod supports can continue over much longer time periods than previously thought. Problems of automatic field data recording and screening are being investigated (Anderson et al., 1981). Portable equipment and software are currently under development.

A study of engineering survey methodology has commenced. Initially, specific problems arising from western Canadian mega-projects are being investigated and a synthesis of survey methods and quality control and calibration techniques compiled. Visiting professors J. Rueger (University of New South Wales) and W. Niemeier (University of Hannover) are employed in this work.

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I (B) GRAVITY

Compiled by: R.A. Gibb

1. Summary

Gravity survey activities and gravity interpretation investigations continued in 1981 at about the same level as in recent years. Under the National Gravity Mapping Program major reconnaissance surveys were completed in the Arctic Channels (M'Clintock Channel, Davis Strait and Lancaster Sound), on the Pacific continental margin, and in the Cordillera. While progress in the reconnaissance survey of the landmass and continental margins continues, there is a trend toward an increasing emphasis on more detailed surveys (often integrated with other geophysical surveys) designed to investigate problems related to resources, to local structural features, or to the AECL nuclear fuel waste management program. Examples include resource-related studies in Saskatchewan, Nova Scotia, New Brunswick and Newfoundland; multidisciplinary studies of geological features such as the Lomonosov Ridge, the crust underlying Davis Strait, and the Juan de Fuca plate system; and geophysical studies of AECL research areas at Chalk River, Atikokan, Lac du Bonnet and East Bull Lake.

The highlight of the year in gravity map production was publication of the fourth edition of the Gravity Map of Canada, which incorporates all new data from many sources since the last edition in 1974, up until December, 1980. Preparations are also underway to produce a North American Gravity Anomaly Map. This project is being undertaken by an SEG committee which has solicited the cooperation of the international geophysics community. Plans call for publication of the map (in colour) and a transparent overlay (to fit other geothematic maps) during 1982. Also under preparation (at AGC) is a gravity compilation of the Appalachians and Caledonides which will appear on a base map showing a Mesozoic reconstruction of the North Atlantic. This project is also international in scope.

Highlights from the Universities include important theses on the relationships between continental topography and gravity (Dalhousie) and postglacial rebound, gravity and mantle viscosity (Toronto). Computational studies were continued at Memorial (inversion techniques), at Manitoba (gravitational attraction modelling), and at Calgary (terrain corrections).

Instrument developments in federal institutions focussed on testing the new LaCoste and Romberg straight line gravimeter (EPB) and the new Bodenseewerk Kss-30 sea gravimeter (AGC). The EPB tests have been successfully completed and intial tests by AGC show great promise for improved accuracy and operation with the Kss-30.

2. Earth Physics Branch

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

A transportable absolute gravity apparatus with 5 Gal precision is currently being constructed under contract by J. Faller at the Joint Institute for Laboratory Astrophysics in Boulder, Colorado. While several years of further engineering will likely be required to make this prototype instrument routinely usable under harsh field conditions, it is expected that by 1983 it will be serving a role in Canada both in vertical crustal motion studies and in the calibration of microgravimeters.

(b) Gravity Data Base (R.K. McConnell and others)

A digital terrain model (DTM) designed for use in the computation of regional terrain corrections has recently been added to the National Gravity Data Base. The DTM is organized by 1:50,000 NTS map sheets and presently contains some 1.2 million elevation picks at 1 km spacing over southern British Columbia. As new detailed topographic and bathymetric maps become available the DTM will be extended to cover all of the Western Cordillera and adjacent offshore regions. The DTM resides in a System 2000 data base and retrievals at cost should be available to users outside EPB by April, 1982.

(c) Gravity Map Production (L.A. Warren and others)

Two new open files (of M'Clintock Channel) were released during the year. Details concerning the maps, scales and locations can be found in the bibliography.

The fourth edition of the Gravity Map of Canada, GMS80-1 (scale 1:5,000,000) was released during 1981. The map features 19 colour separations at 20 mGal intervals and 10 mGal contours. English and French editions are available from the Canada Map Office, Department of Energy, Mines and Resources, 615 Booth Street, Ottawa K1A 0E9.

(d) Gravity Surveys (J.B. Boyd and others)

In 1981 approximately 7500 line kilometres of dynamic gravimeter profiling were surveyed at sea. More than 2375 static gravity measurements were occupied on land and ice-covered regions. Details of the surveys are given below by geographic area:

(i) British Columbia and Yukon

About 7500 line kilometres of dynamic gravimeter profiling were logged at sea, west of the Queen Charlotte Islands to the 200 nautical mile limit. Line spacing was 5 kilometres. The project was undertaken jointly with the Canadian Hydrographic Service.

In the first year of a two year contract survey, about 270 static gravity measurements were made in the Rocky Mountains. The survey area is defined by latitudes 53°N and 54°N and longitudes 114°W and 122°W. Horizontal and vertical positioning of stations was by helicopter-mounted inertial survey system at an average spacing of 12 km.

Approximately 665 gravity observations at 3 km intervals were made (under contract) along two traverses at precise level bench marks in Yukon and British Columbia in support of a program of the Geodetic Survey, Surveys and Mapping Branch. The first traverse commenced at Whitehorse, Yukon and proceeded north to Dawson City; the second commenced at Carmacks, Yukon and proceeded east and south via Ross River, Watson Lake and Dease Lake to Hazelton, British Columbia.

(ii) Northwest Territories

In the first year of a two year contract survey, about 280 gravity observations were made in the East Arm of Great Slave Lake at an average station spacing of 4-6 kilometres.

The two year project to complete the bathymetric and gravity survey of M'Clintock Channel jointly with the Canadian Hydrographic Service was completed. About 1000 gravity stations were observed at a spacing of 6 kilometres.

(e) Gravity Interpretation and Related Studies (R.A. Gibb and others)

(i) Western Canada (R.P. Riddihough and others)

Winona Basin

The presence of up to 7 km of sediment in this young (<2 Ma) basin has been interpreted in terms of the rapid subsidence of a young piece of oceanic crust as part of a locally complex adjustment to changing plate interactions.

Plate Tectonic Geometry, Western Canada Margin

In general, plate movements over the last 100 Ma have been alternately convergent or strike slip with respect to the America plate at speeds which are more than sufficient to explain the large northerly movements suggested by palaeomagnetic and geological studies.

Absolute Plate Motions, Juan de Fuca Plate System

Resolution of motions of this system, with respect to the 'hot-spot' framework and underlying mantle, suggest that the independence of the Explorer plate and continued slowing of convergence is a response to increasing resistance to the subduction of a smaller and smaller plate system.

Contemporary Vertical Movements, British Columbia Margin

The observed pattern of coastal uplift with subsidence further inland is not a postglacial recovery pattern and is comparable to subduction zones elsewhere.

(ii) Arctic Canada (J.R. Weber , J.F. Sweeney and L. W. Sobczak)

Lomonosov Ridge

Analysis of multiparameter geophysical and marine geological data collected during the EMR-sponsored Lomonosov Ridge Experiment (LOREX) in 1979 confirms the widely held belief that this Arctic submarine ridge was formerly part of Eurasia. It appears that initial separation was achieved by left-lateral shearing and that what is now the Alpha submarine ridge may have been part of the original Lomonosov block.

Alpha Ridge

A proposal to study the crustal nature of the Alpha Ridge has been prepared and is presently under review. If approved, this EMR-sponsored sequel to LOREX will be deployed during the spring of 1983.

Arctic Research Objectives

Major progress has been made in identifying future Arctic research objectives in Canada and throughout the Arctic generally. A nationwide survey of geoscientists working in Arctic regions indicates that research interest in Canada's north is focused on the structure and development of the polar margin, early Paleozoic tectonics, sedimentary processes and the geodynamic history of the northern Yukon region.

Arctic Archipelago

A report on the fragmentation of the Canadian Arctic Archipelago - Greenland region during the last 60 Ma is now in press (Meddelesler om Gronland). Possibly three rift-transform shear zones and two triple junctions are indicated from a pattern of northeast trending fractures and northwest trending rifts.

(iii) Canadian Shield (R.A. Gibb, A.K. Goodacre, L.W. Sobczak and M.D. Thomas)

Northern Saskatchewan

A preliminary report is in preparation on the analysis of gravity data (released by Canada Wide Mines Ltd.) over the Midwest Lake uranium deposit at south McMahon Lake, as part of a cooperative project with the Geological Survey of Canada, the Saskatchewan Geological Survey and other provincial agencies sponsored by the Nuclear Energy Agency and International Atomic Energy Agency. Results show no gravity correlation with radioactive deposits on a regional scale. However on a detailed scale there is a related anomaly minimum of amplitude 1.1 mGal but most of this anomaly can be explained by water, overburden and sandstone layers.

Proterozoic Plate Tectonics

The possible role of plate tectonics in the development of major faults in the Canadian Shield was discussed in a review paper that incorporates both previously published and new material. Areas examined include the Slave-Churchill boundary zone, the Superior-Churchill boundary zones in northern Manitoba and Saskatchewan and in Labrador, and the Grenville Front Tectonic Zone.

Chalk River

A further 285 gravity observations were made at the AECL, Chalk River property to determine the regional gravity field. Station spacing ranged from 50 to 400 metres.

Monteregian Hills

The gravity survey of the Monteregian Hills in the Eastern Townships of Quebec continued during 1981 with 90 stations being occupied on and around Rougemont and 61 stations on and around Yamaska. In-situ measurements of magnetic susceptibility were made at selected locations on both hills and, wherever possible, samples were taken for rock density measurements.

(iv) Eastern Canada (A.K. Goodacre)

Gaspé Peninsula

Analysis of gravity, magnetic and crustal seismic profiles indicates the presence of a considerable thickness of Palaeozoic sedimentary rocks near Lac Temiscouata and Lac Matapédia.

(v) Theoretical Gravity (D. Nagy)

A weighted least squares method was applied to derive a polynomial approximation for the theoretical gravity formula. In this way, the maximum error obtained using regularly distributed data can be reduced and at the limit can be as small as that of the Chebyshev approximation.

(vi) Plotting Software (D. Nagy)

Utilizing the World Data Bank II information, a program has been developed to draw coastlines, index maps and polygons from geographic and/or cartesian coordinates. To help those whose primary interest is not graphic display, the various features of the program are explained in an INDEXMP write-up.

(f) Dynamic Gravimetry (H.D. Valliant)

Testing of the new LaCoste and Romberg straight-line gravimeter has been completed. Results show that the new meter is free from cross-coupling errors.

New micro-processor electronics to control the marine gravimeter and its inertial platform, and to record its data have been completed. The prototype system was field-tested in August, 1981 and found to work well.

(g) Geodynamics (A. Lambert and others)

(i) Precise Gravimetry

Semi-annual resurveys of precise gravity networks in seismically active areas of Charlevoix, Quebec and Vancouver Island, British Columbia continued through 1981. The structure of both networks was changed to improve their homogeneity.

A 170 kilometre long precise gravity profile from Tofino to Horseshoe Bay, British Columbia was established by air in 1981 by personnel of the Pacific Geoscience Centre. The profile provides baseline observations to a precision of a few microgals for the study of long term differential vertical crustal movement between Vancouver Island and the mainland.

A 60 kilometre long gravity/levelling profile at the La Grande 2 reservoir, first established in 1978, was successfully resurveyed in 1981. The observed gravity and level changes induced by the reservoir load will be compared to the theoretical changes for a realistic earth model.

(ii) Measurement of Crustal Tilt

An experiment to study the spatial coherence of observed tilt measured by near-surface, short-baselength tiltmeters (Earth Physics Branch), precise relevelling of a local bench mark array (Université Laval), and vertical pendulum borehole tiltmeters (Dalhousie University) continued in 1981 at Charlevoix, Quebec. Clear correlations are seen between surface tilt and water-levels in adjacent boreholes. The attenuation of these effects with depth is being investigated.

(iii) Aquifer Tide Studies

Monitoring of tidal and atmospheric pressure induced variations of water level in uncased boreholes at Chalk River continued in 1981. The theory relating water level variations to the orientation, aperture, compressibility and length of dominant fractures has been developed further. Current experiments are being carried out in packed-off sections of borehole intersecting particular known fractures.

3. Atlantic Geoscience Centre (AGC)

(a) Marine Gravity Measurements (R. Macnab and others)

(i) Davis Strait

In a multiparameter survey program carried out in collaboration with the Canadian Hydrographic Service aboard CSS DAWSON and CSS HUDSON, more than 19,000 line kilometres of gravity data were collected in Davis Strait. Survey coverage consisted largely of a series of east-west profiles beginning near the coast of Baffin Island. Lines run by HUDSON were spaced at 38 km intervals and extended as far east as the coast of Greenland; these were planned to complete a large-scale regional reconnaissance mapping program that was initiated in 1980. The survey pattern run by DAWSON was designed to interline the regional survey tracks; lines were spaced at 9 km intervals.

(ii) Lancaster Sound

In a supplementary hydrographic survey program involving CSS HUDSON, several closely-spaced profiles were run across the eastern end of Lancaster Sound, between Devon Island and the Borden Peninsula. Some 140 line kilometres of data were collected in this area, using the Argo positioning system.

(b) Davis Strait Interpretations (S.P. Srivastava and others)

Gravity and magnetic measurements made during the Davis Strait hydrographic-geophysics survey in 1980 have been combined with previously collected data in order to examine crustal structure. Interpretation of seismic and potential field information suggests that the sill forming the central part of Davis Strait is underlain by a crust that shows closer affinity with continental crust than with oceanic crust. It is perhaps a fragment of Baffin Island crust that got detached during the early stage of sea floor spreading in the Labrador Sea.

(c) Caledonide Orogen

As part of IGCP Project 27 "The Caledonide Orogen" gravity and magnetic data at the northern termination of the Appalachians and southern termination of the Caledonides were compiled at a scale of 1:5,000,000 on an early Mesozoic reconstruction of the North Atlantic, as an aid to testing the suggested geological continuity between the two regions. This is the initial stage of an international compilation for the entire Appalachian/Caledonide orogen.

(d) Labrador Sea Gravity Data

Serious problems have been encountered in merging gravity data from various cruises in the Labrador Sea. Accordingly, the entire data set will be subjected to an adjustment procedure designed in cooperation with the Gravity and Geodynamics Division, Earth Physics Branch to achieve high internal consistency.

It is necessary also to consolidate all Gravity Harbour Base Connection Data as a separate data base and to edit all calibration data for sea gravimeters from all cruises through the Labrador Sea.

(e) Kss-30 Sea Gravimeter

AGC recently acquired the latest instrument of the new generation of sea gravimeters. This is the Kss-30 system, designed and built by Bodenseewerk Geosystem, Uberlingen, Germany (successors to Askania). The main features of the new instrument are: (i) new design of a null reading sensor; (ii) digital signal processing in both the gravimeter and platform control loops; (iii) compact design of sensor and platform; and (iv) interface with an external digital computer for input of navigational information and output of gravity observations.

The Kss-30 sea gravimeter system was taken to sea for the first time on the BIO ship CSS DAWSON in July 1981. Subsequent trials were carried out in September and November, 1981. On test over the Halifax test range, the instrument has demonstrated a capability of measuring gravity with an accuracy of better than 5 mGal. It is expected that a survey accuracy of $\pm$ 1 mGal RMS is achievable when software improvements based on the last set of trials are implemented.

(f) Data Processing

Two software packages have been developed for the processing, archiving, and retrieval of marine potential field data. SHIPAC was developed in-house and runs on shipboard minicomputers. In addition to performing quality control of raw gravity and magnetics coupled with editing and correcting, it combines navigational and bathymetric information with potential field data, and performs preliminary processing and display. GEOFFREY was developed under outside contract and runs on a shore-based mainframe. It performs final processing of the data with provision for adjustments and corrections to achieve consistency between adjacent and overlapping data sets.

4. Memorial University of Newfoundland (H. Miller and others)

(a) Gravity Surveys

(i) Avalon Peninsula

Surveying of the Avalon Peninsula has continued with an additional 130 stations at approximately 2.5 km spacing being added to the grid, thereby completing the survey of the northern portion of the Avalon on both sides of Conception Bay. The 1980 data have been partially interpreted in a B.Sc. thesis by Pittman (1981). Final interpretation awaits the completion of an underwater survey in Conception Bay, scheduled for 1982.

(ii) Deer Lake Basin

A new project in the Deer Lake Carboniferous Basin commenced in 1981 as part of a multifaceted geophysical and geological study of the basin configuration. A total of 325 stations were surveyed, approximately 265 of these at 2.5 km spacing in the basin and on the flanks, and 60 at 0.2 km spacing along three seismic lines.

(b) Inversion Techniques

Studies on gravity inversion techniques are continuing. W. Nickerson (1981) completed a B.Sc. thesis on Pederson's 1977 and 1979 inversion methods and has produced computer programs for utilizing these techniques.

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

Approximately 600 gravity stations were measured in the Stellarton-Thorburn area of Nova Scotia as part of a Research Agreement program funded by the Department of Energy, Mines and Resources. These data will be combined with older gravity measurements to investigate the geological structure of the coal-bearing Pennsylvanian sedimentary basin.

A computer program to calculate the gravity effect of an infinite horizontal polygonal body was converted to a "2 1/2 dimensional" program by incorporating end-corrections.

Commercial gravity surveys were carried out over potash, barite and base metal prospects in both Nova Scotia and New Brunswick.

6. McGill University (O.G. Jensen)

The Development and Deployment of an Extremely High Sensitivity-High Stability Gravimeter/Tiltmeter Observatory

Cooperation between O.G. Jensen and D.E. Smylie of York University concerning the development and installation of extremely-high stability gravimeter/tiltmeter systems has continued during the past two years. Between January and May 1980, Jensen (then on sabbatical leave at York University) undertook a thorough comparative evaluation of the different electronic subsystems being employed in the McGill and York installations. Several serious problems were discovered affecting both systems which are now in the process of being corrected or resolved.

Recently, Smylie has developed a null-test instrument whose sensitivity to accelerations or tilts has been reduced by 5 orders of magnitude over the standard Linton Moore gravimeter. This special instrument is now being used in a mock-up system to determine the ultimate level of stability of the new electronic systems. Subsequently, gravimeter intercomparisons will be conducted to obtain measures of their inherent spectrum of random noise and eventually comparisons with other instruments of different designs will determine "relative" systematic drifts and noise levels.

7. Ontario Geological Survey, Ministry of Natural Resources (V.K. Gupta and others)

The interpretation program to study data from more than 10,500 gravity stations and more than 3400 rock density measurements covering an area of 33,000 km^2 in north-central Ontario

has begun. The interpretation is directed primarily at solving regional geological problems. Extensive use is being made of ODM/GSC aeromagnetic maps to provide geological details and remove ambiguities in the interpretation.

8. University of Toronto (W.R. Peltier and P. Wu)

Postglacial Rebound, Gravity and Mantle Viscosity

A detailed examination of the response of Maxwell models of the Earth to surface mass loads was undertaken. Particular attention was devoted to the factors that determine the isostatic response, since the understanding of this response is crucial in a number of geodynamic problems. One example discussed in detail was concerned with the prediction of free air gravity anomalies produced by large scale deglaciation events. Using the methods developed it was possible to provide the first direct assessment of the importance of initial isostatic disequilibrium on the observed relative sea level variations and free air gravity anomalies formed by the melting of the Laurentide ice sheet. The extent to which such initial disequilibrium might influence the inference of mantle viscosity from isostatic adjustment data has been estimated. The calculations established that free air gravity data, although sensitive to the degree of the initial disequilibrium, provide an extremely high quality constraint upon the viscosity of the lower mantle. A maximum value of 10^{23} poise below the seismic discontinuity at 670 km depth was inferred.

9. University of Western Ontario (L. Mansinha and others)

A gravity survey carried out by the Ontario Geological Survey indicates a prominent anomaly northwest of New Liskeard, Ontario. An interactive surface fitting procedure was developed and tested to separate the regional anomaly from the residual. The contributions of near surface geologic units were estimated and subtracted from the residual. Two intrusive models, with burial depths of 3 km and 4 km were fitted to the data set. Common to both models is the fact that they are partitioned into roughly east and west units. This division is thought to be due to a major fault system which is instrumental in controlling the shape of the intrusive body. Finally the fitted models were refined by an interactive non-linear least squares process.

10. University of Manitoba (W. Moon and others)

(a) Theoretical Studies of Potential Field Modelling

A new method for geopotential field computation and gravitational attraction modelling was developed. The usual method is to use a uniform density discrete numerical integration to represent either the gravitational potential or the gravitational attraction from a given density configuration. If an interpolation scheme is used to represent the arbitrarily varying density configuration, the potential integration is greatly simplified and in some cases where symmetry exists, analytical evaluation of the integral is also possible. The basic theory and the numerical test results for salt domes and vertical dykes with continuously varying density will be published. Patrick Lui and W. Moon extended this new method for magnetic potential field modelling as well as the generalization of the gravity modelling.

(b) Theoretical Study of Earth's Dynamic Parameters

In whole Earth geodynamics, the internal density structure, the rotation rate of the Earth, the figure and the thermal history model (and mantle convection model) are all interrelated. Robert Tang and W. Moon investigated some of these parameters throughout geological time, and computed the Earth's axial moment of inertia and the hydrostatic ellipticity of the Earth for several formation models as a function of time. Currently the preliminary results are being tested with recently proposed thermal history models for the Earth.

11. University of Calgary (J.A.R. Blais and others)

Terrain Corrections

Under a contract with the Earth Physics Branch, Ottawa, the investigation of gravimetric terrain corrections has continued over the past year. Results of the feasibility study on accuracy requirements for Western Canada and comparison of existing computer software were presented at the CGU meeting of May, 1981. The second phase of this project includes the development of computer software using optimal computational methods for the terrain corrections.

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II SEISMOLOGY AND PHYSICS OF THE EARTH'S INTERIOR

Compiled by: E.R. Kanasewich

1. Canadian Seismograph Stations

The seismograph facilities administered by the Earth Physics Branch of the Department of Energy, Mines and Resources, Ottawa, and several Canadian universities are listed in Table 1.

The following changes were made to the Eastern and Western Canada Telemetered Networks (ECTN and WCTN) during 1981. Three radio-telemetered stations at Chalk River, Ontario, and Grand-Remous and Mont-Tremblant, Québec, were added to the ECTN, the former (CKO) on January 12, and the latter two (GRQ, TRQ) on March 16, 1981. The ECTN was further expanded to incorporate four telephone-linked stations at Grosses-Roches (GSQ), Québec, and Edmundston (EBN), St. George (GGN) and Caledonia Mountain (LMN), New Brunswick, on October 28, 1981. Two data stream concentrators were installed at St. John, New Brunswick, and Rivière-du-Loup, Québec, to minimize telephone line requirements. The station MIQ at Maniwaki, Québec, was closed on June 30, 1981. The ECTN computer operating system was upgraded to handle thirty 60-sample/sec components, in a variety of multiplexing schemes, plus the nine GAC borehole components.

An expanded version of the computer operating system, similar to that of the ECTN, was installed in the WCTN to handle three new radio-telemetered stations at Saturna Island (SNB), Sechelt (SHB) and Campbell River (CBB), B.C. on January 28, 1981. The station PIB at Pender Island was closed on April 27, 1981 and a telephone-linked station at Whistler (WHB) was added to the WCTN on November 9, 1981.

2. Canadian Seismicity - Earth Physics Branch, Ottawa (EPB), and Pacific Geoscience Centre, Sidney, B.C. (PGC)

(a) Canadian Earthquakes

(i) Preliminary Summaries, Catalogues and Earthquakes of 1981

For 1981 the following provisional data are available. Twenty-seven earthquakes with magnitude of 4.0 or more occurred in or near Canada; five of these had magnitude 5.0 or greater. The largest, magnitude 5.6, occurred on 24 August in the northern Labrador Sea, southeast of Frobisher Bay, N.W.T. The other earthquakes with magnitude 5.0 or greater occurred on 04 January near Thule, Greenland, on 14 February in the Mount St. Helens area of Washington State, on 14 June in the northern Yukon Territory south of Inuvik, N.W.T. and on 18 August northeast of Baker Lake, N.W.T. All earthquakes in eastern Canada in 1981 had magnitudes less than 4.0.

Forty-four earthquakes in or near Canada were reported felt, but no significant property damage was reported. The most widely felt tremors were the ones near Mount St. Helens, Washington, on 14 February, felt from southern British Columbia to northern California, and two tremors located near Cornwall, Ontario, on 04 and 05 July with magnitudes of 3.6 and 3.4, respectively, which were felt to distances of 70 km in Ontario, Québec and New York State. The strongest intensities experienced in Canada from earthquakes in 1981 were isolated reports of intensity V at Kuroki, Saskatchewan, from a magnitude 3.1 earthquake on 10 January and intensity IV-V at Maxville and St. Raphael's West, Ontario, from the first earthquake near Cornwall, Ontario on 04 July.

(ii) Special Studies

Eastern Canada

J. Drysdale and J. Bérubé (EPB) conducted a field survey of aftershock activity near Cornwall, Ontario, following the two earthquakes of 04 and 05 July with magnitudes 3.6 and 3.4, respectively. Three analogue seismographs and one digital event detector were deployed in the epicentral area from 06 to 10 July. Two aftershocks, magnitude 1.9 and 0.2 on 07 and 08 July, respectively, were recorded by the analogue systems, but none was recorded by the digital system. Epicentral distances were in the range from 5 to 9 km. Hypocentral solutions including the field data give focal depths for the aftershocks in the range from 13 to 19 km.

G. Buchbinder and F. Anglin (EPB) continued their studies of the microseismicity pattern in the Charlevoix region. Data were obtained from the six-element telemetered array and the two stations, LMQ and LPQ. Correlations between the projected hypocentres and some of the northeast trending faults exposed on the north shore of the St. Lawrence River were noted.

Seismic monitoring of the LG-2 reservoir, Québec, continued using the new regional station LTQ located near the LG-3 dam site. No earthquakes were located in the region of the LG-2 reservoir during 1981. Using the new array of stations, JAQ, JBQ and JCQ, three small events ($M_L \leq 1$) were located in the region of the LG-3 reservoir.

H.S. Hasegawa (EPB) is studying Lg spectra of local earthquakes recorded by the Eastern Canada Telemetered Network (ECTN) and has derived spectral scaling laws for eastern Canadian earthquakes using digital ECTN records for smaller ($M < 4.5$) earthquakes and standard station analogue records for larger ($4.5 < M \leq 6.6$) earthquakes. For the smaller earthquakes both seismic moment and corner frequency have a weaker dependence on magnitude than do larger events.

J. Adams (EPB) has investigated disturbances in 8500-yr-old glaciolacustrine varved sediments near Iroquois Falls, Ontario. Historic earthquake effects in eastern Canada suggest the earthquake had magnitude 5.7 or greater.

Table 1 Canadian Seismograph Stations (December 31, 1981)

	STATION CODE	STATION	LATITUDE °N	LONGITUDE °W	COMMENT
		Standard Stations (Energy, Mines and Resources)			
1.	ALE	Alert, N.W.T.	82.48	62.40	
2.	EDM	Edmonton, Alta.	53.22	113.35	University of Alberta
3.	FCC	Fort Churchill, Man.	58.76	94.09	
4.	FFC	Flin Flon, Man.	54.73	101.98	
5.	FRB	Frobisher Bay, N.W.T.	63.75	68.55	
6.	INK	Inuvik, N.W.T.	68.29	133.50	
7.	LHC	Thunder Bay, Ont.	48.42	89.27	
8.	MBC	Mould Bay, N.W.T.	76.24	119.36	
9.	MNT	Montréal, Qué.	45.50	73.62	
10.	OTT	Ottawa, Ont.	45.39	75.72	
11.	PGC	Sidney, B.C.	48.65	123.45	
12.	PHC	Port Hardy, B.C.	50.71	127.43	
13.	PNT	Penticton, B.C.	49.32	119.62	
14.	RES	Resolute, N.W.T.	74.69	94.90	
15.	SCH	Schefferville, Qué.	54.82	66.78	
16.	SES	Suffield, Alta.	50.40	111.04	
17.	STJ	St. John's, Nfld.	47.57	52.73	
18.	YKC	Yellowknife, N.W.T.	62.48	114.47	
		Regional Stations (Energy, Mines and Resources)			
19.	BLC	Baker Lake, N.W.T.	64.32	96.02	
20.	BMS	Minton, Sask.	49.21	104.79	
21.	BQB	Bob Quinn Lake, B.C.	57.02	130.24	B.C. Hydro, commenced Oct. 9, 1981
22.	CHQ	Charlesbourg, Qué.	46.89	71.30	
23.	DLB	Dease Lake, B.C.	58.43	130.07	B.C. Hydro, commenced Oct. 7, 1981
24.	DLY	Dezadeash Lake, Y.T.	60.37	137.06	Closed April 1, 1981
25.	EFO	Effingham, Ont.	43.09	79.31	
26.	FSB	Fort St. James, B.C.	54.48	124.33	
27.	GDR	Gold River, B.C.	49.78	126.05	
28.	HAL	Halifax, N.S.	44.63	63.60	
29.	HYT	Haines Junction, Y.T.	60.82	137.50	Commenced July 27, 1981
30.	IGL	Igloolik, N.W.T.	69.38	81.81	
31.	KBT	Komakuk Beach, Y.T.	69.59	140.18	Dome, commenced Aug. 8, 1981
32.	KEY	Kluane Lake, Y.T.	61.05	138.50	Closed July 25, 1981
33.	KRY	Koidern River, Y.T.	61.97	140.41	Closed April 1, 1981
34.	LMQ	La Malbaie, Qué.	47.55	70.33	
35.	LTQ	LaGrande-3, Qué.	53.70	76.09	
36.	MCE	Mica Creek, B.C.	52.01	118.56	Closed Aug. 12, 1981
37.	MNB	Mount Dainard, B.C.	52.20	118.38	B.C. Hydro, commenced Sept. 29, 1981

Table 1 (continued)

	STATION CODE	STATION	LATITUDE °N	LONGITUDE °W	COMMENT
38.	MUB	Muncho Lake, B.C.	58.96	125.76	B.C. Hydro, commenced Oct. 14, 1981
39.	NPT	Nicholson Point, N.W.T.	69.93	128.96	Dome, commenced Aug. 08, 1981
40.	PBQ	Poste-de-la-Baleine, Qué.	55.28	77.74	
41.	PWM	Pinawa, Man.	50.19	96.04	
42.	QCQ	Québec City, Qué.	46.78	71.28	
43.	SIC	Sept-Iles, Qué.	50.19	66.74	
44.	SKB	Skidegate, B.C.	53.25	132.00	
45.	SUD	Sudbury, Ont.	46.47	80.97	
46.	SWT	Sachs Harbour, N.W.T.	71.99	125.28	
47.	TUK	Tuktoyaktuk, N.W.T.	69.44	133.03	
48.	UNB	Fredericton, N.B.	45.95	66.63	
49.	WHC	Whitehorse, Yukon	60.74	135.10	
		Eastern Canada Telemetered Network (ECTN) (Digital recording, single component) (Energy, Mines and Resources)			
50.	CKO	Chalk River, Ont.	45.99	77.45	Commenced Jan. 12, 1981
51.	EBN	Edmundston, N.B.	47.54	68.24	Commenced Oct. 28, 1981
52.	FHO	Fitzroy Harbour, Ont.	45.45	76.22	
53.	GAC	Glen Almond, Qué.	45.70	75.47	3-comp., SP and LP borehole seismograph
54.	GGN	St. George, N.B.	45.12	66.82	Commenced Oct. 28, 1981
55.	GNT	Gentilly, Qué.	46.36	72.37	
56.	GRQ	Grand-Remous, Qué.	46.61	75.86	Commenced Mar. 16, 1981
57.	GSQ	Grosses-Roches, Qué.	48.91	67.11	Commenced Oct. 28, 1981
58.	JAQ	LaGrande-3, Qué.	53.80	75.72	Commenced Mar. 31, 1981
59.	JBQ	LaGrande-3, Qué.	53.61	75.60	Commenced Apr. 1, 1981, then closed as ECTN stations on Aug. 17, 1981, but continued as regional stations
60.	JCQ	LaGrande-3, Qué.	53.47	75.82	
61.	LDQ	La Grande-2, P.Q.	53.81	77.43	Closed March 10, 1981
62.	LMN	Caledonia Mountain, N.B.	45.85	64.81	Commenced Oct. 28, 1981
63.	LPQ	La Pocatière, Qué.	47.34	70.01	
64.	MIQ	Maniwaki, Qué.	46.37	75.97	Closed June 30, 1981
65.	MNQ	Manicougan, Qué.	50.53	68.78	
66.	MNT	Montréal, Qué.	45.50	73.62	
67.	OTT	Ottawa, Ont.	45.39	75.72	
68.	SBQ	Sherbrooke, Qué.	45.38	71.93	
69.	TRQ	Mont-Tremblant, Qué.	46.22	74.56	Commenced Mar. 16, 1981
70.	VDQ	Val-d'Or, Qué.	48.23	77.97	
71.	WBO	Williamsburg, Ont.	45.00	75.28	

Table 1 (Continued)

	STATION CODE	STATION	LATITUDE °N	LONGITUDE °W	COMMENT
		Western Canada Telemetered Network (WCTN) (Digital Recording, single component) (Energy, Mines and Resources)			
72.	ALB	Port Alberni, B.C.	49.27	124.83	
73.	CBB	Campbell River, B.C.	50.03	125.36	Commenced Jan. 28, 1981
74.	HNB	Haney, B.C.	49.27	122.58	
75.	PGC	Sidney, B.C.	48.65	123.45	
76.	PIB	Pender Island, B.C.	48.80	123.32	Closed April 27, 1981
77.	SHB	Sechelt, B.C.	49.60	123.87	Commenced Jan. 28, 1981
78.	SNB	Saturna Island, B.C.	48.77	123.17	Commenced Jan. 28, 1981
79.	WHB	Whistler, B.C.	50.13	123.96	Commenced Nov. 09, 1981
		Yellowknife Array, N.W.T. (Energy, Mines and Resources) (18 elements of short-period vertical recording, analog telemetry, digital event storage; 3 elements of long-period vertical recording)			
80.	YKA	Yellowknife Array	62.493	114.605	Centre
		Special Stations (Energy, Mines and Resources)			
81.		Charlevoix Array, La Pocatière, Qué.	47.55	70.33	A six-element telemetered array recording on analog tape.
		University of British Columbia (Mica Dam, B.C. telemetered array, analog single component)			
82.	DPR	Downie Peak Ridge	51.575	118.196	
83.	GST	Gold Stream	51.660	118.685	
37.	MNB	Mt. Dainard, B.C.	52.1986	118.3845	
84.	TAB	Tabernacle Mtn., B.C.	51.7512	117.7617	
85.	THO	Mt. Thompson, B.C.	52.6892	119.1208	
86.	SPR	Mt. Spring-Rice	52.015	117.256	
87.	EPM	Eagle Pass Mtn.	51.063	118.540	
88.	SLE	Sale	51.167	118.134	
		University of Manitoba			
89.		Glenlea, Manitoba (one short-period cluster of Willmores and one vertical long-period on analog tape)			

Table 1 (Continued)

	STATION CODE	STATION	LATITUDE °N	LONGITUDE °W	COMMENT
		University of Western Ontario (Seismic array on FM analog tape)			
90.	LND	London	43.040	81.183	
91.	DLA	Delaware	42.858	81.390	
92.	ELF	Elginfield	43.193	81.315	
		University of Alberta			
2.	EDM	Edmonton - 3 components of the standard short-period station are recorded digitally at 18 times per second as 14-bit words. Three components of the standard long-period station are recorded digitally 3 times per second.			
93.	MLE	Marie Lake Environment	54.5938	110.3007	Single Z
94.	ELE	Ethyl Lake Environment	54.5344	110.3243	5-component
95.	LPE	Leming Plant Environment	54.6208	110.4302	Single Z
96.	HLE	Hilda Lake Environment	54.5014	110.4798	Single Z
97.	LLE	Leming Lake Environment	54.6074	110.5014	Single Z
98.	BLE	Bourque Lake Environment	54.6776	110.5823	Single Z
		Stations 93 to 98 are provincially owned, Alberta Environment stations with data interpreted at the University of Alberta. All stations have buried single vertical seismometers at depths of 66 to 135 m. The data are telemetered to the Ethyl Lake Base Station and recorded continuously in a digital format at 55.5 Hz or 167 Hz. ELE has a 3-component short period system and a small array of vertical seismometers.			
		Memorial University			
99.	CBK	Corner Brook, Nfld.	48.92	57.97	Single-component short-period station
100.	PKP	Parker's Pond, Nfld.	47.5859	52.7834	Short period vertical telemetered station
		University of Saskatchewan			
101.		Saskatoon, Sask.	52.1916	106.3835	Digital recording short-period station in process of installation

J. Adams, in conjunction with workers at AGC and EPB, has begun an investigation of seismicity offshore from Nova Scotia and Newfoundland. A key problem is understanding the nature and cause of the 1929 Grand Banks earthquake and determining the frequency of similar earthquakes.

Central Canada

Unusual seismic activity near Saskatoon, Saskatchewan, is shown to correlate both spatially and temporally with increased (potash) mining activity southwest of Saskatoon. A paper titled "Induced earthquakes at a potash mine near Saskatoon, Canada" by D.J. Gendzwill (U. of Sask.), R.B. Horner (PGC) and H.S. Hasegawa (EPB) will appear in the Can. J. Earth Sci. in 1982.

Western Canada

R.J. Wetmiller (EPB) has completed analysis of the microearthquake data collected in the fall of 1980 in a field survey near Rocky Mountain House, Alberta. Sixty-seven earthquakes, $M \leq 2.1$, were located in a 21-day period. The activity is concentrated in a volume approximately 4 km (N-S) x 4 km (E-W) x 2 km (vertical) located at 52°12.5'N, 115°15.0'W and at a depth of 4 km below sea level. The well-defined composite P-nodal solution suggests predominantly thrust faulting on faults striking S23°W and dipping 43°NW or striking E58°S and dipping 62°NE with the principal axis of deviatoric compression striking N82°E and plunging 11°. The location of the seismogenic zone and the mechanism derived from the field data are believed to be equally applicable to the more than one hundred earthquakes with magnitudes as large as 3.5 that have occurred in the region since 1976.

The seismogenic zone lies in or immediately underneath the Strachan D3A gas reservoir, a Devonian-age limestone reef. Some of the seismic activity appears to be spatially related to the gas-producing wells. However, daily individual production curves from the wells for a 13-month period from September, 1979 to September, 1980 do not show a direct relationship to the rate of seismic activity as recorded at the EDM seismograph station 175 km northeast of the seismogenic zone.

D.H. Weichert (PGC) has carried out a program of monitoring microseismicity in the area of the Frank Slide, Alberta. No events clearly associated with the slide area, which might suggest future hazard, were detected.

D.H. Weichert participated in a joint project with Atlantic Geoscience Centre and Dome Petroleum Ltd. to monitor the seismicity of the Beaufort Sea employing ocean-bottom seismographs and calibration explosions.

G.C. Rogers (PGC) has evaluated 3 years of data in the WCTN region to compare magnitudes based on vertical amplitudes and magnitudes based on signal duration. The duration magnitudes are more internally consistent and comparison with magnitudes computed from Wood-Anderson seismographs shows the duration magnitudes are very similar while the vertical amplitude magnitudes are about one half a magnitude unit too low.

G.C. Rogers has reviewed the seismicity associated with the volcanic regions of British Columbia. The Garibaldi Belt and the Anahim Belt have slightly higher seismicity than surrounding regions but no seismicity has been associated with a specific volcano.

R. Horner (PGC) has continued an evaluation of the seismicity of SW Yukon.

(b) Strong Motion, Seismic Risk and Earthquake Engineering

P.W. Basham, F.M. Anglin (EPB) and D.H. Weichert (PGC) have prepared new seismic risk maps of Canada depicting peak horizontal acceleration and velocity at a probability of exceedence of 10% in 50 years. Basham used the new maps as a regional framework for a more detailed assessment of earthquake risk along the proposed ALCAN pipeline route in the southwestern Yukon.

The new risk maps also provided the regional framework for a comprehensive assessment by P.W. Basham, P. Morel-à-l'Huissier and F.M. Anglin of the seismic ground motion required for design of LNG terminals at Gros Cacouna, Québec, and Melford Point, Nova Scotia, the two locations being considered for the southern terminal of the Arctic Pilot Project.

During 1981, two contracts with Geo-Analysis Ltd., Ottawa, and a master's thesis by J. Harris of Carleton University were completed on a study of linear features from Landsat imagery over areas in northeastern and northwestern Ontario. In addition, magnetic anomaly maps for the same areas were compiled at EPB. From a comparison of seismicity, Landsat, magnetic and geology data sets, D.A. Forsyth (EPB) has suggested that earthquakes may correlate with some linear features and that the Kapuskasing structural zone may be more active than previously thought. P. Morel-à-l'Huissier (EPB) has reviewed the geological information available on the Kapuskasing-Timiskaming area. A tectonic map and a synthetic geological map have been produced to aid the interpretation of the geophysical data.

3. Atlantic Geoscience Centre

Seismology

(a) Seismic Reflection/Refraction Studies

(i) LASE (Large Aperture Seismic Experiment)

This experiment involved multichannel seismic methods somewhat modified to extend the effective array length. The objective was to determine whether the deep structure of continental margins could be delineated using deep reflection/refraction techniques. The experiment was conducted across the continental margin off the coast of New Jersey. Plans are being formulated to carry out a similar experiment off Eastern Canada in 1983.

(ii) FRAM III

The Fram experiment involved OBS refraction and single channel 5000 joule sparker seismic reflection in the Arctic Ocean Basin and on the Yermak Plateau. The objective was to determine oceanic crustal thickness east of the Mid Arctic Ridge and the structure of the plateau. Four successful refraction lines describe thin oceanic crust and a 12 km thick section on the flanks and top of the plateau. The data is presently being interpreted in terms of the plate tectonic history of the region.

(iii) LADLE

The data analysis from this long range seismic experiment over oceanic lithosphere in the Western Atlantic has been completed. The results show that the crust-mantle transition occurs over about 2 km, below which a velocity of 8.2 km/s is observed. This velocity is associated with a very small positive gradient. At a depth of 20 km the velocity increased rapidly to 8.4 km/s, forming a high velocity lid, such that a low velocity layer occurs between 20 and 45 km. Below 45 km, velocities as high as 8.5 - 8.6 km s^{-1} are present, and exhibit small positive velocity gradients. Although arrivals were recorded to ranges of 1200 km, there is no evidence for a deep low velocity zone at the base of the lithosphere.

Physics of the Earth's Interior

(a) Geodynamics

Modelling the evolution of rifted continental margins is being continued by C. Keen and C. Beaumont (Dalhousie). The models have now been successfully applied to the Nova Scotian and Labrador margins off Eastern Canada and to two segments of the margin off the eastern U.S. Results show that the rim of the marginal sedimentary basins are most sensitive to details of the extensional processes and to the state of isostacy during rifting. Depth-dependent extension, in which the amount of extension varies with depth, appears to produce the best fit to the data.

In order to apply the models as a tool in petroleum exploration, studies of the physical properties of the sediments are in progress. Radiogenic heat production was measured (with T. Lewis, PGC) on 32 sediment samples from the Nova Scotian shelf. The results showed that heat production in the sediments provide an important contribution to their paleotemperatures. Thermal conductivity measurements of sediments are also in progress (with J. Wright, Memorial).

S. Srivastava has completed a study of the origin and evolution of Davis Strait, using a compilation of geological and geophysical data. The Strait is interpreted to be underlain by crust which exhibits affinities to that of the Iceland-Faeroe Ridge. It was uplifted either due to excess volcanism or to the presence of a hot spot in mid-Paleocene time. The western side of Davis Strait probably contains fragments of continental crust which had formed part of south Baffin Island shelf prior to separation of Greenland from Baffin Island. Its eastern side contains old basaltic flows intermixed with sediments. Sometime in Paleocene or earlier times the portion of the shelf which constitutes the western side of the Strait was detached from Baffin Island shelf and started to move north, either as part of the Greenland plate or independently, along a leaky transform fault relative to Baffin Island. It stopped moving in early Oligocene time when sea-floor spreading ceased in the Labrador Sea.

4. Earth Physics Branch

Seismology

(a) Lithospheric studies

As part of a continuing Earth Physics Branch program to search for changes in seismic velocities in the seismically-active La Malbaie, Québec, area, four more calibration shots were fired in June and October, 1981, by G. Buchbinder and recorded by EPB staff using up to 17 instruments at up to 14 sites. Variations of 10 to 15 ms were detected with respect to the 1980 shots.

D.A. Forsyth and A. Mair completed a study on crustal structures of the Canada Basin near Alaska, and the Lomonosov Ridge and adjoining basins near the North Pole. The work indicates that the crust of the Lomonosov Ridge is of near-continental thickness ($\sim$27 km), has an asymmetric root dipping beneath the Makarov Basin but lacks a "normal" continental upper crustal layer with p velocity near 6.1 km/s. The structure of the ridge closely resembles that of the Kara Sea shelf at 82°N, supporting the view that the ridge may be a fragment split from the shelf by the opening of the Eurasian basins.

D.A. Forsyth and A.G. Green are continuing the interpretation of part of the USGS refraction data across the Arabian Shield-Red Sea transition. The model suggests that the crust thickens from 15 km east of the Red Sea rift to near 20 km beneath the western edge of the Arabian Shield. The upper-mantle velocity appears to be near 8.6 km/s.

K. Yamazaki (Visiting Fellow) and his collaborators in Japan have investigated the temporal behaviour of seismicity along the interplate region of northeastern Japan.

D.A. Forsyth, A.G. Green, R. Grogan and A.J. Wickens participated in a 3-dimensional refraction survey, August 3-14, 1981, across the Williston Basin. This COCRUST project was a continuation of cooperative efforts between Canadian universities and EPB to obtain large-scale refraction and reflection data in areas of tectonic or economic interest.

A.G. Green has completed an integrated interpretation of five high-resolution seismic reflection profiles and geophysical logs from deep boreholes on the Lac du Bonnet batholith (WNRE site) in southeastern Manitoba. Two major sub-horizontal fracture systems, with shallow E-W to NE-SW dips have been identified. Warm water is flowing up these fractures from depth, causing anomalous heat flow estimates and significant alteration of the granite at depths less than 400 m.

A.G. Green is supervising the processing and interpretation of 10 km (10 profiles) of high-resolution seismic reflection data at the underground research laboratory (URL) site

on the Lac du Bonnet batholith. In contrast to the data collected at the WNRE site, there is little evidence of extensive fracturing at depth in this region. However, the relatively narrow fracture zone that has been intersected in two of the boreholes has been recorded on the seismic reflection data.

K. Cory (University of Waterloo COOP student) and A.G. Green are in the final stages of processing four high-resolution seismic reflection profiles collected across the Eye-Dashwa Lakes pluton near Atikokan.

(b) Seismological Instrumentation

The Eastern and Western Canada Telemetered Networks (ECTN and WCTN) have been considerably expanded during 1981 as described above in section 1.

Work has begun on replacing the standard photographic seismograph stations with automated digital equipment. The new system will include an LSI 11/23 computer, a 10 megabyte hard disk, and a 1 megabyte floppy disk.

Staff in the Ottawa instrument section include R. Hayman, F. Kollar, F. Anderson, J. Lyons and J. Thomas.

Physics of the Earth's Interior

(a) Heat Flow and Heat Production

Estimates of the terrestrial heat flow at 72 sites offshore eastern Canada have been made by M. Reiter, a visiting scientist with the Geothermal Studies group, on sabbatical leave from the New Mexico Bureau of Mines and Mineral Resources and the New Mexico Institute of Mining and Technology.

J. Majorowicz has concluded his studies on regional heat flow patterns in the Western Canadian Sedimentary basin. Using temperatures taken in "shut-in" holes in some of the oil pools and average lithologic conductivities estimated from net rock analyses, he has shown that geothermal gradients and heat flows within the basin are exceptionally high compared to other Precambrian platform areas.

M. Burgess and V.S. Allen participated in the 1980 Hudson cruise to the Sohm Abyssal Plain, western North Atlantic Ocean. Five heat flow stations were occupied using a gradiometer probe and 450 thermal conductivity measurements were made on retrieved core samples.

M.J. Drury has obtained and analysed data from consecutive temperature logs in several boreholes drilled into granitic plutons at Chalk River, Atikokan, Pinawa and Lac du Bonnet. Disturbances to temperature gradients arising from water flow have been used to locate and characterise fractures.

(b) Geothermal Energy

B.C. Hydro has taken over investigations at Mt. Meager. A large rig was used to drill a 3000 m hole in July-November, 1981; bottom-hole temperatures inferred from mud returns were 250-280°C. At nearby Mt. Cayley, a temperature observation well has been drilled as part of a small scale program supervised by J. Souther, GSC Vancouver. In the south-central interior of the province, a shallow drilling program has commenced; about 30 holes are being drilled along an E-W line from Merritt to the Monashee Pass under the supervision of T. Lewis and E. Davis (PGC).

Deep temperature data are being gathered on an opportunity basis in Alberta by A.S. Judge in the foothills, and by F.W. Jones through an EPB contract to the University of Alberta. A.S. Judge has observed high temperatures and gradients in several abandoned oil exploratory wells in the Cameron Hills area south of Hay River, N.W.T. A net rock data-file for 220 selected prairie wells has been set up to facilitate the assessment of resistivity logs used with existing temperature and reservoir data.

(c) Permafrost studies

The acquisition and preservation of Arctic wells for deep temperature observations has been continued by A.S. Judge, A. Taylor, M. Burgess and V.S. Allen. Eleven new sites in the southern Yukon were added in 1981; to date, precision temperature data to depths greater than 125 m are available at about 130 sites in the permafrost region of Canada. Thermal conductivity measurements have been made on samples from many of these sites.

Observations at a number of shallow sites in the Yukon have been continued by M. Burgess, generally in areas being considered for the Alcan natural gas pipeline. A. Taylor and others have completed an analysis of over two years of shallow ground temperatures taken by Department of National Defence personnel at Alert, N.W.T.

In the Mackenzie Delta at the Illisarvik site (a lake drained artificially in 1978), nine more holes were jet-drilled and instrumented with thermistor cables. Permafrost has grown from 5 to 8 m into the bowl shaped unfrozen zone under the lake bed; this talik extends to approximately 15 to 20 m, at which depth permafrost is again encountered.

(d) Tectonophysics

K. Yamazaki (Visiting Fellow) and H.S. Hasegawa are determining temporal and spatial variations in the deviatoric stress pattern in eastern Canada, i.e. the Appalachian Province and adjoining Canadian Shield. Finite-element techniques are applied to a viscoelastic lithospheric model.

J. Adams has studied quarry-floor buckles in the McFarland Quarry in the west-end of Ottawa, as an indication of regional stresses released by unloading. The main buckles trend NW and suggest the principal stress to be horizontal, in the NE quadrant, and of the order of a few tens of MPa in magnitude. These results agree with shallow stress measurements in the Toronto area and are further support for regional NE-SW compression across this part of eastern Canada and the adjacent northeastern United States.

J. Adams has completed a study on deformation of the Pacific Northwest and has demonstrated active landward tilting of the coastal ranges of Oregon, Washington and Vancouver Island, and active shortening of the continental margin with the rate of shortening decreasing rapidly eastwards from the Juan de Fuca - North American plate boundary. The results confirm active subduction of the Juan de Fuca plate and do not exclude the possibility that large earthquakes occur on the boundary.

5. Pacific Geoscience Centre

(a) Lithospheric Studies

G. McMechan has applied the theory of resonant scattering for fluid filled inclusions to seismological configurations and extended and applied wavefield inversions for refraction and reflection interpretation.

R.D. Hyndman organized a marine geophysical program for the Bedford Institute ship CSS HUDSON off the Canadian west coast involving the examination of the structure and thermal state of the Queen Charlotte fault zone and Queen Charlotte Sound rift basin.

R.D. Hyndman participated as co-chief scientist on Leg 78B of the Deep Sea Drilling Project, which was devoted to downhole geophysical measurements in a previously drilled deep crustal borehole into the mid-Atlantic ridge including:

R.D. Hyndman and C.J. Yorath have studied the structure and subsidence history of the Queen Charlotte Basin and produced formation models in terms of margin underthrusting, lithosphere flexure and rift formation.

Physics of the Earth's Interior

(a) Heat Flow and Heat Production

T. Lewis has used a gamma-ray spectrometer to measure the heat generation in representative samples of crustal rocks from DSDP old ocean floor sites, the Scotian Shelf, Flin Flon, and Cordilleran sites.

T. Lewis and C.E. Keen (AGC) have shown that the calculated temperatures in Scotian Shelf Sediments change by up to 17K if the heat generation within the sediments is included in the calculation. This contribution significantly shifts the hydrocarbon maturation window.

T. Lewis and J. Wright (Memorial University) have made further measurements in Jervis Inlet, defining the large transition in heat flow occurring over a lateral distance of 20 km as the volcanic arc is approached. Lewis studied the changes in bottom water temperatures of inlets, as recorded in the bottom sediments.

R.D. Hyndman, T.J. Lewis, J.A. Wright (Memorial University), D.S. Chapman (Univ. of Utah) and M. Yamano (Univ. of Tokyo) obtained a suite of new marine heat flow measurements on the Queen Charlotte fault zone that substantiate the model of underthrusting beneath this margin. Additional measurements were made in western Queen Charlotte Sound to evaluate the rift model for this area.

R.D. Hyndman and C.J. Yorath have estimated the heat flow using data from eight Shell Canada Ltd. wells in Hecate Strait and Queen Charlotte Sound. The results and paleoheat flow from vitranite reflectance data have been employed to constrain thermal models for the area and estimate petroleum maturation.

E. Davis, J. Sclater (M.I.T.) and C. Lister (Univ. of Washington) have used deep (10m) piston corer-outrigger measurements over Mesozoic sea floor in the northwestern Atlantic to confirm the results of previous years multiple penetration instrument (3m) survey. The heat flow is higher than that predicted by lithospheric plate or boundary layer cooling models, and there is no decrease in the level of heat flow from 110 Ma to 150 Ma.

(b) Geothermal Energy

T. Lewis and E.E. Davis, for geothermal energy potential studies in the interior of B.C., contracted for a deep borehole to be drilled just outside each of the Summerland and Kelowna Tertiary Basins, and a number of shallow holes (100m) in an east-west profile across the Okanagan region.

(c) Tectonophysics

R.D. Hyndman and D.H. Weichert have completed a study quantitatively relating the seismicity and cumulative seismic moment of the major fault zones of western Canada to the rate of motion estimated from plate tectonic models.

G.C. Rogers has proposed that the earthquakes occurring within the subducted Juan de Fuca plate are due to phase changes. The amount of seismicity, its character and its distribution are consistent with this hypothesis.

6. University of Alberta

Seismology

(a) Theoretical Studies

Making use of the computer software specially developed for the Alekseev-Mikhailenko method, several thousand synthetic seismograms were computed for a large variety of complex geological models. It was at this stage that a new wave, denoted by S*, was discovered in the numerical solution of Lamb's problem.

Mr. R. Chan and Dr. F. Hron contained their investigation of diffracted seismic waves in layered media with sharp edges and other interface irregularities. The basic model consists of one or more wedge-shaped bodies embedded in an otherwise homogeneous halfspace. The solution for the diffracted wave field is obtained by a modification of the Sommerfeld integral as proposed by Malyuzhint with the results improved by successive computational iterations. A computer program is being developed for the numerical modelling of seismic wave diffraction on geological fault models.

Theoretical seismograms from a horizontal stress discontinuity on a layered solid are being studied by Drs. E.R. Kanasewich, F. Abramovici and Mr. P.G. Kelamis. The theoretical solution is by the Cagniard-Pekeris method and gives the complete wave solution for a buried source. The previously unrecognized head wave at the surface (SP*) is a prominent second arrival on the radial component. The compressional waves are also prominent on the radial component and are of interest to vibrator source studies and to studies of earthquake sources within the crust. The theoretical studies are being expanded to include attenuation.

(b) Experimental Studies

The CO-CRUST group undertook a large-scale program in Saskatchewan this past summer in order to trace the trends of the exposed Precambrian Shield of northern Saskatchewan, into the central and southern part of the province. The consortium obtained data from three shot points forming an equilateral triangle approximately 300 km in size, with reversed inline data on the sides of the triangle, and overlapping broadside data in the central portion of the triangle. The multiply redundant data in the central portion of the area should provide a unique data set for seismic inversion studies. The design of the triangle followed a suggestion of E.R. Kanasewich, and he and his students will be concentrating on the interpretation of the broadside data.

An east-west profile from the 1979 - Saskatchewan COCRUST experiment is being interpreted by M. Shahriar and Dr. G.L. Cumming. Mr. S. Chiu is interpreting data from the 1980 COCRUST experiment on Vancouver Island.

Cecilio Rebollar and Dr. Nyland are completing their study of the seismicity of the Foothills of the Rocky Mountains.

A new array of six digital recording stations has been established at Cold Lake, Alberta, the site of a heavy oil deposit that is being injected with steam by Esso Resources. The array was installed by Alberta Environment and the interpretation of the data is being directed by Dr. E.R. Kanasewich. Involved in the project are Dr. E. Nyland from the University of Alberta and Chris Gold, Tom Sneddon and Dr. Doug K. Bingham from Alberta Environment.

Drs. E. Nyland and M. Dusseault of the Department of Mineral Engineering at the University of Alberta are investigating the in-situ study of seismicity related to oil recovery operations using hydrophones in wells. Mr. M. Kumai of Japan Petroleum Exploration Company and Dr. E. Nyland have devised an inversion technique which can obtain parameters of a hydraulic fracture from surface observations of ground strain and tilt.

Another aspect of the geodynamics of plate margins, i.e. their seismicity, is being investigated by R. Lamoreaux. He and Dr. Nyland have continued their collaboration with Dr. V.I. Keilis-Borok while the latter visited Caltech as a Fairchild Scholar.

Antonio Uribe and Dr. Nyland have completed a study of the risk of induced seismicity at the proposed Itzantun reservoir in S.W. Mexico. He expects significant stress changes on the Itzantun fault and cannot rule out the possibility of damaging seismicity in this area which has till now suffered few large events.

Physics of the Earth's Interior

Mr. Kovar and Dr. Nyland are investigating the feasibility of using terrestrial photogrammetry and modern digital and analogue processing of the resulting images for the detection of strains in the Earth.

Dr. Jones and Dr. J.S. Rogers of the Low Temperature Group in the Department of Physics and M. McLaren have constructed ten Stacey-type mercury tiltmeters to be used for measuring Earth tides and local tilts. Two instruments have been in operation at the Leduc Observatory since May, 1979. Two instruments were installed in Victoria in December, 1979 and have been operating since that time. In June, 1980 two instruments were installed at Penticton, B.C., so that simultaneous recordings are now being carried out at three stations in Western Canada. Work is now beginning on the data so far recorded.

An investigation of geothermal energy resources of Alberta is underway by Drs. F.W. Jones, H.-L. Lam and T. Nasr. A review of available data from oil and gas well logs is in progress.

Drs. Bell and Gough continue their study of azimuthally aligned spalling of oil-well walls, called breakouts, as indicators of orientation of the horizontal principal stresses.

7. University of British Columbia

Seismology

Daniel Au and R.M. Clowes have completed the interpretation of an extensive set of P- and S-wave marine seismic data recorded on 3 three-component ocean bottom seismometers (OBS's) deployed around the Nootka fault zone, a narrow region along which the relative movements between the Explorer and the Juan de Fuca plates are taking place.

Dr. D.N. Bird, J.R. Horn, R.M. Clowes and R.M. Ellis are nearing completion of the interpretation of a seismic refraction study carried out in 1979 in the southern Queen Charlotte Islands as part of a cooperative project with the Pacific Geoscience Centre. The uppermost layer is sediment (V=2.3 km/s), having constant thickness (1.4 km) to the west but of variable thickness within the fault zone. The second layer has a velocity of 5.2 km/s increasing to 5.8 km/s in the fault zone. This layer displays pronounced thickening beneath the terrace. The third layer (V=6.5 km/s) lies above the upper mantle (V=7.9 km/s assumed), and there is evidence for the interface between these two layers dipping eastward at 15° beneath the fault zone. The increasing velocity of layer 2 and its thickening beneath the terrace may be the result of compressional metamorphism caused by oblique subduction of the Pacific plate beneath the America plate. The dipping mantle is explained by the same mechanism.

J.R. Horn has completed interpretation of the marine explosive profile running parallel to the fault zone on its oceanic side.

Analysis is underway of data obtained from the 1980 Vancouver Island experiment (VISP 80) undertaken by CO-CRUST (Consortium for Crustal Reconnaissance Using Seismic Techniques). In this program, for which R.M. Ellis and R.M. Clowes served as co-ordinators and G.D. Spence as a principal organizer, refraction profiles were shot along the length of Vancouver Island, from the deep ocean across Vancouver Island into Jervis Inlet, and along strike in both deep ocean and on the continental shelf. Further, a 10 km test reflection profile was shot on the central island to determine if reflections could be obtained in the disturbed environment. Also, a 32 l airgun was detonated into the 48 channel land recording system to test the feasibility of obtaining deep crustal information in coastal areas without the use of explosions.

Operation of a four element digital telemetered seismic network in the lower mainland to southern Vancouver Island region has been initiated by R.M. Ellis and R.D. Meldrum. A fifth station will be added in 1982.

R.R. Coenraads and R.M. Ellis are analysing the seismic events recorded by a twelve station (7 digital, 5 analogue) seismic array on a 40 km area around the Sullivan lead zinc mine near Kimberley, B.C. The objective of this study is to determine whether faults in the mine region can be delineated by accurate microearthquake hypocentre determination and to investigate the nature of the stresses by focal mechanism determination. In the six week experiment conducted in 1980, 366 events were recorded on four or more digital seismographs.

W.F. Slawson and J.C. Savage (U.S.G.S., Menlo Park, CA) have constructed a simple dislocation model of the San Andreas fault near Cholame, California.

8. University of Calgary

Seismology

Theoretical investigations are being carried out by Dr. E.S. Krebes on the various aspects of seismic wave propagation in a layered linear viscoelastic medium. Such a medium exhibits absorption and dispersion of seismic energy. Also, the direction of maximum attenuation is not, in general, the same as the direction of wave propagation, which necessitates the use of generally inhomogeneous plane waves. Reflection and transmission coefficients have been computed and shown to differ significantly from the ideal elastic case for certain ranges of the incidence angle and the attenuation angle (the angle between the directions of maximum attenuation and propagation).

Field tests by Dr. D.C. Lawton of explosive surface seismic sources conducted in the Foothills of Alberta illustrate that data quality obtained from surface shooting can be significantly improved by source array design and the placement of detonation points within the array. A source array design which maximizes the data quality is a cross configuration of linear explosive (tp kg charge) with detonation from all ends. Multi-fold profiling with the cross configuration illustrates that quality seismic data can be derived in the Alberta thrust-belt through the use of surface seismic sources. This project is supported through the University of Calgary Geophysics Field School.

Detailed reflection seismic studies (0 to 1 sec, two-way time) are currently being carried out by D.C. Lawton over coalfields and shallow stratigraphic traps (channel sands) in Alberta. This research is directed towards defining optimum acquisition and processing parameters to yield high-quality, cost-effective reflection data. The coal studies are supported by the Energy Resources Research Fund (ERRF) and the channel sands project is supported by the Natural Sciences and Engineering Research Council (NSERC).

Studies by R.J. Brown have begun into the general area of multidimensional filtering of which conventional f-k or velocity filtering is a rather restrictive special case. Initially, a program has been developed to carry out the two-dimensional Fourier transformation using a very efficient algorithm. The extension to four dimensions (3 space and time) would be straightforward. Questions such as shape of the filter (pie-slice, polygon, etc.), truncation effects, phase effects, order of application in a processing sequence, etc., shall be examined. It is anticipated that testing such filters on high-resolution shallow reflection data would be particularly appropriate and helpful in bringing out reflections from ground roll and air wave noise.

9. Dalhousie University

Seismology

In April 1981, CSS HUDSON crossed the East Pacific Rise crest at 21°N during transit from the East to West coasts. This is an area where extensive hydrothermal activity and sulfide mineralization have been discovered. Advantage was therefore taken by I. Reid of the opportunity to carry out a detailed seismic refraction study of this zone, using air gun and sonobuoys, with the principal objective of locating the magma chamber responsible for the hydrothermal activity. This was successful, with an apparent magma chamber being detected about 1 km below the hydrothermal vents. The chamber appears to be only 2-3 km wide and to have sharp lateral boundaries.

10. University of Manitoba

Seismology

Wanda DeLandro and W. Moon completed the detailed interpretation of 1977 COCRUST refraction data using inversion, ray tracing and synthetic seismogram modelling techniques. Bruce Mattocks and W. Moon also completed the interpretation of 1979 COCRUST refraction data. Currently the second phase of the detailed interpretation has started to

evaluate Q-structure and possible anisotropy along the Superior-Churchill Precambrian boundary zone.

Derbew Messfin and W. Moon have started to compile P and S wave velocity data from a set of typical Precambrian lithologic units (17). They are being used to study the seismic impedance contrast between different lithologic units and consequently, to develop an efficient seismic technique suitable for Precambrian terrain. This research will be extended to incorporate the theoretical study of reflectivity of velocity gradients for deep and shallow crustal seismic interpretation.

Roger Tang and W. Moon are testing seismic inversion techniques for flat layered Earth (Herglotz-Weichert, t-method, wavefield extrapolation, etc.) and attempting to extend the flat layer inversion techniques to include dipping reflectors by incorporating the generalized inversion theory.

Physics of the Earth's Interior

W. Moon completed the elastodynamic aspect of the study of Earth's long-period oscillations and computed the periods of the Earth's normal modes ranging from the seismic free oscillations to Chandler wobble.

Roger Tang and W. Moon started to investigate the Earth's dynamic parameters throughout Earth's history. For reasonable early and present day Earth models, the changes in the Earth's axial moment of inertia and the hydrostatic ellipticity are computed as a function of time. The variation of these parameters with time can have very significant implications for the Earth's tectonic processes as well as for the Earth-Moon system which, in turn, can provide us with some clues on the significant geological events in the Earth's past. The preliminary results are being tested with thermal history models for the Earth.

Patrick Lui and W. Moon have started to solve hydrodynamic differential equations (HDE) in spherical coordinate system. The objectives of this research are a) to study the ocean-earthtide interactions with non-linear term, b) to develop a formalism to study the normal modes of fluid contained in spherical boundaries and c) to apply the technique to the ocean surface perturbation and accurate satellite altimetry. Ultimately these results may become an indirect geophysical tool to probe Earth's interior.

11. Memorial University

Seismology

A seismic field study of the crustal structure in central Newfoundland is being continued by I.C.F. Stewart. Quarry blasts at Baie Verte are monitored using two analog seismographs and two digital Microcorders and used for the establishing of a refraction line across both margins of the proto-Atlantic ocean in Newfoundland. The recording phase of this study is now complete and the data analysis well underway. Preliminary results indicate an anomalously thick crustal section. This is also confirmed by a study of P-wave residuals for teleseismic events recorded by the field recorders. The permanent stations at Corner Brook and Parker's Pond are used to improve timing for the recorded events.

H.G. Miller and J.A. Wright conducted a reflection seismic survey along selected lines in the Deer Lake Carboniferous basin.

I.C.F. Stewart and J.A. Wright are involved in several related projects studying the physical properties of east coast sedimentary rocks at in situ conditions as simulated in a pressure vessel.

12. University of Saskatchewan

Z. Hajnal coordinated the CO-CRUST Group's (Consortium for Crustal Reconnaissance using Seismic Techniques) 1981 field program in southern Saskatchewan.

Z. Hajnal, M.R. Stauffer and M.S. King are completing the petrophysical analysis of some segments of the Athabasca sandstone basin. Geological and rock mechanic analysis of 463 rock samples reveal that the Athabasca sandstone has complex acoustic velocity characteristics. The velocity variations are controlled by porosity, clay content and cementation. The regolith portion of the underlying basement also is associated with frequent velocity fluctuations. These changes are mainly correlatable to the level of weathering of the basement rocks. Synthetic seismograms reveal that the sandstone basement contact will generate complex reflection events as a consequence of the irregularity of the weathering level of the basement surface.

M. Lomas and Z. Hajnal continued the laboratory investigations of the seismic reflection characteristics of the Saskatchewan segment of the Lloydminster heavy oil deposits. The study is focusing on the Celtic Pool area, where closely spaced wells will provide detailed geological and seismic log information.

Z. Hajnal and B. Reilkoff analysed six multifold high resolution reflection profiles from the south central region of the Athabasca Basin. The data exhibit the heterogeneous seismic behaviour of the Athabasca sandstone indicating significant alteration of the downward propagating elastic energy.

D.J. Gendzwill has been leading research in several areas of seismology especially as pertains to problems in Saskatchewan.

In 1979, 1980 and 1981 five small earthquakes occurred very near the Cory Potash mine west of Saskatoon. An investigation was carried out and the earthquakes were found to have been caused by the mining activity, probably a dip-slip failure in the competent carbonate rocks overlying the Cory mine. A paper is in press describing the investigation (Gandzwill, Horner and Hasegawa, 1982, induced earthquakes at a potash mine near Saskatoon, Canada, Can. J. Earth Sci.).

Earthquakes have been observed near one other potash mine in Saskatchewan, the Esterhazy mine of International Minerals and Chemical Corporation. These events may also have been induced by the mine activity but a thorough investigation has not yet been completed.

Physics of the Earth's Interior

M.S. King and B.I. Pandit continued their research on the physical properties of permafrost and gas hydrates.

A study of seismic, electrical and thermal properties of sub-seabottom permafrost from the Beaufort Sea was completed. Samples of sand, silt and clay permafrost were studied. Their physical properties were similar to those of the onshore permafrost samples from the Mackenzie River. Laboratory measurements on the compressional wave velocities agreed well with those inferred from seismic and temperature surveys in the same areas as those from which the test samples were obtained.

A preliminary investigation of the elastic wave propagation in propane gas hydrates was carried out. Compressional and shear wave velocities of propane gas hydrates and ice were measured as a function of temperature (-16.5°C to +2.4°C) and stress (0.53 MPa to 2.1 MPa). Below 0°C, the respective velocities were 3.25 km/sec and 1.65 km/sec and 2.04 km/sec for ice. Amplitude data seem to suggest that wave attenuation is higher in hydrates than in ice.

13. University of Toronto

Seismology

C.H. Chapman and R. Drummond have continued work on extending the WKBJ seismogram theory and program to generally inhomogeneous media. Program development was initially begun based on an intuitive extension of the WKBJ seismogram theory. It was discovered, however, that Maslov asymptotic theory provides a rigorous basis for this extension. This obscure Russian mathematical theory combines the advantages of asymptotic ray theory and

transform methods. Singularities (caustics) in normal asymptotic theory can be avoided in a transform domain. The theory provides a uniform, asymptotic solution valid everywhere. Program development is complete for 2-dimensional (axially symmetric) models.

N. Bergman and C.H. Chapman have continued work on exact inverse methods for reflection data.

The slant stack or Radon transform is important in a number of branches of physics. The slant-stack method of analysing seismograms is an example, but the transform also arises for travel-time anomalies of rays passing at various angles through a study region. This is analagous to X-ray tomography. For realistic datasets only a finite number of angles (rays) is sampled. Unfortunately, the usual discrete form of the Radon transform, the filtered back summation, provides an interpretation which is inconsistent with the data. It does not correspond to any physical interpolation of the discrete data. P. Cary and C.H. Chapman have continued work to improve the discrete Radon transform. Starting with a realizable interpolation of the data in terms of harmonic coefficients, a consistent Radon transform is found. Using this, the streaks normally found in inversions are removed.

C.H. Chapman has continued work developing programs for the Floating Point System array processor AP120-B. Using a new decomposition of the second order minors, the Haskell matrix method has been programmed for the AP.

Physics of the Earth's Interior

(a) Glacial Isostasy: Further work with the gravitationally self consistent model for glacial isostatic adjustment by W.R. Peltier and Patrick Wu has focussed on improving the constraint on the viscosity of the mantle beneath the transition region. Joint inversion of free air gravity and relative sea level data have decreased the upper bound from 10^{23} Poise to about 3×10^{22} Poise so that the contrast across the phase transition at 670 km depth is only a factor of 3.

(b) Mantle convection and the thermal history of the earth: The model for sea floor flattening has been extended to include the effect upon the convective circulation of rigid plate-like motion of the surface boundary layer (Jarvis and Peltier). Although incorporation of this effect explains why topography flattens with increasing age whereas heat flow does not, it does not lead to any substantial modification of the inferred extent to which the planetary mantle is heated from within. The idea of parameterized convection as a means of studying the thermal history (Peltier and Sharpe) has been further extended to allow for continuous chemical differentiation of the mantle. Results show that the timescale of about .8 Ga over which continental crust could not be stabilized following planetary accretion coincides with the time taken by the planet to cool secularly into the high viscosity present day state in which secular cooling is extremely slow (Peltier).

14. University of Western Ontario

Seismology

Mereu, Brunet, Price and Yapp continued their studies of the microearthquakes which are occurring in the Gobles oilfield west of Woodstock, Ontario.

While on Sabbatical leave in Norway, R. Mereu conducted a cooperative study with S. Mykkeltveit and E. Husebye on the nature of the seismic signals recorded at the 42 sensors of the NORSAR seismic array of the FENNOLORA long range deep seismic sounding experiment which was carried out across Scandinavia in 1979.

Ojo, under the supervision of R. Mereu, completed his Ph.D. thesis on the scattering of P waves through random medium type models of the crust and upper mantle. Papers on this research work have been published or are in press.

Over the past few years the University of Western Ontario has been operating a short-period tripartite seismic array network near London, Ontario. Mok and Mereu in an

analysis of 129 well-recorded teleseismic events found that the deviation of measured values of slowness and azimuth formed a well defined anomaly pattern around the array. An analysis of the causes of the pattern indicates that it is localized in the crust near the array and is a direct result of an azimuth dependent set of travel-time residuals at the stations.

It is well known that heterogeneous elastic materials subjected to stress generate bursts of elastic waves known as Acoustic Emission (AE). With sustained stress, the level of AE activity increases until fracture occurs. In this experiment Mr. Chouliaras and Dr. L. Mansinha have attempted to observe AE events in glass plates. Their results indicate that there is no AE activity prior to fracture in uncracked glass. However, there is an exponential rise in AE level prior to the rapid extension of a pre-existing crack. Work is underway to identify the location of each AE event on the crack surface. The ultimate aim of the project is to see if any characteristics of AE can be used to predict the timing or size of the extension of pre-existing crack.

The principle of maximum entropy and the earthquake frequency-magnitude relation was studied by Drs. Shen and Mansinha.

M.C. Mwenifumbo and H.H. Schloessin have completed a first series of laboratory experiments devised to provide (partial) answers to the questions of what physical mechanisms could feasibly explain luminescence phenomena proceeding and accompanying earthquakes on the ground and in the adjacent air space above ground (in some cases 2-3 degrees away from the seismic source regions). Phosphorescence, thermo-, tribo- and chemi-luminescence of several minerals were studied to determine the photon efficiencies for given thermal, mechanical and electric stimuli. The results show that under the assumption of sufficiently high concentrations of certain minerals (e.g. $CaSiO_3$, $CaCO_3$, SiO_2) glows on the ground could be explained as due to phosphorescence and thermoluminescence. High vacuum absorption experiments on $CaSiO_3$ and SiO_2 fail to show that the heat of adsorption of water vapour, released on adsorption after degassing, provides sufficient thermal stimulus to trigger off transient thermoluminescence (pseudo-chemiluminescence) in previously excited crystals. The occurrence of luminescence has been successfully demonstrated in air streams rising with moderate speed through dilute suspensions of fine dust particles ($CaSiO_3$). Streaming potential and charge separations thus appear to provide a possible mechanism for luminescence in the air above ground.

Physics of the Earth's Interior

R. Govindarajan, C.M. Carmichael and H.H. Schloessin have collaborated in high pressure-high temperature studies and also some high vacuum experiments on single crystals and polycrystalline samples of magnetite.

H.H. Schloessin has continued the experiments and interpretation of the thermoelectric (Seebeck) coefficient for minerals and mineral couples under varying conditions of p and T.

W.R. MacPherson and H.H. Schloessin have devised a steady-state method for the determination of the apparent, lattice and radiative, thermal conductivity and its p,T-dependence up to 6 GPa and over a wide temperature range from 300 to 1600 K. Results have been obtained for M_gO, NaC, KBr, $CaCO_3$, SiO_2 and some basalts.

Precision logging of temperature gradient and the extraction of past climates has been studied by Drs. A.E. Beck, P.Y. Shen and Mr. Wein. The departure of geothermal gradient from its equilibrium regime reflects the presence of disturbances such as the variation of surface temperature in the past and the flow of ground water. To extract information about these disturbances, however, the gradient must be precisely and densely read. This stringent condition is now met owing to the development of specialized equipment at the University of Western Ontario.

Two analytical techniques for identifying disturbances in the past surface temperature have been evaluated using both real and simulated temperature gradient loss (Beck and Shen 1980).

15. McGill University - Laboratory in Applied Geophysics (Drs. O.G. Jensen, W.H. Cannon, Messrs. P. Tyraskis, C. Tsingas; Mr. K. Heaton (York U.))

(a) Earth Mechanics - seismology at ultra-long periods

The theory of the dynamical response of the body of the earth to quadrupolar gravitational radiation with periods between a few minutes and several hours has been largely completed in cooperation with Ph.D. student K. Heaton and Professor W.H. Cannon of York University. This geophysical analysis of one approach to the broader problem of gravitational radiation detection accounts for the material-strain/geometry-strain interaction between the earth and a time varying background geometry as well as accounting for the inertial response of the earth's own distributed mass. It now appears that the earth is approximately twice as sensitive to continuous-wave gravitational radiation as had been previously thought. At very long periods (e.g. 54 minutes corresponding to the S_2 mode of free oscillation), it is now possible to reduce the upper limit on the cosmic background gravitational radiation level to perhaps $< 10^6$ W.m^{-2} . Hz^{-1}. The analysis also obtains the transfer function for the earth forced by transient radiation exciting the radial overtones of the quadrupole-coupled S_2 modes.

(b) Seismic Analysis - Vector deconvolution

The multi-channel (or vector) deconvolution theory based upon the autoregressive data model has been extended by Mr. P. Tyraskis to allow for the extrapolation and interpolation (as statistically valid procedures in editing) of multi-channel data as well as their separation into vector source and multi-channel response function pairs. These developments have given rise to the ability to make efficient direct computations of the cross-spectral relationships between various components of geophysical signals. Mr. Tyraskis is now applying these several procedures in the resolution of multi-component spectral character of high order overtones of the low spatial order modes of the earth's free oscillation as produced by a suite of recent earthquakes. It is expected that certain properties of these modes are especially sensitive to the ratio of the compressional-to-shear velocity in the upper regions of the mantle. Also, it may be possible to accomplish an inversion for a density profile within the liquid core.

(c) A refraction seismic survey to determine the structure of the Beloil intrusive

A refraction seismic survey is being conducted over an area near Beloil, Quebec, where aeromagnetic and ground gravity surveys indicate the presence of a Monteregion hill-type structure which has not penetrated to the surface, in an attempt to resolve its extent and depth.

During the autumn of 1981, Mr. C. Tsingas conducted a reconnaissance survey using refracted arrivals of seismic waves generated by large blasts at the Francon quarry on Montreal Island. This survey has established that a time record consistent to 20 msec across a 20 km refraction line is possible using the WWVB time-code transmissions from Boulder, Colorado. Refraction surveys will continue during the late winter and a final analysis and interpretation of the results prepared by April 1982.

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III (A) GEOMAGNETISM

Compiled by: P.J.C. Ryall

1. Introduction

This report has been compiled from contributions from researchers at the government and university laboratories. This year it is worth noting two particular areas of work: 1) the continuing magnetic survey of Canada and 2) the palaeomagnetic studies of Palaeozoic and Proterozoic rocks that occupy the energies of a large fraction of Canadian palaeomagnetists. The magnetic survey of Canada proceeds with the addition of sixty thousand line-kilometres of data. Of these, about twenty thousand were covered by ship in the Davis Strait between Baffin Island and Greenland (GSC - Atlantic Geoscience Centre) and forty thousand were flown over Labrador (GSC - Regional Geophysics). The major area of Canada not yet covered by aeromagnetic survey (other than proprietary data) is the western plains of Alberta and southern Saskatchewan.

A focus of effort for many researchers, both in government and university laboratories lies in unravelling the complexities of Palaeozoic and Proterozoic plate tectonics. New data from alkaline intrusions from the Slave province dated at 2.2 Ga (Earth Physics) are consistent with a plate tectonic origin for the Hudsonian orogen. The reality, or otherwise, of two Loops in the polar wander paths is being studied. An NRM component with a palaeopole which falls near the 1.9-1.7 Ga "Coronation Loop" has been isolated from the Abitibi sub-province rocks (Toronto). A reexamination of the Powdermill Volcanics which define the E arm of the 1.1 Ga Logan Loop has shown that the E arm of the Loop and hence the Loop itself is not necessarily demonstrated (Western Ontario and Toronto). Considerable work is underway on rocks from the Grenville province (Earth Physics, Windsor, Toronto). Palaeomagnetic results from these rocks are very complicated often requiring the separation of Grenvillian poles from either younger or older poles. Palaeozoic rocks are being studied at many universities, a particularly interesting result is the inference of an absolute width of 3,300 $\pm$ 2,200 km for the proto-Atlantic Ocean (Memorial).

2. Geomagnetic Surveys, Charts and Compilations

(a) Atlantic Geoscience Centre

(i) Marine Magnetic Measurements

In a multiparameter survey program carried out in collaboration with the Canadian Hydrographic Service aboard CSS DAWSON and CSS HUDSON, nearly 20,000 line-kilometres of magnetic data were collected in Davis Strait.

Survey coverage consisted largely of a series of east-west profiles beginning near the coast of Baffin Island. Lines run by HUDSON were spaced at 38 km intervals and extended as far east as the coast of Greenland; these were planned to complete a large-scale regional reconnaissance mapping program that was initiated in 1980.

The survey pattern run by DAWSON was designed to interline the regional survey tracks; lines were spaced at 9 km intervals, and extended eastward only about as far as the median line of Davis Strait.

Varian Model V-75 proton procession magnetometers were used for most measurements. Ship positioning on survey lines was accomplished by BIONAV - the Bedford Institute of Oceanography Integrated Navigation System - which combined data from the U.S. Navy Navigation Satellite System, rang-range Loran-C, and ship's log and gyro.

In a supplementary hydrographic survey program involving CSS HUDSON, several closely-spaced profiles were run across the eastern end of Lancaster Sound, between Devon Island and the Borden Peninsula. Some 420 line-kilometres of data were collected in this area, using the Argo positioning system.

(ii) Caledonide Orogen

As part of IGCP Project 27, "The Caledonide Orogen", gravity and magnetic data at the northern termination of the Appalachians and southern termination of the Caledonides were compiled at a scale of 1:5 million on an early Mesozoic reconstruction of the North Atlantic, as an aid to testing the suggested geological continuity between the two regions. This is the initial stage of an international compilation for the entire Appalachian/Caledonide orogen which it is hoped to complete during the next two years.

(iii) Labrador Sea Magnetic Compilation

A backlog of magnetometer data from past cruises in the Labrador Sea has been reviewed, edited, and machine-contoured in preparation for eventual publication in the Natural Resource Map (NRM) series. The data are in an area situated between latitudes 52 and 56 north, and covered by 24 NRMs, each measuring one degree of latitude by two degrees of longitude.

Pending publication in the NRM series, the data will be released through the GSC Open File in the form of preliminary contour maps, profiles along track, and digital data files.

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

(i) Testing of Proposed and Adopted IGRF Models

The three candidate series of models (IGS, USGS, NASA) for the new International Geomagnetic Reference Field have been tested against North American test data for the period 1965 to 1984. The test data consisted of Canadian map and aeromagnetic data and the U.S. ground-based data. All models provide an excellent fit at epochs 1965, 1970 and 1975, but only the USGS and NASA model fit the data satisfactorily at 1980.

The secular variation models which best fit predicted component values of X, Y, Z and F for 1982 and 1984 for 27 North American observatories are the IGS and USGS models.

The relative and internal consistencies of the proposed models were analyzed by comparing their rms amplitudes over the Earth's surface. The comparison confirmed the "anomalous" behaviour of the IGS 1980 main field model and the NASA 1980-85 secular variation model.

Similar tests have been made on the composite series of models recently adopted by IAGA.

(ii) Magnetic Repeat Stations Survey

As part of a continuing study of magnetic secular variation, 18 repeat stations were occupied throughout Canada, primarily in Ontario, Manitoba and Saskatchewan. Five stations provided auxiliary ground-based information for the MAGSAT program. Nine stations were occupied by contract. The routine occupation and observation is similar to that outlined in Can. Geophys. Bull. V32, p. 60, 1979.

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

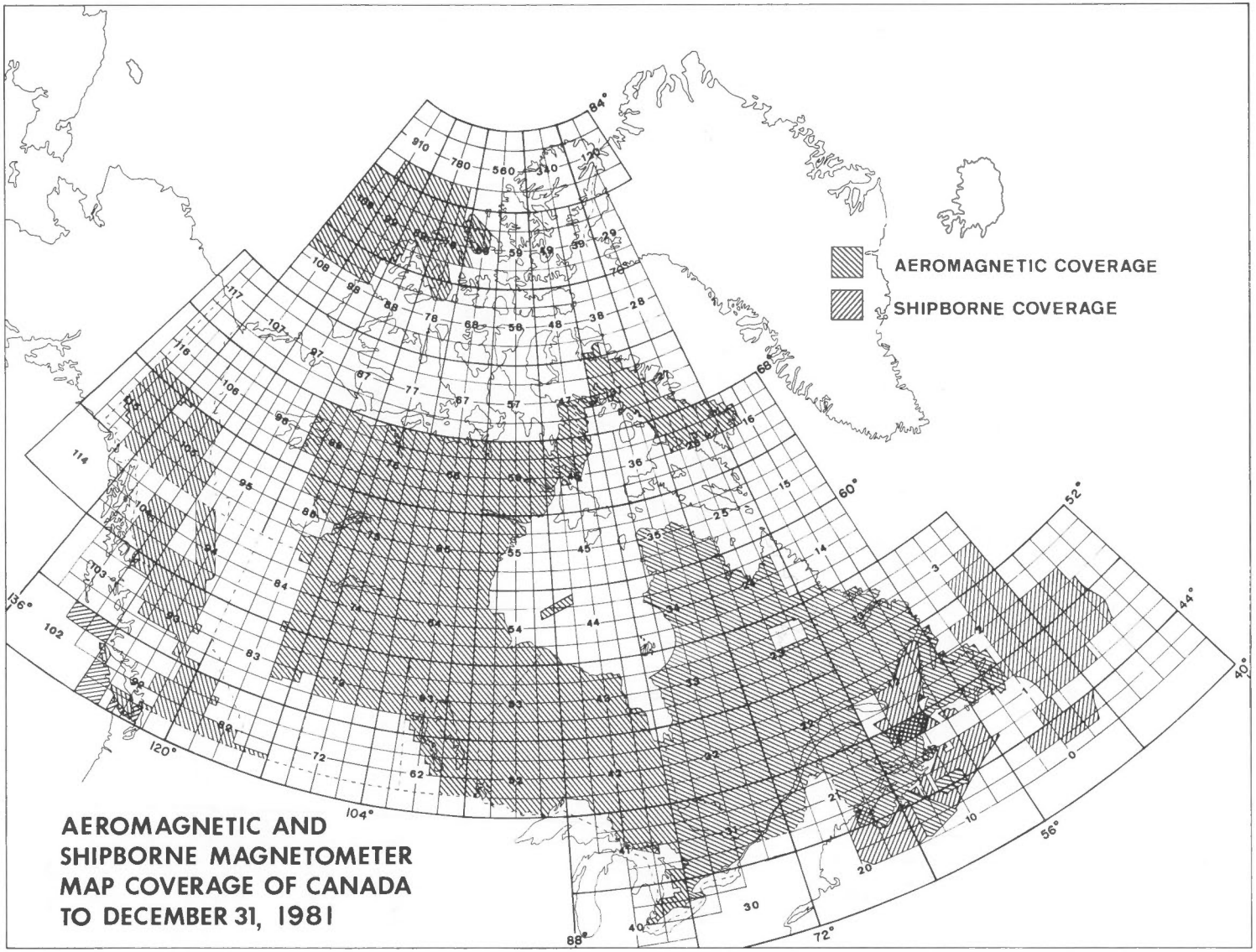
The aeromagnetic survey of Canada continues and during 1981 39,784 line kilometres were flown in Labrador to bring the grand total flown in Canada since 1947 to 8,085,794 line kilometres.

A total of 247 aeromagnetic maps were published by the Geological Survey of Canada during 1981. Of these 211 were 1:50,000, 32 were 1:250,000 scale total field aeromagnetic maps and the first 4 coloured magnetic anomaly maps in the 1:1,000,000 series were issued. The aeromagnetic and shipborne magnetometer coverage of Canada to December 31, 1981 is shown on page 49.

High resolution aeromagnetic gradiometer surveys were flown by the GSC Queenair aircraft in the Flin Flon area of Manitoba (9100 line km) and two Radwaste research sites (RA 7 & 8) for AECL in the East Bull Lake and Caviar Lake areas of western Ontario. In addition an aeromagnetic survey of Lake Ontario was commenced using Loran C as the primary navigation system for track positioning. Ten vertical gradient and ten total field aeromagnetic maps for the Weldon Bay - Goose Lake survey area of Manitoba flown by the GSC Queenair aircraft in 1980 were Open Filed on June 30, 1981 as OF 756.

An aeromagnetic survey of the Kane Basin, NWT was flown by the Convair 580 aircraft of the National Aeronautical Establishment as part of the GSC/NAE project. The objective of the survey was to provide data which might throw light on any relative movement that has occurred along the Nares Strait. However the 10 km line spacing flown was too wide for correlations across the flight lines to be positively made so it will be necessary to infill between the lines during the 1982 survey operation. A set of parallel profiles was also flown north of Bylot Island in northern Baffin Bay to geophysically map the extension of the Lancaster Sound graben into Baffin Bay. To support the compilation of the Magnetic Anomaly Map of North America, a series of lines was flown in the vicinity of Barbados in March 1981 and in the area of St. Marten in December 1981. Much of the magnetic data in the Caribbean has been obtained by ships and there is need for a series of tie lines to connect adjacent surveys especially in the vicinity of the numerous islands.

P.H. McGrath, after completing the compilation of a Magnetic Anomaly Map of the Canadian Arctic in cooperation with the Department of Indian and Northern Affairs, has commenced the compilation of the fourth edition of the 1:5,000,000 Magnetic Anomaly Map of Canada. The new edition will utilize the appropriate IGRF instead of the F map of the Earth Physics Branch to remove the core field. Digital compilation techniques will also be utilized to the greatest extent possible in the new map and will incorporate much of the digital data generated in the production of the new 1:1,000,000 magnetic anomaly map series as well as that resulting from the compilation of the Arctic Map which contains a great deal of private sector data. However aeromagnetic coverage for the western plains of Canada remains sparse and oil companies holding such data which is mostly about


AEROMAGNETIC COVERAGE
SHIPBORNE COVERAGE
AEROMAGNETIC AND
SHIPBORNE MAGNETOMETER
MAP COVERAGE OF CANADA
TO DECEMBER 31, 1981

30 years old are encouraged to send their contour maps to the Geological Survey of Canada. Appropriate acknowledgement will be given on the Magnetic Anomaly Map of Canada to such donors.

(d) Dalhousie University

Some 640 line-miles of magnetics and bathymetry were recorded over Explorer Seamount (49°N, 131°W) in support of a geological investigation by R.L. Chase (UBC). Bathymetric and magnetic charts have been prepared showing a series of peaks perpendicular to the Explorer Ridge. One of the peaks further from the spreading centre coincides with a magnetic low suggesting an increase in age along the series.

(e) University of Manitoba

D.H. Hall and T. Millar, in collaboration with D.E. Ajakaiye and J. Ashiekaa (Ahmadu Bello University, Zaria, Nigeria) have been compiling in digital form maps of the aeromagnetic survey of Nigeria, recently completed. The digital data is being processed to produce a long-wavelength map of the area and to interpret individual anomalies. The targets are basement depths and igneous bodies within the Benue trough and features such as the ring-dyke complexes in the Precambrian area.

3. Interpretation of Magnetic Surveys

(a) Atlantic Geoscience Centre

(i) Davis Strait Interpretations

Gravity and magnetic measurements made during the Davis Strait hydrographic-geophysics survey in 1980 have been combined with previously collected data in order to examine crustal structure. Interpretation based on published seismic refraction data and unpublished reflection data, together with potential field information suggest that the sill forming the central part of Davis Strait is underlain by a crust which shows closer affinity with continental crust than with oceanic crust.

(ii) Magnetic Anomalies and Sea Floor Spreading Rates

R. Jackson and I. Reid investigated the amplitude of magnetic anomalies compared to spreading rate. A series of digitized observed magnetic profiles where spreading rate varied from .5 to 5 cm were modelled. The inclination, declination and intensity of the earth's field were adjusted for geographic location. On matching observed and modelled profiles a general positive correlation was found between spreading rate and vertically integrated magnetization. This is believed due to a greater melt supply under fast spreading ridges.

(iii) Geomagnetic Field Models

Three models that have been proposed as replacements for the International Geomagnetic Reference Field (IGRF) were evaluated through application to multi-year data sets selected from AGC's collection of marine magnetometer data. The results showed significant improvement over those obtained with the existing IGRF standards.

(iv) Data Processing

Two software packages have been developed for the processing, archiving, and retrieval of marine potential field data: SHIPAC and GEOFFREY. Both replace older versions of software that had become unreliable and difficult to maintain.

SHIPAC was developed in-house, and runs on shipboard minicomputers. In addition to performing quality control of raw gravity and magnetics coupled with editing and correcting, it combines navigational and bathymetric information with potential field data, and performs preliminary processing and display.

GEOFFREY was developed under outside contract and runs on a shorebased mainframe. It performs final processing of the data with provision for adjustments and corrections to achieve consistency between adjacent and overlapping data sets. It also supports selective retrieval on a time- or location-dependent basis.

(b) Earth Physics Branch

(i) MAGSAT

The Division of Geomagnetism is participating in the analysis and interpretation of magnetic field data from the MAGSAT satellite as part of NASA's Resource Observation Program. Scalar and vector component anomaly maps have been produced from selected quiet MAGSAT data. These maps show anomalies in the wavelength range 300 km to 3000 km, north of latitude 40°N. Correlations exist between many of these anomalies and known geologic and tectonic features.

These same MAGSAT data were used to produce main field charts in north, east, vertical, and total force components over Canada and adjacent areas. These charts were compared with corresponding charts produced primarily from Canadian aeromagnetic data. Good agreement exists between charts produced from the two data sets; the overall rms difference is 150 nT. (R.L. Coles, G.V. Haines, E. Dawson, L.R. Newitt, G. Jansen van Beek, A. Nandi, J.K. Walker).

(ii) Hudson Bay

Qualitative interpretations of regional magnetic trends and major anomalies over Hudson Bay have been made, using the data from the shipborne survey described in previous Bulletins. Correlations between the magnetic anomalies and regional gravity patterns have been found. (R.L. Coles and G.V. Haines).

(iii) Lake St. Martin Impact Structure, Manitoba

Ground magnetic survey data from the Lake St. Martin impact structure have been interpreted in terms of a shallow source body at the geometric centre of the structure. Related rock magnetism studies have led to the conclusion that the source body carries a chemical remanent magnetization caused by hydrothermal alteration of mafic minerals immediately post-impact. (R.L. Coles and J.F. Clark).

(c) Université Laval

M.K. Séguin and E. Gahé have undertaken an interpretation of aeromagnetic as well as some terrestrial magnetic data from the Chibougamau area, Quebec. The models constructed are constrained by petrophysics data (densities and susceptibilities) obtained by a statistical sampling of the lithological units of the area.

(d) University of Manitoba

D.H. Hall and T. Millar have continued interpretation on an aeromagnetic data set at Lynn Lake, Manitoba. This is a continuation of work reported in 1979 and 1980.

D.H. Hall, T. Millar, and I. Noble are continuing interpretation of the MAGSAT data set, using data over a large area of the Canadian Shield centred on the Manitoba portion of the Churchill-Superior province.

4. Magnetic Observatories and Instruments

(a) Earth Physics Branch - Canadian Magnetic Observatory Network (G. Jansen van Beek, G. Brown, J. Hruska, R. Libbey, F. Plet)

Six more stations in the Canadian Magnetic Observatory Network (St. John's, Nfld., Ottawa, Ont., Great Whale River, Que., Glenlea, Man., Fort Churchill, Man., and Baker Lake, N.W.T.) have been equipped with the new Automatic Magnetic Observatory System, AMOS Mk III. This is the second set of installations in a program to replace the aging AMOS

Mk I; Meanook, Alta., and Resolute, N.W.T. were previously re-equipped. Completion of the program is expected in 1982.

Twenty-seven day forecasts of geomagnetic activity are issued every three weeks by the Ottawa Magnetic Observatory and distributed on request by mail. Shorter term magnetic predictions recorded in English and French are available via telephone: (613) 824-5595. These forecasts are updated twice a week in summer and once a week in winter.

Two issues of the Geomagnetic Bulletin (edited by J. Hruska) were distributed in 1981. The titles were: Canada charts its magnetic field 1843-1980, by E. Dawson and L.R. Newitt, and Geomagnetic predictions and amateur radio, by A.K. Goodacre.

5. Electromagnetic Induction in the Earth

(a) Earth Physics Branch

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

(i) Ocean bottom magnetometer results across the continental slope of southern Vancouver Island: coast effect and oceanographic wave

The 'geomagnetic coast effect' was determined by a line of three component magnetometers extending from the deep ocean across the continental shelf and across southern Vancouver Island. The ocean bottom instruments were located at the top of the continental slope (290 m depth), at the base (2220 m) and 100 km further out in the ocean (2705 m). The power ratios and induction vectors show that the electric currents are concentrated along the continental slopes in the deep ocean. This signal is almost certainly caused by an oceanographic wave. (L.K. Law, J.M. DeLaurier, D.R. Auld).

(ii) Central Vancouver Island apparent resistivity study

A program to monitor changes in apparent resistivity in the central Vancouver Island region related to increased stress was started. Magnetotelluric data in the period range from 2 to 2000 seconds are systematically obtained at several sites on a regular schedule. (L.K. Law, J.M. DeLaurier, D.R. Auld).

(iii) Ocean-floor soundings

Instrumentation for determining the electrical conductivity of the sea floor using a controlled source is under development in a co-operative program with the University of Toronto. (L.K. Law, R.N. Edwards).

Ottawa (R.D. Kurtz, E.R. Niblett, P.A. Camfield, S. Handa

(i) Time dependence of magnetotelluric parameters

Magnetotelluric (MT) fields have been recorded at 60s intervals at a station (CHR) near Les Eboulements, Québec, since 1974. Additional stations were installed in 1975, 1977, 1978 and 1981 in this tectonically active region north-east of Québec City. Some of the stations have displayed significant short term (months) and long term (years) changes in electrical impedance and telluric field polarization angle. The changes in polarization angle at CHR have been found to correlate well with a groundwater recharge model. Work is in progress to remove this effect to reveal changes related to tectonic causes. (R.D. Kurtz and E.R. Niblett).

(ii) Magnetic variation study in north central Saskatchewan

Seven recording magnetometers monitored time-varying fields at points on a NW-SE line 300 km long in north central Saskatchewan during July 1981. We wished to test the hypothesis advanced by Alabi, Camfield and Gough (1975) that the conductivity anomaly in the North American Central Plains links with the Wollaston Domain in the exposed precambrian of Saskatchewan. We found that the conductor lies

beneath the Rottenstone-La Ronge Magmatic Belt, to the immediate east of the Wollaston. Lewry (1981) terms the Belt a Hudsonian "Cordillera-type" arc massif, and gives evidence for collisional suturing and microplate interaction in this part of the Churchill Province. (P.A. Camfield and S. Handa).

(b) Ecole Polytechnique - Génie Minéral (Montréal)

Structure of La Malbaie region (Québec) from MT Soundings

MT surveys were conducted during the summers 1980 and 1981 in La Malbaie region. Five components were recorded in the frequency band (.005-20H_z). Results show three distinct features. First, the very conductive zone near Ste. Mathilde investigated in 1978 shows a complex 3D structure trending N30°E lying at depths of 100 to 200 m, shallower than the first interpretation (Kurtz et al. 1981). Second, a conductive layer is found in the region at an average depth of 18 km with resistivity in the order of 30 to 100 Ωm which correlates with other MT measurements (Kurtz, 1981) and with an increase in seismic velocity Vp. Finally, very high in-phase transfer functions (H_z/H_x) with maximum around 5 H_z suggest a N50°W conductive path under the Malbaie river at a depth of 1.4 km (M. Chouteau).

(c) University of Alberta

(i) Magnetometer Array Studies (D.I. Gough, D.K. Bingham, M.R. Ingham, M. Mareschal, M. Day, G.M. Turner)

The program of magnetometer array studies in western Canada has been continued. They are named by the year of the field work.

Array 1980A - Data for several substorms and several events during storms, which give more uniform inducing fields over the array, have been processed and interpretation has been carried far enough to define objectives for the 1981 arrays. Array 1980A covered Alberta and B.C. south of the Edmonton-Prince Rupert highway. One anomaly produces intense enhancement of X (N-S horizontal) and Y in a limited area around Tête Jaune Cache, in the Trench west of Jasper. The other new anomaly is caused by induced currents flowing NE-SW across southern Alberta, passing just east of Calgary, and across strike of the Rockies into south-eastern B.C. Kanasewich (Science, 161, 1002, 1968) observed gravity and magnetic anomalies striking NE-SW through his rift profile, and suggested this might be the strike of the rift. It is too soon to be sure that our induced currents coincide with the other anomalies, but the array 1981B now running should decide.

Array 1980B - This array was a small one of high resolution (stations 15 km apart) located over a known geothermal anomaly in groundwater temperature in the Hinton-Edson foothills west of Edmonton. Present indications are that there is a small conductivity anomaly which persists to periods of about 1 hour.

Array 1981A - This was a medium-scale array, with station spacing about 50 km, centred near Tête Jaune Cache and extending across three ranges of mountains. The intention was to map the anomaly observed by the 1980A array, at Tête Jaune Cache in the Rocky Mountains Trench and at one other station in the Trench (and previously reported at Valemont by H. Dragert).

Array 1981B - In August-November this array was deployed and run over a broad strip covering the southern Alberta-B.C. anomaly discovered by the 1980A array. This was a long array, designed to map the induced currents from the Saskatchewan-Alberta border near 53°N to the B.C.-U.S.A. border. It consisted of six lines of magnetometers transverse to the conductor as mapped by the 1980A array. These lines are about 150 km apart. In each line the stations are 50 km apart, so the position of the conductive structure should be well defined.

(ii) Magnetotellurics and Micropulsations

Dr. D. Rankin is currently using the magnetotelluric method on a variety of problems ranging from plate tectonics to the detection of flame fronts in the in-situ heating of shallow heavy oil deposits. In addition to field studies Dr. Rankin and his colleagues, Dr. F. Pascal and Dr. H. Pascal, are developing a new inversion technique and new approaches in microwave logging theory.

Under an AOSTRA Contract Dr. Rankin and Dr. H. Pascal are investigating two-phase flow of steam and water and developing a new device for the measurement of steam quality and flow rate.

(iii) Numerical Modelling Studies (F.W. Jones, H.-L. Lam, L.J. Pascoe)

The perturbation of uniform and nonuniform electromagnetic fields by two-dimensional and three-dimensional electrical conductivity anomalies is being investigated by numerical techniques. The electromagnetic response of a subducting slab, in which the electrical conductivity is derived from the thermal regime obtained from the heat flow modelling work, is being studied. The effects of shear strain heating and upward movement of partial melt on the temperature regime, and consequently on the electromagnetic response, are being considered. Also, a study of the effect of a continental/oceanic interface in such models is underway.

(d) University of Manitoba

D.H. Hall, D.R. Vohra (Earth Sciences), in collaboration with L. Shafai, M. Tarnawecky, E. Aboul-Atta (Electrical Engineering) and D. Woodford (Manitoba Hydro) are continuing the interpretation of deep electromagnetic sounding data obtained from pulsed current through a power line (reported in 1979 and 1980). Electromagnetic anomalies on a regional scale have been mapped using these data in the area between Winnipeg and Lac du Bonnet, Manitoba.

(e) University of Victoria

(i) Geomagnetism Laboratory (H.W. Dosso, W. Nienaber, R. Chan, G. Heard, D. Hebert)

A model study of the British Isles region has been carried out in collaboration with Dr. V.R. Hutton (Edinburgh). The effect of the complex coastline and the surrounding shallow sea on induced electric and magnetic fields has been examined and the analogue model results compared with field station results available for the British Isles.

In collaboration with Dr. J.P. Lokken (Defense 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) are being analyzed with the aid of laboratory analogue model results.

An analogue model study of the Queen Charlotte Islands region, and a comparison of model results and field station results has been carried out in collaboration with Dr. L.K. Law (Earth Physics Branch, Department of Energy, Mines and Resources, Victoria). Detailed model measurements were used to produce contour plots of field components for the region.

In collaboration with Dr. J.A. Wright (Memorial University) a laboratory analogue model of the Newfoundland region has been constructed and detailed measurements carried out. The model results are being used to produce contour plots of the field components as well as induction arrow plots. The model results will be compared with field station measurements available for Newfoundland.

(ii) Theoretical Studies (J.T. Weaver, D. McA. McKirdy, E.L. Friesen)

Dr. Weaver has returned from a Study Leave at the University of Edinburgh where he used a newly devised algorithm (Dawson & Weaver, 1979) for solving the 3-dimensional problem of electromagnetic induction in a thin sheet of variable conductance at the surface of a conducting half-space, to model short-period (25s) induction in Scotland. Model calculations have been compared with field data obtained by the Edinburgh group.

Dr. D. McA. McKirdy has recently arrived from Edinburgh as a postdoctoral fellow and is currently extending the algorithm to include a layered half-space beneath the thin sheet.

In collaboration with Dr. A.G. Jones (Munster) the program has also been used to model induction by the auroral electrojet in Scandinavia.

An exact analytic solution of the E-polarization coast effect, in which the ocean is represented by a perfectly conducting half-sheet at the surface of a finitely conducting half-space representing the solid earth, has been obtained by the Wiener-Hopf technique.

An analytic solution has also been obtained for B-polarization induction in two generalized thin half-sheets at the surface of the conducting half-space. The solution has some very interesting mathematical properties and shows that the resistivity of the lower crust plays an important role in determining how induced currents in the solid earth and ocean adjust themselves from one side of a conductivity discontinuity to the other.

In collaboration with Dr. G. Fischer (Neuchâtel), the effect of topography, layering, and a geological overlap on AMT soundings carried out in the Val de Ruz area of Switzerland is being studied by 2-dimensional numerical modelling using the method of finite differences. Preliminary results suggest that the AMT soundings are quite sensitive to the angle of declination of the overlap.

6. Paleomagnetism, Rock Magnetism and Tectonomagnetism

(a) Earth Physics Branch (J.K. Park, E. Irving, P.L. Lapointe, J.L. Roy)

(i) Precambrian Program

The magnetic history of the Neohelikian Mackenzie Mountains Supergroup of the N.W.T. is gradually being unfolded. Two papers were published this year on the Little Dal Group and the regional sill intruding the Tsezotene Formation, both units occurring near the top of the sequence. A further paper comparing the results from the sill with those obtained from sills of the Brock Inlier was also published. Work continues on other sites of the Little Dal; older units of the sequence, the Katherine Group and the Tsezotene Formation; and another unit collected this year above the Little Dal lavas, the Redstone River Formation.

Current work on the Mealy dykes of Labrador occurring within the Grenville Province is complete and should be published in 1982. Results clearly reveal a magnetization which sees through the Grenville regional metamorphism.

New data (obtained in collaboration with the G.S.C.) from alkaline intrusions dated at 2.2 Ga from the Slave Province do not agree with equivalent data from the Superior Province indicating a greater separation in the Early Proterozoic. They are consistent with a plate tectonic origin for the Hudsonian orogen.

(ii) Programme des Appalaches

L'histoire magnétique des intrusives cambro-ordoviciennes de la région de Buckingham a été publiée et indique un mouvement très rapide du pôle pour cette période pour le craton nord-américain. De plus on y retrouve des résultats de la

datation K-Ar d'un dyke de diabase relié à une période d'activité du graben d'Ottawa. Une étude des propriétés des roches d'un dyke de diabase dans la région de Bellefeuille, Québec indique que les différents paramètres magnétiques ont été affectés par un phénomène que l'on a interprêté comme étant la signature d'un paléostress. Celui-ci permet d'expliquer le phénomène de paraléllisme des grands plans structuraux, du précambrien au récent, dans l'est du Canada.

Une étude approfondie de roches sédimentaires siluriennes du Nouveau Brunswick (voir bibliographie) établit la nécessité d'utiliser plusieurs des méthodes techniques et analytiques présentement disponibles si l'on espère déchiffrer l'histoire magnétique de la formation. En effet, il est démontré que des travaux expérimentaux limités auraient conduit à une toute autre interprétation qui, quoiqu'erronée, aurait probablement éprouvé peu de difficultés à être acceptée, d'autant plus que ce résultat aurait supporté une hypothèse présentement en vogue.

(iii) Cordillera Program

A new paleomagnetic unit at the Pacific Geoscience Centre at Sidney, B.C., is in the process of being established. Jurassic and Cretaceous rocks of Vancouver Island are presently under investigation.

(iv) Programme de l'archipel Arctique

Les résultats de trois études sur des grès rouges d'âge siluro-devonien provenant de 3 îles distinctes de l'Arctique central en plus d'un résumé des travaux accomplis seront publiés en 1982. Les résultats indiquent qu'il y eu un déplacement considérable du pôle pendant la période en question.

L'échantillonnage en 1981 a été concentré dans la région nord d'Ellesmere et Axel Heidberg.

(v) Technical and Analytical Program

The continuous high and low temperature magnetometer (CHALT) is nearing completion and should be in operation in 1982.

A new procedure for the analysis of the coercivity spectrum of natural rocks by continuous and alternating fields has been developed. The procedure is particularly useful for establishing the presence of hematite-carried remanence in rocks having a large magnetite-carried remanence. It also permits one to correlate the coercivity spectrum with the unlocking alternating field.

(vi) Map and Interpretation Program

A review of late Paleozoic paleomagnetic results show that they are not consistent with the classical Wegener reconstruction of the continents. Apparently the southern continents were about 4000 km farther east relative to the northern continents at that time. New results from Algeria obtained in collaboration with French workers support this idea. Reference apparent polar wandering paths for the Late Carboniferous to present have been compiled and a sequence of global paleocontinental maps at 20 Ma intervals produced from them.

A review of Precambrian results from North America (prepared in collaboration with J.C. McGlynn of the G.S.C.) shows that they are consistent with the hypothesis that plate tectonic processes were operative back as far as the Middle Proterozoic, although it cannot be determined when they began.

A review of results obtained from Siluro-Devonian rocks indicate that at some time between the Ordovician-Devonian interval and the Carboniferous, the eastern part of the Appalachians was latitudinally displaced by about 60°.

(b) University of Alberta (G.M. Turner, M.E. Evans, G.S. Hoye)

(i) Quaternary Geomagnetic Secular Variation

Magnetic measurements have now been completed on samples from an 18 metre section of sediments deposited during the Olympia Interglacial in southern British Columbia. The section covers the time period from ca. 31,000 to 19,000 yr bp (C-14 years before present). An approximate sedimentation curve has been constructed using 5 radiocarbon age determinations previously obtained on material from the site.

Natural remanent magnetization (NRM) measurements have been made on all 727 samples (from 212 stratigraphic horizons). The stability of the remanence was verified by routine stepwise alternating field demagnetization.

The amplitude and character of the variations are typical of "normal" geomagnetic secular variation. The changes are similar to those observed in British, European and North American lake sediments from similar latitudes spanning the last few thousand years. There is no evidence of large scale "excursions" such as those found at Mono Lake, California.

The mean direction over the whole sequence is D-5.8°E, .I=64.2° (α_{95}=0.9°), which is significantly shallower and to the east of the axial dipole field (ADF) at the site, and different from the present magnetic field D=22.2°E, I=72.6°. The results suggest their source may be a recurring phenomenon superimposed on a principally axial dipole main field.

(ii) Palaeomagnetism of Lake Sediments

During the winter and spring we have constructed and tested a Mackereth sediment corer. This corer is particularly suited for palaeomagnetic work. In September three cores were collected from two sites in Mara Lake, near Sicamous, British Columbia. This locality was chosen in the hope of finding the volcanic tephra layers from Mt. Mazama (Crater Lake) Oregon and Mount St. Helens, Washington State, and the Bridge River ash dated at 6600, 3000 and 2400 yrs bp respectively, which have been found in peat exposures in the area.

(iii) Archeomagnetism

Results from the 11 historic lava flows of Mt. Vesuvius (1631-1944) have been published, and measurements have been completed on the archeological features sampled in 1979. These span the time interval from the 8th Century B.C. to the 4th Century A.D. The secular variation curve obtained consists of two counterclockwise loops superimposed on a gradual trend toward shallower inclinations, in broad conformity with archeomagnetic data from Bulgaria and paleomagnetic data from British Lakes. However, the signal/noise ratio is small and the data are sparse; therefore further sampling is planned. This is important because of the suggested connection of looping with drift. It is of interest to discover to what extent drift is a permanent feature of the Earth's magnetic field.

A second archeological project concerns the possibility of obtaining archeomagnetic data from ancient coins. These invariably contain iron as an impurity and are usually well-dated. A preliminary experiment involving a few dozen coins from the University of Alberta Classics Department coin collection indicated that: they all possess a reasonable remanence; (through the inclination) they were all struck obverse down; and magnetic methods offer a non-destructive way to discriminate between cast and struck coinage.

(iv) Magnetic Anisotropy and Rock Fabric (G.M. Turner)

In 1976 rock samples were collected from the Precambrian Miette group at three localities along the Yellowhead Highway through the Rocky Mountains, with the aim of studying the development of magnetic anisotropy in sedimentary rocks with deformation and folding. Several tens of sites were sampled at each locality. In

most cases two oriented hand blocks were taken from each site and up to six cylindrical samples were drilled from each. At the most easterly locality, 4 miles west of Jasper, several lines of sites were sampled across the limbs and around the nose of a plunging synclinal fold. This fold had previously been mapped in detail by Dr. H.A.K. Charlesworth of the Geology Department, providing valuable structural information.

Magnetic anisotropy was measured using the Boetzkes-Gough spinner magnetometer. Corrections were required for folding and plunging. This suggests that the magnetic fabric originated in shortening of the beds before the folding occurred. There is no evidence of an original depositional fabric. The magnetic fabric is consistent with a compressional strain having existed in a generally NE-SW direction - perpendicular to the fold axis, and to the overall trend of the Rockies.

(c) Dalhousie University (P.T. Robinson, J. Mehegan, G. Schonharting, F. Vine, H.P. Johnson, U. Bleil, J. Hall)

(i) Cyprus

Initial field and site survey studies directed toward a major reinvestigation of the Troodos Ophiolite were started in 1981. The study, which will involve collaboration from USA, UK, Cyprus, FRG, Denmark and France, and 5 km of diamond drilling to be carried out by a Canadian company, will have as one of its major aims the recovery of a complete magnetic profile through the upper 4 km of oceanic crust. Analyses of magnetic surveys already carried out suggests a relationship between hydrothermal alteration associated with ore deposition and reduced magnetization and has shown the presence of at least one reversely magnetized zone in the otherwise normally magnetized extrusive sequence. Another recent observation which will be relevant to the applicability of the Troodos magnetic profile to oceanic crust is the presence of abundant fresh glass in the extrusive sequence. (P.T. Robinson, J. Mehegan, G. Schonharting, F. Vine, H.P. Johnson, U. Bleil, J. Hall).

(ii) Iceland

The initial report stage of the Iceland Research Drilling Project of 1978 is nearly complete and the results of magnetic interest will be described in full in 1982 in a dedicated issue of the Journal of Geophysical Research. Some results are as follows. Flow initial susceptibility decreases systematically with depth reducing to zero at an extrapolated depth corresponding to the onset of greenschist facies metamorphic conditions, consistent with the very low magnetization of greenschist facies matabasalts recovered from the ocean floor. Magnetic overprinting is found in highly hydrothermally altered flows in the vicinity of groups of dikes below 3 km crustal depth in the IRDP section, suggesting a second type of source for the linear anomalies of the ocean basins, the first type being initial cooling remanence in the least altered flows.

Crustal Structure. Paleomagnetic results from the IRDP section have been used to confirm Palmason's model for crustal formation in Iceland, involving concurrent volcanic activity, spreading and subsidence.

(d) Université Laval

(i) Aphebian

An extended study of the gabbro sills of the northern sector of the Labrador Trough was undertaken with the geological party of T. Clark and A. Fournier from the Quebec Department of Energy and Natural Resources. Some five additional sites (25 oriented specimens) were sampled during the 1981 summer season. It is now hoped that this sampling added to the one conducted last year will be sufficient to conclude this paleomagnetic study.

(ii) Hadrynian

The paleomagnetic studies related to the Avalon Zone are under way. This includes basaltic flows of the Harbour Main volcanic sequence in the Colliers Bay area (7 sites) and Bauline-Cape St-Francis (5 sites); ignimbrites of the Finn Hill sequence (7 sites); rhyolitic intrusives of the Cape St. Francis area (7 sites); porphyrite intrusives from the Harbour Main-Colliers area (11 sites). Except for the rhyolites, the laboratory work is nearly completed.

(iii) Paleozoic

a) France

Avec l'aide de M.F. Paris et M. Robardit de l'Institut de Géologie de l'Université de Rennes, M.K.-Seguin a presque terminé l'étude de formations cambriennes, ordoviciennes et siluriennes de Vendée ouest. Les résultants obtenus montrent une excellente stabilité des échantillons utilisés pour étude paléomagnétique.

b) Nova Scotia

The paleomagnetic research done by M.K.-Seguin and K.V. Rao in collaboration with E.R. Deutsch (Memorial) is now at the following stage.

studies completed: 1) Keppoch formation, 2) Antigonish alaskite, 3) Eden pluton, 4) Dunn Point volcanics, 5) Torbrook formation and Nictaux Falls gabbro sills, 6) Morrison River formation.

studies pending: 1) Meguma formation, 2) Central Range granite, 3) Fisset Brook formation.

studies presenting specific difficulties and probably unreliable for paleomagnetic studies: 1) Fourchu formation, 2) Bourinot Group.

c) Newfoundland

Lower Paleozoic dykes setting the Hadrynian rocks of the Avalon zone. This study was undertaken by M.K.-Seguin and M.S. Khalfi. It is now completed.

d) New Brunswick

A paleomagnetic study was undertaken by M.K.-Seguin and K.V. Rao in collaboration with L.R. Fyffe (NBDNR) and E.R. Deutsch (Memorial). The units sampled include: Middle to Upper Carboniferous continental lava flows (11 sites); Upper Devonian and Lower Carboniferous diabase and diorite dykes (5 sites); Lower Devonian metasedimentary and metavolcanic units (10 sites) in the Dalhousie-Edmunston area.

e) Québec

M.K.-Seguin a entrepris un échantillonnage paléomagnétique des unités devoniennes continentales de Miguasha, La Garde, Escuminac et Fleurant (25 sites). Cette collection représente la plus belle section du Devonien en Amérique du nord.

Ile d'Anticosti-Golfe Saint Laurent. M.K.-Seguin et A. Petryk (MERQ) ont entrepris une étude paléomagnétique dans la section type du Silurien sur l'ile d'Anticosti. Cette étude comprend quelques 8 sites ainsi que trois sites additionnels de dykes de diabase du Jurassique.

Basses-Terres du Saint-Laurent. M.K.-Seguin a fait un échantillonnage détaillé de tous les affleurements de roches plus ou moins arénacés de

l'Ordovicien. Ceci comprend les formations suivantes: Black River, Trenton, Chazy, Beekmantown, Richmond et Portgravé. Un total de plus de 50 sites a ainsi été prélevé sur le terrain.

(iv) Baltic Shields

A joint project between Université Laval (M.K.-Seguin) and the University of Lund in Sweden (Goran Bylund) with the collaboration of P. Nystuen (Norway) was started in the summer and fall of 1981. The ongoing paleomagnetic study covers part of Norway, Sweden, the Baltic islands and part of Poland. This study covers an uninterrupted Vendian-Cambrian-Ordovician-Silurian and Devonian sequence which makes it probably unique in the world. A total of 1500 oriented samples were collected on type well studied sites. The Vendian rocks are tillites while the Paleozoic rock units are mainly sandstones, siltstones, grits, marls and red limestones. The laboratory work is under way both at Laval and Lund universities.

(v) Laves récentes et tertiaires du Pacifique central

Avec l'aide de H.G. Barsczus du Centre ORSTROM de Papeete, Tahiti, Polynésie francaise, M.K.-Seguin a effectué les travaux de recherche suivants sur les échantillons des Iles Rapa:

a) propriétés magnétiques (K, ARN, AR isotherme, Θ_c, T_{UB}, Hc, Jn, Js, etc...)

b) analyses chimiques (éléments majeurs, mineurs et traces).

c) microsonde électronique.

d) études minéralogiques et minéralographiques.

e) construction de diaporamas pour étude des conditions de différenciation.

f) évaluation de la fugacité d'oxygène.

g) géothermie.

La synthèse de ces données permettra de vérifier l'existence et la nature du mécanisme des panaches de cette région du Pacifique central.

(e) Memorial University of Newfoundland

(i) Precambrian and Paleozoic Paleomagnetism

G.S. Murthy is continuing studies of magnetic properties of granites, gabbros and diabase dikes from the Gander zone of the Newfoundland Appalachians. Three paleomagnetic poles were obtained for the diabase dikes. Magnetizations, particularly in the eastern portions of the study area, are likely the result of a shear zone affecting that area preferentially. Further work is in progress on some gabbros and granites in the area.

J.P. Hodych continued work on Lower Paleozoic paleomagnetism of the Avalon zone of Newfoundland to help infer the origin of the Avalonian microcontinent and the evolution of the Iapetus Ocean. With K.L. Buchan, it was found, contrary to an earlier study, that the Bell Island-Wabana oolitic hematite ores of Lower Ordovician age did not move far from their NRM direction on thermal demagnetization, yielding a paleopole at 33°N, 102°E, not far from Ordovician paleopoles for North America. J.P. Hodych and R.R. Patzold continued their paleomagnetic work on the probably Upper Cambrian folded sills at Point Lance. Dating of the sills is continuing.

A paleomagnetic investigation of late Precambrian and Paleozoic rocks of the Avalon zone (C.G.B., 1980) was continued as a joint project between Professor M.K.-Seguin and Mr. K.V. Rao of Laval University, and E.R. Deutsch. In 1981 this

work centered on rocks in Nova Scotia and New Brunswick. Progress is reported in this chapter under "Laval University".

E.R. Deutsch has compared stable mid-Ordovician paleomagnetic directions from volcanic rocks in SE Ireland (C.G.B., 1980) and in western Ireland, showing that reconciliation of a 30° angular difference between the respective paleopoles would place the two parts of Ireland on opposite margins of a Proto-Atlantic (Iapetus) Ocean about 460 Ma ago. located uniquely, a step that is essential for inferring the tectonic analysis suggests a wide (3,300 $\pm$ 2,200 km) Proto-Atlantic Ocean. This appears to be the first time an estimate of absolute (rather than minimum) Proto-Atlantic width has been obtained.

(ii) Cenozoic Paleomagnetism

E.R. Deutsch and R.R. Patzold have nearly completed a study of early Tertiary basalts from Durban and Padloping Islands off Baffin Island (C.G.B., 1980). These normally magnetized rocks are extremely stable to AF and thermal demagnetization, producing well-grouped remanence directions whose mean paleopole departs significantly from a pole based on early Tertiary basalts in west Greenland.

(iii) Magnetic Properties, Stable Remanence and Domain Structure

Professor H.C. Soffel and other members of the University of Munich rock magnetism group have investigated, jointly with E.R. Deutsch, the domain structure of synthetic stoichiometric titanomagnetites (TM) and cation-doped TM of typical ocean basalt composition. Using the Bitter pattern technique they produced for the first time evidence of domain formation over the entire range between magnetite and 75% ulvospinel content.

As part of a continuing study on the source of stable remanence in rocks, G.S. Murthy and R.R. Patzold observed Rayleigh (low-field hysteresis) loops for samples with confirmed multidomain magnetic behaviour, an observation that is in conflict with certain aspects of the magnetic granulometry interpretation.

J.P. Hodych has applied measurements of coercive force (H_c) as a function of low temperature to infer the domain state and assess the controls on coercive force in deep-sea basalts containing large titanomagnetite grains (x=0.6). The results support the expected multidomain state of the titanomagnetite grains, and suggest that H_c is often controlled by the magnetostriction constant perhaps through internal stresses.

E.R. Deutsch, G.S. Murthy and Prof. C. Radhakrishnamurty measured magnetic hysteresis and susceptibility as a function of temperature on three flood basalt bodies, the Rajmahal and Deccan traps and the Columbia River basalts, of ages 90 to $<$15 Ma. It was shown that a comparison of magnetic properties obtained from these and other basaltic bodies can provide clues on the occurrence and evolution of magnetic minerals in basalts of different age and origin.

(f) University of Toronto

Department of Physics (K.S. Argyle, D.J. Dunlop, M.E. Bailey, C.J. Hale, L.D. Schutts, H. Hyodo, T. Knight, M.O. McWilliams (Stanford U.)

(i) Fine-particle rock magnetism

Three commercial hematite powders of size ranges 0.3-1.2 μm, 2.0 - 4.0 μm and 3.8 - 5.9 μm have been reduced successfully to magnetite in oxygen fugacities of 10^{-23}. Room temperature hysteresis properties of the annealed powders dispersed to 1% volume concentration in kaolin give J_{rs}/J_s values of 0.078, 0.073, 0.045 and Hcr/Hc values of 2.87, 2.79 and 4.28 respectively. High temperature hysteresis and TRM measurements will investigate the PSD mechanism in this size range.

(ii) Ferromagnetic domain theory

Following the methods of Rhodes and Rowlands, Amar, and Moskowitz and Banerjee, we are calculating demagnetizing energies of multidomain cubes as a function of domain wall displacement. Results on two-domain cubes indicate that the effective demagnetizing factor is reduced by about a factor of 2 compared to bulk material, but is almost independent of wall position.

(iii) CRM experiments

Experiments to study the magnetic properties of CRM (chemical remanent magnetization) are continuing. Laboratory induced CRM in magnetite (produced by heating metastable titanomaghemite to 350°C) lies between the NRM (natural remanent magnetization) external field directions. CRM produced during other chemical reactions is being studied.

(iv) Contact and regional remagnetization in Abitibi subprovince rocks

Paleomagnetic studies, supplemented by Curie point and hysteresis measurements, are complete for a collection of about 160 Archean country rocks and intruding Matachewan and Abitibi diabase dikes from the Kirkland Lake-Matheson area, Ontario. In about one-fifth of the samples, an NRM component whose paleopole falls near the 1.9-1.7 Ga section of the Laurentian polar wander path (The "Coronation Loop") has been isolated.

(v) Paleomagnetic restudy of the Grenvillian Tudor gabbro

Paleomagnetic resampling of the Tudor gabbro is complete. From the Tudor body itself, 68 samples were taken at 12 sites. Complete contact tests were also made with the intruded Hastings marble (31 samples, 10 sites) and Tudor volcanics (35 samples, 7 sites).

Preliminary AF and thermal demagnetization results in some cases reveal two components of NRM. This result contrasts with earlier studies, which revealed a single, apparently young (675 Ma) NRM. In view of recent $^{40}Ar/^{39}Ar$ stepheating hornblende ages of about 1110 Ma for the Tudor (A.K. Baksi, Geophys. J., in press) the second NRM component could be much older than the first.

(vi) Grenville Front Traverse

Measurements and analysis are complete for the 1980 collection of Keewatin volcanics, Nipissing diabase, late Hadrynian dikes and mafic Grenville Province intrusions from the North Bay - Temagami - Sudbury region. Grenvillian overprinting of Nipissing diabase extends up to 5 miles NNW of the Front and overprinting of Keewatin volcanics is detectable 10 miles NNW of the Front.

(vii) Paleointensities and paleodirections of NRM from 3.3 Ga Onverwacht komatiites, Transvaal

Ninety-six oriented samples were collected from 16 sites in the type locality of the Komati Fm which is the uppermost formation of the Lower Ultramafic Unit of the Onverwacht volcanics. Nine sites have thus far yielded acceptable paleomagnetic directions ($k>10$) from serpentinized peridotitic komatiite while 3 basaltic komatiite units sampled were found to be too weakly magnetized to permit measurement with our spinner magnetometer and 2 other sites are apparently lightning struck. A pole position lying near the only other African Archean pole position (the Modipe gabbro pole) was calculated. A paleointensity of 9.2 μT, roughly a third of the present day value, was inferred.

Erindale College (R.E. Ernst, H.C. Halls; R.P. Meyer, M. Bengtson, J. Karl (University of Wisconsin)

(viii) Paleomagnetism of Dike Swarms in the Hearst Area, Northeastern Ontario

NW-trending dikes in the Hearst region, west of the Kapuskasing Structural zone (KSZ) correlate both petrologically and paleomagnetically with the 2.6 Ga Matachewan swarm.

(ix) Paleomagnetism of the Kabetogama-Kenora (KK) Dike Swarm, Minnesota-Ontario Border Region

Paleomagnetic results from the southern end of the NW-trending, 400 km long KK swarm reveal a primary component that correlates with that obtained by Schwarz from the approximately 2.0 Ga Richmond Gulf volcanics in Hudson Bay. Significant overprints are present, one of which probably dates from about 1.7 Ga, reflecting possible uplift or metamorphism associated with the Penokean orogeny. Work is continuing on samples collected from the northern end of the swarm near Kenora.

(x) Geophysical Studies of the Slate Islands Impact Site

Aeromagnetic and shipborne magnetic, sparker and seismic surveys have been completed in the vicinity of the Slate Islands. The seismic and magnetic results together indicate that the ridge is probably made of basement material with a thin veneer of Keweenawan sediments, while a thicker section of cover is preserved beneath the trough and has been relatively down-faulted against the ridge. The tentative conclusion therefore is that the annular bathymetric pattern around the islands is fault controlled.

(g) University of Western Ontario (H.C. Palmer, R. Govindarajan, C.M. Carmichael, H.H. Schloessin, A. Hayatsu; W.R.A. Baragar (GSC); J.H. Foster (Phoenix Geophysics, Toronto); M.C. Fortier (Amoco Canada, Calgary); H.C. Halls (Erindale College); Dr. Mothersill (Lakehead U.))

(i) Polarity Sequence during the Franklin Magnetic Interval

Widespread occurrences throughout the Canadian Arctic of 625-675 Ma tholeiitic dolerite sills and dikes constitute the Franklin magnetic province. Previous paleomagnetic studies on Franklin rocks indicate that field reversals occurred throughout this igneous episode. Franklin rocks on Victoria Island include a 700 m thick succession of superposed lava flows (Natkusiak Formation) which has been sampled in this study. Thermal demagnetization separates the sites into easterly (reversed) and westerly (normal) magnetic polarities. The polarity sequence recorded through the lava pile from the base upward is R-N-R.

(ii) A Test of the Logan Loop

Combined af-thermal demagnetization has been carried out on 160 samples of the Keweenawan Powdermill Volcanic Group (South Range traps), Michigan, collected along a strike length of 100 km and across a maximum stratigraphic thickness of 6 km. The Powdermill Group has yielded the only poles (Books, 1968,72) defining the E arm of the 1.1 Ga Logan Loop. Analysis is continuing.

(iii) Permeability and Curie Temperature of Magnetite at High Pressure

Numerous experiments have been performed in a cubic press in the range from 0 to 6 GPa and 0 to 1100K. Polycrystalline or single crystal cylinders of natural magnetite form the axial core of two concentric coils. The permeability μ is deduced from the inductive coupling between the coils, and the variations of μ with p and T are uniquely determined. Isobaric permeabilities have been obtained; Hopkinson's peak between 820-880 K, just before the steep descent at the Curie temperature, has been observed as have Curie temperature shifts.

(iv) Magnetic Overprinting by Late Devonian Dykes in the Glen Coe Area of Scotland

The magnetizations of the contacts of 23 of the northeast to southwest trending dykes in west central Scotland have been studied. Most of the samples were collected in Glen Coe where the dykes cut the Devonian age ryolitic volcanic complex that underwent cauldron subsidence toward the end of the volcanic episode. The magnetic overprinting by the dykes is correlated with K-Ar resetting in an attempt to distinguish the imprinted magnetization from the original. The directions of the field at the times of dyke injection were quite scattered, compatable with the field having a large nondipole to dipole ratio at this time.

(v) Magnetization of Sediment Cores from Lake Erie

The magnetization of cores collected by the Canada Centre for Inland Waters' research vessel Limnos in November, 1979 were measured at the University of Edinburgh. The declination and inclination changes down the core make an ambiguous match with those of some earlier cores from Lake Erie measured by Creer. Two additional cores were collected by CCIW during the Fall of 1980 but the study of these has not been completed.

(vi) Magnetization of Sediment Cores from Lake Ontario

Cores from the deeper basins at the west and east ends of Lake Ontario for a joint study with Dr. Mothersill were collected by the Canada Centre for Inland Water's research ship Limnos during cruise 80-22-010 October 14 to 16, 1980. An area where the sediment was at least 20m thick was found in each of the western and eastern basins. Additional cores were collected on a cruise in early May, 1981. The measurement of the magnetization of the sediment from these cores is in progress.

(h) University of Windsor (D.T.A. Symons, M. Stupavsky, A. Quick, I. Osmani, S. Dey, U. Atuanya, C.P. Gravenor; E. Deutsch, D. Morgan, G.S. Murthy (Memorial U.))

(i) Paleomagnetism of Algoman Banded Iron Formations

During the past year, paleomagnetic and rock magnetic properties studies on the Algoman banded iron formation and host rock Archean volcanics have been: a) completed and published for the Adams Mine near Kirkland Lake, Ontario; b) completed and published with respect to the surface magnetic anomaly at the Sherman Mine near Temagami, Ontario; and, c) completed but awaiting final analysis and publication for the Griffiths Mine near Red Lake, Ontario. Two basic conclusions have been arrived at: 1) the iron formations and host rocks have contemporary prefolding primary components acquired about 2.75 Ga, metamorphic secondary components acquired about 2.5 Ga during the Kenoran orogeny, and in some places a third component related to intrusion of the Abitibi dikes; and 2) a reasonable fit to the measured surface anomalies can only be achieved if the calculation includes the effects of the demagnetizing factor, the natural remanent magnetization, and the anisotropy of magnetic susceptibility.

(ii) Paleomagnetism of the Memesagemesing and Caribou Lake Norites

S. Dey has completed his M.Sc. thesis on this topic. The results show preservation of a Hudsonian (about 1.7 Ga) component and a Grenville (about 1.1 Ga) component. Susceptibility and fabric studies indicate that previous interpretations of the shape of the plutons based on the surface magnetic anomaly are wrong, i.e., they simply reflect the surface distribution of magnetite in the plutons rather than a "funnel" or "canoe-shape". The results have been presented orally.

(iii) Paleomagnetism of Cordilleran rock units

Paleomagnetic studies involving 30 to 60 sites per unit are in progress on the Westcoast diorite of the Insular Belt, and the Cache Creek, Hazelton, and Nicola volcanics of the Interior Plateau. Measurements are completed and data analysis is in progress.

(iv) Paleomagnetism of rock units along the Grenville Front

Paleomagnetic studies have been completed and are now in press on: a) Nipissing diabase and Gowganda units north of the Grenville Front in the Southern Province which shows that Grenvillian metamorphic components are found only within approximately 2 km of the Front; and b) anorthosite plutons south of the Front in the French River area that retain Hudsonian (about 1.7 Ga), Sudbury dike intrusion (about 1.3 Ga), and Grenvillian orogeny (about 1.0 Ga) components. Studies are also in progress on the amphibolite and on the carbonatite plutons in the same area.

(v) Paleomagnetism of the basal Huronian volcanics

Paleomagnetic studies are in progress on approximately 43 sites of basal volcanics around the Elliot Lake syncline from 4 distinct areas. Preliminary results indicate that they retain a post-folding or post-Penokean remanence.

(vi) Paleomagnetism of the Gunflint iron formation

U. Atuanya has collected and is currently measuring specimens from approximately 55 sites in the Gunflint iron formation of the Lakehead area. The intent is to update rather primitive early results obtained in 1963.

(vii) Paleomagnetism of the Late Precambrian Port Askaig tillite

A major conglomerate test has been run on the Port Askaig tillites of Scotland. The results have been submitted for publication and indicate that the remanence component giving an equatorial pole that has been used to indicate a worldwide Late Hadryian glaciation is in fact an Ordovician remagnetization.

(viii) Paleomagnetism of the Late Precambrian Gaskiers tillite

The Gaskiers tillite outcrops on the Avalon Peninsula in Newfoundland. D. Morgan has completed an M.Sc. thesis at Memorial under the direction of E. Deutsch and G.S. Murthy, and the Windsor group (C.P.G., M.S., and D.T.A.S.) completed a study of similar magnitude about 2 years ago. Using a fold test, conglomerate test, various stability tests, and petrologic tests, it is evident that the unit retains a postfolding Paleozoic remanence only. The results will be published jointly.

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III (B) AERONOMY AND SPACE PHYSICS

Compiled by: D. Venkatesan

1. Introduction

GOVERNMENT OF CANADA

2. National Research Council
3. Communications Research Centre, Ottawa
4. Energy, Mines & Resources
5. Herzberg Institute of Astrophysics

UNIVERSITIES

6. University of Alberta
7. University of British Columbia
8. University of Calgary
9. University of Saskatchewan
10. University of Tokyo
11. University of Victoria
12. University of Western Ontario

1. Introduction

This report was compiled for the Canadian Geophysical Bulletin from information supplied by Dr. R.E. Horita, Dept. of Physics, University of Victoria, Victoria, B.C., who has edited the DASP newsletter for the year January - December 1981. The primary purpose of this report is to present an overview of activities of the various institutions; thus no bibliography has been included.

GOVERNMENT OF CANADA

2. Associate Committee on Space Research (ACSR)/National Research Council (NRC), Ottawa

The ACSR/NRC met in Ottawa November 27, 1981. The following summarizes important issues, and is taken from the report of G.J. Sofko, DASP representative to ACSR.

I.B. McDiarmid, Director, Canadian Centre for Space Science (CCSS)/NRC reported on following major items: (i) Procedure for evaluating and selecting scientific proposals. These can be submitted to CCSS at any time, but the annual DASP/CAP meeting in general, will be the forum for generating and discussing new collaborative projects. These projects would then be evaluated by the Science Advisory Committee (SAC)/CCSS. (ii) Discussion currently going on with the Government regarding an on-going space science budget (equal to 15% of the total Government spending on Space). (iii) A summary of the status of 1981/82 and 1982/83 rocket and balloon programs, present instrumentation development, and future projects (STARLAB, Micro-gravity and Space Materials, Viking collaboration and campaigns in conjunction with Viking).

Ron Barrington and T. McGrath reported on behalf of the Local Organizing Committee, about the 24th COSPAR meeting, Ottawa, May 17 - June 2, 1982 with a Solar-Terrestrial Physics Symposium during the first week. This meeting presents a rare opportunity for the Canadian space science community to interact with radio, TV, and newspaper reporters and thus present Canada's space science role to the Canadian public. Prof. R. Nicholls, York University, is putting together films on the history of Canadian Space Science; any contributions of suitable photographic/film material would be appreciated.

The meeting discussed the space physics report prepared by Peter Forsyth on behalf of ACSR for NSERC. This is one of 7 reports on the various branches of physics, of which five groups have been submitted, with only the ACSR and ACA reports remaining. Four recommendations forming the essence of the Forsyth report for ACSR are summarized below:

(a) A joint committee of NSERC and NRC should be set up to recommend mechanisms to overcome the crucial shortage of manpower in space science, particularly at junior levels in the universities. Strong consideration should be given to full-time professional

research appointments at the universities, to direct payment by the Federal government of the salaries of older professors so that new young scientists could be added by the universities, and to the establishment of scientific institutes such as the Max-Planck Institutes in Germany.

(b) NSERC should strive to produce funding for cooperative projects under terms matching the NRC funding portion for those same projects.

(c) NSERC should establish a grant selection committee to deal with all aspects of space science in the universities. The membership should be chosen in consultation with NRC, ACSR, and DASP, and the members should act also as the CCSS Science Advisory Committee.

(d) The presidents of NSERC and NRC should be invited to set up a committee to recommend the scope and division of responsibility for a Canadian MAP program regarding the middle atmosphere. The procedure should be generalized to ensure a method by which Canadian scientists can participate in future international programs.

To some extent, recommendation (b) has been acted upon through the recent establishment of Cooperative Special Project Grants by NSERC. Also, NSERC and CCSS have set up a joint committee to act as the grants group for NSERC and the Science Advisory Committee for CCSS, so recommendation (c) appears to have already borne fruit.

3. Communications Research Centre, Ottawa (H.F. James and D.B. Muldrew)

(a) Radio Propagation: WISP

The conceptual design phases of the U.S. and Canadian instruments were both completed in 1981. However changes have resulted in both countries due to budgetary restrictions, on the design and development phases (II, III) of WISP and associated equipment. NASA has required the WISP project (prime contractor: TRW) to downscale equipment as follows: VLF transmitter now delivers 1 kW into a matched load, the WISP computer has fewer experiment coordination functions and the WISP dipole is reduced to 100 m tip-to-tip. NASA budget restrictions have also led to an important reduction in the subsatellite (RPDP) concept: the RPDP will not be released from the Remote Manipulator (R.M.S.) on Flight 1, a consequence of a descoping of the Space Plasma Physics Investigation part of the Spacelab 6 mission. The Active Experimenters' Working Group (AEWG) accepted a NASA HQ suggestion that the first AEWG flight, Spacelab 6, be restricted to a Beam-Plasma theme. This mission now contains only WISP, RPDP, the charged-particle gun (SEPAC) and beam diagnostic equipment (BPP). The flight is proposed for early 1987.

In September SPAR-Montreal submitted a phase-II proposal for the Canadian part of WISP, the High Frequency Sounder System (HFSS); the cost exceeded available NRC resources by 30%. Because of this and because a free flying RPDP is not available for a HFSS receiver on flight 1, it was agreed that NRCC/CCSS and SPAR should examine a descoped HFSS: they appear close to an informal agreement.

The descoped HFSS for flight 1 will probably have the following principal reductions from the Phase I conceptual design: no equipment on RPDP, removal of real-time display and decision-making functions for payload specialist and simplify transmitter to produce full power in 2-30 MHz, with pulses no longer than 10 msec, square-pulse modulation only. Our plan will be to build first a HFSS that permits easy add-ons to get to a flight-2 version with all the capability originally planned. The basic design philosophy for HFSS will not change. The flight-1 transmitter will have most of the flexibility it will ever need. The flight-1 synthesizers and receiver will be usable on both the Orbiter and RPDP, and the control electronics will be easily updated for more extensive experiment routines.

In short, all monostatic experiments originally conceived should be feasible on flight 1. Optimal use of system's flexibility and exercising novel features such as the fine frequency resolution, doppler sounding/radar and driving-point measurements are envisaged. The WISP/HF Group may meet early 1982 to discuss the rearranged science program.

(b) ISIS Research

It appears that the Dept. of National Defence will continue its support for ISIS operations. The ratio and optical instruments on ISIS 1 and 2 are functioning well; thus, barring any satellite failure, the spacecraft passes will be scheduled and recorded through 1982-83 and the DASP community is invited to use the data. Scientific requests for radio data should be addressed to Don Muldrew or H.W. James.

Various international groups have continued to use ISIS data with success. Collaboration with Stanford Radioscience Laboratory has produced a stock of interesting data on transionospheric VLF phenomena, and we are analyzing these. A new Siple VLF transmitter campaign starts in Jan. 1982 and ISIS coverage of the Siple conjugate point at Roberval is planned. The National Institute of Polar Research of Japan has catalogued a large body of auroral-latitude VLF data from their Antarctic telemetry at Syowa and these are valuable for auroral VLF studies.

(c) ISIS Sounder Research

For plasma frequency $\gg$ the gyrofrequency and near perigee positions of Alouette 2 and ISIS 1, a peculiar signal is seen on ionograms from the lowest frequency up to approximately one half the plasma frequency. This signal starts about 1 ms after the transmitter pulse and is then observed for a few msecs and its shape depends on the phase of the transmitted signal at the end (and/or perhaps the start) of the square transmitted pulse. This implies the signal results from energy supplied directly to the plasma, in the vicinity of the antenna, by the RF pulse. Pending satisfactory explanation a likely possibility is that the initial lack of signal is due to the plasma being driven away from the antenna by the pulse and the returning plasma is unstable to certain plasma waves which are detected by the sounder.

Simultaneous measurements were taken with the Chatanika incoherent radar in Alaska and with ISIS 1 near perigee in the nighttime auroral zone. Aspects-sensitive backscatter from small irregularities (30-60 m) was observed on the ionograms from a region having a sharp equatorial boundary. The incoherent radar showed this was a region containing large scale irregularities (tens of kilometers) or blobs. The small scale irregularities are generated by instabilities in the blobs. Strong hiss observed on the ionograms indicated the presence of keV electrons near the poleward edge of the auroral zone. The incoherent scatter data show that a blob was forming low in the F region at the same invariant latitude as this precipitation.

4. Energy, Mines and Resources: Earth Physics Branch: Division of Geomagnetism

(a) Magnetic Stations and Observatories

The Observatory Unit of the Division of Geomagnetism continued its management of the Canadian Magnetic Observatory Network (CMON) of the following 13 magnetic observatories: Alert, Resolute, Mould Bay, Cambridge Bay, Baker Lake, and Yellowknife in N.W.T., Fort Churchill, Man., Great Whale River, Que., Meanook, Alta., Glenlea, Man., St. John's, Nfld., Ottawa, Ont., and Victoria, B.C. In addition several variation stations recording at ten-second intervals were also in operation. Igloolik, N.W.T. operated throughout the year. Ten-second data also exist for mid-December, 1980 to end-March, 1981 for Churchill, Gillam, and Rankin Inlet in support of the FALCON project.

Full descriptions of the Network (CMON) and variation stations are contained in the various annual reports for magnetic observatories. Copies of magnetograms and raw or edited digital data are available at cost plus 100% handling charge from the Division of Geomagnetism, Earth Physics Brasnch, Ottawa, K1A 0Y3. Details of other services available are listed in the Catalogue of Services for the Division of Geomagnetism.

(b) Undisturbed Levels at Magnetic Observatories and Secular Variation

A new method was developed by J.K. Walker to determine the undisturbed baseline at magnetic observatories. These baselines are important for the separation of internal and external fields and sources. Extremely quiet dark nighttime intervals were carefully

selected by considering times when both the global activity was low (Dst, Kp and AE less than 10-20 nT) and the local activity was minimal. Short period disturbances were removed by low pass filtering before the quiet levels were calculated. A quadratic regression analysis of the quiet levels determined the undisturbed baselines and the main field secular variation. The standard deviation of this analysis was 4-10 nT. All the available 1 min digital data for eleven Canadian magnetic observatories, spanning the interval 1973-80, were examined. The differences between the undisturbed baselines and the annual means indicate an equivalent net westward current in the auroral zone of approximately 40 KA.

(c) Magnetic Storms and Upper Atmospheric Disturbances

The investigation into the relationship between magnetic storms and changes in the upper atmosphere by J.K. Walker is continuing with the development of parameters to characterize both magnetic disturbances and atmospheric changes. All the available digital data on the middle atmosphere were acquired from NCAR and algorithms are being developed to analyze these data so that they can be compared with corresponding parameters determined from the magnetic indices AE, Kp and Dst. A preliminary comparison of these reduced magnetic and atmospheric parameters indicates a high degree of correlation with the atmospheric disturbances occurring a few days after magnetic events. Refined models of the Joule heating rate during disturbed conditions indicate an additional significant peak at approximately 75 km as well as the main peak at approximately 125 km. This heating in the thermosphere and mesosphere may lead to their coupling and cause changes in the polar middle-atmosphere circulation system during magnetic storms.

(d) IMS Analysis

The one min. magnetic data from 21 EPB observatories and IMS stations were assembled, together with their undisturbed baselines, for the IMS coordinated Data Analysis Workshop (CDAW6). The 10s data for the IMS stations were also sent to GSFC for this study of the storms on 22 and 31 March 1979. The purpose of this international study is to determine the energy transfer from interplanetary space through the magnetosphere to the ionosphere and upper atmosphere.

Magnetic data from the observatories and IMS stations were also assembled and analyzed for studies of 3 magnetic storms with coordinated observations from the Millstone radar.

(e) Solar and Lunar Variations

J.C. Gupta examined the solar and lunar harmonic coefficients from long series of North American data to study the geomagnetic seasonal variations. He found that the lunar magnetic tide undergoes an annual variation with maximum of amplitude occurring in August in several station components and a semi-annual variation with maxima of amplitude occurring at equinoctial months. The two variations dominate in different latitude ranges. The in-flux of the EUV radiation may contribute significantly in producing periodicities. Previously reported global enhancement of lunar tide in the month of January has not been found at several North American stations. At auroral zone stations anomalously large amplitudes of the lunar tide are found. Also the Y-component amplitude of the lunar tide in the northern summer is found to be unexpectedly large at Agincourt and Fredericksburg when the lunar dynamo in the southern hemisphere is either weak or totally absent.

(f) Pulsations

Analysis of the Nurmijarvi Pc5 pulsation data for the years 1967 and 1972 revealed that the diurnal variation of occurrence changed significantly with varying geophysical conditions. The diurnal variation of Pc5 amplitude was found to change from an inverted U-type variation in 1967 to a U-type variation in 1972. The influence of magnetic activity on the Pc5 pulsation period is found to be different from that at similarly located stations. The difference noted in the strength of the autumn and spring equinoctial peaks may be due to the difference in the solar hemispherical activity. Also Pc5 periods are found to be strongly correlated to the sunspot numbers.

J.C. Gupta is also actively engaged in the analysis of the Pc1 data collected at Ottawa during the IMS period.

5. Herzberg Institute of Astrophysics: Planetary Sciences Section (A. Vallance Jones, R.L. Gattinger, F. Creutzberg, F.R. Harriss, D.R. McDiarmid, A.G. McNamara, B.A. McIntosh, P.M. Millman, I. Halliday, A.A. Griffin, A.T. Blackwell)

(a) Auroral Photometry

(i) Operation of the 12-inch H_β photometer at Ottawa was terminated in May 1981. Data analysis has commenced with emphasis being placed on long term calibration stability, special geophysical conditions, and summary plots.

Analyses of the results from the 15 channel zenith photometer are continuing. Preliminary results have been obtained on the decay rate of the O_2 Atmospheric emission. Auroral pulsation events have been analyzed.

A pre-ARIES experiment was conducted at the end of February 1981, from Churchill and Gillam to simultaneously measure auroral heights and obtain spectra of type-B aurora using T.V. imaging systems, bore-sighted photometers, meridian scanning photometers, and zenith photometers. The experiment will be repeated in January 1982, in a further attempt to make successful observations of type-B aurora at or near the magnetic zenith at Churchill.

Additional ISIT T.V. cameras and related equipment purchased by CCSS are being assembled into systems suitable for all-sky or narrow field observations in both broad band and selected wavelength modes. These cameras will be used during the winter of 1981-82 for project CENTAUR, the second pre-ARIES experiment and Waterhole II.

The first paper on the results of the IMS meridian photometer chain is essentially complete. It deals with the signatures of "isolated" substorms as a function of substorm time and magnetic local time.

There has been considerable involvement in the planning of future projects such as VIKING, CANOPUS, BARS, and WAMDII. Members of the Section have made a major effort in connection with the optical design of the Viking UV Imager camera. The CANOPUS Project has involved planning of the instruments for the meridian photometer chain.

(ii) Ground-based measurements for project Waterhole 1 were extensively analyzed and produced interesting supporting evidence to the in situ rocket measurements regarding the electric field in and near auroral arcs. A close correspondence between the ion convection velocity normal to the arc and the drift motion of the arc is observed which implies a near zero tangential electric field inside an auroral arc. Useful experience was gained for further such experiments. Measurements are planned for project Waterhole II in February 1982.

An attempt to make coordinated drift motion/ion convection measurements in project FALCONS in March 1981 was less successful due to fickle auroral behaviour and viewing aspect.

Preparations are well in hand for project CENTAUR, an extension of previous expeditions to Cape Parry to study the optical morphology of the prenoon sector of the auroral oval.

(iii) During the new moon period in February and March of 1981 photometric instrumentation and a T.V. system were operated at Churchill in conjunction with a similar system at Gillam, Man. The purpose of the program is to gather data from the aurora and to test and refine systems to be operated during an auroral modelling campaign. A similar system will be placed at the same locations during January 1982.

Analysis of auroral photometric data acquired during the flights of rockets VA-50 and VA-52 is nearing completion. This experiment is an attempt to model the O_2 atmospheric bands. Two photometers will be flown this winter on the Waterhole II rocket payload. These are to provide a time-position history of the water cloud at selected wavelengths. One additional photometer will be flown into nightglow from White Sands in october 1982. The experiment is dedicated to the measurements of the altitude profiles of the O_2Atm. (0,0) and (0,1) bands. The photometer is to be recovered and flown later into aurora.

(b) Radio Aurora

The pre-BARS II field campaign during the summer of 1981 yielded an extensive and rich data set. The Planetary Sciences Section assisted the originators of this project, Sofko and Koehler, and we are now engaged with them in the analysis of the radio scatter from the auroral plasma. These analyses, among other things, will investigate a) both the magnetic and streaming aspect sensitivity of the scatter, b) the dependence of the Doppler spectra of the scatter on both the magnetic and streaming aspect angles, and c) the character of the fading spectra and its relationship, if any, with certain geophysical parameters. These results will extend to higher magnetic aspect angles than those of previous work.

(c) Pc5 Pulsations

The first stage of a non-uniform transmission line model of Pc5 pulsations has been completed and is in press. The most important contribution of this model is its description of the transient phase of the disturbance. Some characteristics of the transient phase differ from those of the steady state. It is hoped to further develop the model.

(d) Plasma Probes

A paper on the results of probe measurements on ADD-VA-50/52 in pulsating aurora has been published. Measurements of electron density and temperature and the suprathermal electron flux were obtained. Their relationships to the observed optical fluctuations were examined. No evidence was found to support an ionospheric feedback model for the generation of these pulsation events.

Plasma probes flown on Waterhole 1 clearly registered a plasma density depletion as the payload traversed the explosion cavity. A sharp initial drop of several orders of magnitude was observed, followed by a rapid recovery to a lower level of depletion while within the cavity. A similar experiment has been instrumented for Waterhole II.

Analysis is continuing on data obtained during the auroral flight of AAF-IVB-36 and the electron gun flight of AAF-NVB-06. On the latter, probes on the mother and daughter payloads gave evidence of beam-plasma breakdown and unusual interactive effects in the vehicle-beam-plasma system. A paper on some of the preliminary results has been presented.

In Deccember, Project CENTAUR rockets from Cape Parry will carry plasma probes for cleft measurements.

(e) Space Science Program

Members of the Section have been active in the design, specification, and working groups of a number of space science instruments. These include WISP, WAMDII, and the auroral imager, scanning photometers, and BARS parts of CANOPUS. The design and specification of the U.V. Imager for the Viking spacecraft has also been a major activity.

(f) Meteor Observations

The meteor radars at the Springhill Meteor Observatory were operated for a few days during each of the major meteor showers. Such data accumulated over a long period of time (now $>$ 20 years) determine the cross-section of a meteor stream and the distribution of particles around the stream. Differences in these distributions as a function of the size

of the meteoroids are important in assessing the past and continuing evolution of meteor showers.

A sensitive (light intensified) TV camera was used to record meteors during the Delta-Aquarid and Perseid meteor showers. The latter is being monitored for possible increase in activity associated with the return of the parent comet (1862 III P/Swift-Tuttle, period 120 yr.).

(g) Meteor Spectroscopy

A study of video-tape records of meteor spectra, secured on observational programs of the Herzberg Institute of Astrophysics in Ottawa, and the NASA Marshall Space Flight Center in Huntsville, Alabama, has been continued. These spectra are produced, in the main, by the cometary meteoroids, small solid fragments of various comets with orbits that intersect the orbit of the earth. During the past year the emphasis has been on refining the photometric techniques used in the analysis of the video-tape records. Priority is being given to the spectra of meteoroids from Comet Halley and Comet Swift-Tuttle, both of which comets are expected to be visible from the earth some time within the next decade. They have produced the three major annual meteor showers known as the Orionids, the Delta Aquarids, and the Perseids. The first aim of this program is to derive information concerning the relative chemical abundances of the various elements in the meteoroids originating from different comets.

(h) Meteorite Recovery

No searches have been conducted in the past year for meteorites associated with fireballs photographed by the MORP camera network. About 100 fireball trajectories and orbits have now been reduced. Particular attention is being directed to those cases in which any surviving meteorite is too small to justify a search (less than about 100 grams) in order to derive better statistics on the frequency of such small meteorite falls.

A study has been completed of the relative rates of meteorite falls to be expected over the surface of the earth as a function of time of day, time of year and geographic position. The calculations are based on a distribution of orbits assumed to be representative of meteorite falls, based on orbital data from the camera networks. This approach avoids making uncertain assumptions about the efficiency of meteorite recovery by rural populations under differing conditions.

During the spring of 1981 a 23-cm diameter metal gas bottle was found by a farmer northeast of North Battleford, Sask., along the projected path of the Cosmos 1220 rocket re-entry observed by the MORP cameras on November 4, 1980. The object is similar to others recovered from satellite re-entries but is covered with mm-size pits, possibly due to high-speed impacts with drops of satellite debris from leading fragments during entry. A.A. Griffin, A.T. Blackwell.

(i) Infrasound

An array of microbarographs has been operated near Saskatoon in an unsuccessful attempt to measure infrasound from meteorites. There were many records of wavetrains which were coherent across the array but moving at subsonic velocities, of the order of 10 m/s. The most spectacular of these lasted for about three hours and was associated with the eclipse of 1979 February 26. Others, of shorter duration and lower amplitude were recorded, predominantly during the dark hours, as frequently as several per week. A study of these leads to the conclusion that they are forced gravity waves induced by shear layers at heights of 1 km or less. The shear layers are frequently, but not necessarily, associated with weather fronts.

6. University of Alberta, Institute of Earth and Planetary Physics/ Department of Physics: Magnetospheric Physics (G. Rostoker)

The primary efforts, as earlier, deal with the analysis of ground-based magnetometer array data (supplemented by selected spacecraft data) aimed at understanding how the solar wind energy penetrates into the interior of the earth's magnetosphere and eventually dissipates in the earth's upper atmosphere.

The major breakthrough from past year's research by G. Rostoker, M. Mareschal and J.C. Samson is the discovery that the electric current in the magnetotail (responsible for much of the tail magnetic field) can be dumped suddenly into the ring current system which (in part) short circuits through the ionosphere. It appears that this tail current rerouting is triggered by northward turnings of the IMF. Thus, while southward IMF leads to storage of energy in the tail, a northward turning results in the impulsive release of that stored energy leading to major magnetospheric substorm activity.

Present effort is to upgrade the comprehensive three-dimensional current system developed by T.J. Hughes and G. Rostoker, for use in modelling studies of the magnetosphere's response to solar wind effects. Some of the final refinements being carried out by M. Mareschal and G. Rostoker are the proper arrangements of upward and downward field-aligned current sheets in the post-noon quadrant. Programs for the modelling presently being organized by E. Shaver and G. Rostoker will include both the above mentioned refinements and a modification of the dayside current flow to represent the DPY current system and of the nightside current flow to better simulate the currents flowing in the magnetotail.

Theoretical studies initiated this year, are designed to provide an understandable framework in which to describe the relationship between plasma convective flow in the magnetosphere and the electric currents coupling the magnetosphere to the ionosphere. M.S. Tiwari and G. Rostoker are now attempting to develop a mathematical framework in which to quantitatively present the above-mentioned relationship.

The detailed analyses of Pi 2 pulsations associated with magnetospheric substorms by J.C. Samson and G. Rostoker over the past two years have enabled the development of sophisticated models for these pulsations; only simple hydromagnetic resonances have been proposed in the past. In particular, the onset of Pi 2's is being related directly to the development of the westward travelling surge in an auroral breakup and the polarization characteristics of the pulsations in the near vicinity of surges is being used to understand the development of Pi 2 pulsations in the context of oscillations of the substorm-disturbed westward electrojet and its associated field-aligned currents.

The other major activity is the study of ULF magnetic pulsations, particularly those associated with the onset of magnetospheric substorms. The study of such short-lived impulsive bursts has necessitated the development of relatively sophisticated analysis methods in order to deal with the unpredicatable mixture of random noise and polarized signals detected by arrays of multichannel detectors. Samson has developed a number of methods for determining the estimators of the spectra of these polarized waves which have, in turn, permitted us to study the development of Pi 2 pulsations in the region of auroral breakup, despite the large amplitude broadband ULF noise background in that region.

7. University of British Columbia, Department of Geophysics and Astronomy (T. Watanabe)

(a) Geomagnetic Pulsations

In cooperation with the Universities of Tokyo and Kyushu, Japan, T. Watanabe has investigated the geomagnetic pulsations concurrent with a latitudinally propagating on-off switching auroral event observed during the Pulsating Aurora Campaign (Saskatchewan, Jan. and Feb. 1980). A series of propagating aurorae (time interval about 10 s) were recorded simultaneously at Rabbit Lake (68° geomag. lat.) and La Ronge (64° geomag. lat.). The polarizations of the concurrent geomagnetic pulsations observed at the stations indicate that they were caused by periodic enhancements of the ionospheric electric currents due to precipitations of energetic particles of the latitudinally-propagating on-off switching aurorae and that the ionospheric currents were westward at Rabbit Lake and eastward at La Ronge.

S.J. Visser has analyzed in detail the fine structure of Pi 2 type geomagnetic pulsations of Pi 2 event on September 18, 1976 (recorded by T. Watanabe, T. Oguti et al., of Tokyo and R.E. Horita, of Univ. of Victoria) with the help of F. Maxwell. This yielded a dynamic spectrum in frequency range 0.1 to 1.6 Hz approximately. The spectrum computation used multiple digital filtering (Gaussian filter) and complex trace analysis. The dynamic spectrum indicates that the geomagnetic pulsation is separated into at least

two bands divided roughly at 0.4 Hz and that the mid-frequency of the lower frequency band increases with time whereas no trend is clear for the higher frequency band.

B.E. Chapel is developing a system to time-integrate the output of an induction magnetometer, to yield information on geomagnetic field variations as a fluxgate magnetometer does, rather than time-derivatives of field variations. Induction magnetometer output recorded on a magnetic tape can be integrated by tape play-back at high speed and using an operational amplifier; but the wow-flutter of a taperecorder/playback unit inevitably gives rise to errors in integration. To overcome this, Chapel is designing a digital integrator using the Mostek Z-80A microprocessor. Other sources of errors such as the temperature change in impedance of the head sensor of the induction magnetometer system and the D.C. drift of the amplifier are also being investigated.

8. University of Calgary, Department of Physics (L.L. Cogger, C.D. Anger, J.S. Murphree, D. Venkatesan, A.W. Harrison, S.R. Sreenivasan, B.A. McIntosh)

(a) Ground-based Optical Studies of the Upper Atmosphere

A Fabry-Perot Spectrometer (FPS) and a scanning photometer have been installed on a 40-ft. observing trailer near Calgary (collaborators: P.B. Hays and J.W. Meriwether, Univ. of Michigan; NSF grant to U of M). The 15-cm FPS measures routinely temperatures and winds in the thermosphere using the λ6300 emission of atomic oxygen. The photometer provides emission rates of prominent airglow and auroral lines. Both instruments operate unattended. The computer controls all the procedures associated with the trailer operation. A 1-m grating spectrometer (on loan from C.A. Barth, Univ. of Colorado), complementing the other instruments, is to be installed in Jan. 1982.

One exceptional auroral event produced winds of magnitude 800 m/s which to our knowledge are the largest that have been measured from the ground.

The development of all-sky monochromatic imagers is continuing. The presently operating instrument comprising all-sky fisheye optics and a Fairchild 100x100 CCD detector is being installed for the winter in a trailer a few miles from Calgary.

Our next version containing more suitable optical components and an RCA 256x320 CCD detector is being built. An image display and processing system under development will handle the enormous amount of data that will be acquired. Experience gained will hopefully help with imager development for the CANOPUS program. The imager experiment involve L.L. Cogger assisted by C.D. Anger, S. Babey, Bob King, Peter King, and S. Murphree.

(b) Viking Ultraviolet Imager Science Team

A major project (funded by NRC) is to produce a dual wavelength intensified CCD imager for the Swedish Viking satellite due for launch in 1984. Work is well underway on the Engineering Model by Canadian Astronautics Ltd., and a Science Team consisting of 15 Canadian scientists and 3 from Sweden and the United States have been assisting NRC and the contractor in technical aspects of the instrument and data analysis system design, and working scientifically with Swedish colleagues in preparing for the mission. During the prime observing period in 1984-85 the scientists will gather at Kiruna, Sweden to work with and share the incoming data. The capability to examine the data in real time and to modify instrument modes in response to observations is expected. This capability will be a first for missions of this type. The spacecraft will carry an impressive array of wave, particle, field, and auroral imaging instruments into regions where the acceleration of auroral particles is known to occur. With the imager we expect to observe the global auroral pattern, and the specific auroral activity at the foot of the field lines traversed by the spacecraft. Much of the calibration and evaluation of the UV cameras, which will image in two wavelength regions covering the N_2LBH band and the OI 1304A line, respectively will be at team member A.L. Broadfoot's laboratory in Tucson.

(c) Project Galileo

The future of this mission is under a cloud of uncertainty at present; nevertheless, work is progressing.

The CCD imager to be used to study the dark sides of Jupiter and its satellites has changed somewhat over the past year. In order to avoid radiation noise (due to its small full well capacity) the 3 phase 800x800 TI array has been abandoned in favour of the new virtual phase array which is much more stable in a radiation environment and has lower dark current. Unfortunately (for lowlight level imaging) and rather unexpectedly, the readout noise of these devices is proving to be quite high (possibly up to 100 electrons). It is hoped that the Engineers will succeed in bringing this back to the vicinity of 25 electrons - otherwise more averaging of pixels than anticipated will be needed in order to get the needed sensitivity for dark side viewing.

(d) Auroral Physics

Recent work using the most comprehensive two-dimensional data from the ISIS-2 optical detectors, has concentrated on interpreting the instantaneous auroral distribution in terms of its magnetospheric implications. In particular the interaction of dayside and nightside auroras and the lack of distinction (at times) between polar cap and auroral oval features have been studied. Present study deals with two aspects (i) continued analysis of acquired ISIS data, with specific reference to the diffuse aurora, significance of auroral boundaries, and characteristics of particle energy deposition: A detailed quantitative analysis of the diffuse aurora has yet to be completed. There are clearly local time variations in its intensity and spatial extent and since its existence reflects pitch angle scattering processes in the plasmasheet it is an important tracer of activity in the magnetosphere. Also, studies of the instantaneous two-dimensional distribution of the energy deposition rate and the average energy associated with the particles producing the optical emissions have been undertaken: The latter involves ratios of 5577/3914 and 6300/3914 emissions. Correlating data from two optical instruments on ISIS 2 in a quantitative manner, is now becoming possible. (ii) Collaboration with the imaging photometer experimenters on the Dynamics Explorer Satellite (DE): The primary limitation of satellite imaging devices up till now is their lack of temporal resolutions; e.g., The auroral scanning Photometer on ISIS 2 provides one image (at both 4477A and 3914A) during each satellite orbit (approximately 110 minutes). Thus short term modifications in the auroral distribution cannot be studied. This shortcoming is now overcome since the launch of the Dynamics Explorer (DE) satellite (July 1981) carrying a multi-wavelength image. This imager is capable of providing images at the rate of about 1/min., although at a reduced resolution compared to ISIS-2.

The ISIS 2 imagers are still functioning normally and can be compared with DE imager. Arrangement for exchange of data is underway. Note that the DE imager provides quantitative data from very high altitudes with excellent temporal resolution, while the ISIS imagers provide very good spatial resolution.

(e) Space Physics: Cosmic Rays

Routine operation of the Calgary Neutron Monitor continues. The result of collaboration with S.P. Agrawal (formerly of HIAS/NRC, Ottawa; present address APS University, Rewa, India, and L.J. Lanzerotti, Bell Labs, Murray Hill, N.J.) continues. A number of manuscripts have appeared in the Journal of Geophysical Research.

(f) Auroral X-Rays

The Cospar International Conference (Budapest, June 1980) proceedings have been published in 1981; papers by D. Venkatesan and K.K. Vij on "A decade of auroral X-ray observations" have been published in the Advances of Space Research, Vol. 1, containing the proceedings.

During the months of October and November 1981, D. Venkatesan and group (L. Varga, H. Graumann, and Z. Spevak) and C.D. Anger's group (S. Murphree, Bob King, Steve Babey, Peter King) were at Cold Lake for a collaborative balloon program cum ground observations - the

former to measure auroral X-rays by balloon-borne payload, the latter to measure optical auroral emissions by the ground based CCD System. SRFB/CCSS support personnel present were Pat Worth, Dennis Euchuk and Bob Ruehlan. Unfortunately bad weather involving cloudy conditions, wet snow, and high winds prevented any successful launch. The difficulty of such a coordinated program is of course to be recognized.

(g) X-Ray Astronomy

Two papers, Soft X-Ray Emission from Supernova Remnants, 1C443 and SN1006 have appeared in Journal of Astrophysics, and Astrophysical Letters (1981), collaborators are D. Venkatesan, C.M.F. Galas and G. Garmire (Penn. State).

(h) Far Infrared Solar Studies

Data from the far IR photometer flown on the NASA Convair Airborne Laboratory from Panama City in August 1980 to observe the annular solar eclipse have been analysed and a manuscript is underway. Although the annular eclipse geometry is less than ideal for providing high angular resolution scans of the extreme solar limb, these data also show a flatter limb distribution than predicted for a homogenous chromosphere. The planned total eclipse expedition for the 1981 eclipse over the Pacific Ocean was cancelled by NASA for budgetary reasons.

The rebuilt balloon-borne solar telescope incorporating a high resolution Michelson interferometer and an in-flight calibration source was successfully test flown from the Space Research Facility at Gimli in July, 1981. The telescope, interferometer and all support systems functioned well, but no solar or calibration source spectra were measured. The refurbished telescope is almost ready for the 1982 flight season.

The data from these flights will be utilized for further work on the absorption spectrum of the stratosphere in support of O_3 depletion studies. Synthetic spectral analysis indicates that OH and H_2O_2 lines should be easily detected at the altitude and spectral resolution attainable with this equipment.

The overall spectral envelope at these wavelengths (100-500 μm), when suitably radiometrically calibrated in flight, should provide valuable information on the temperature distribution from source depths in the Sun around the temperature minimum at the boundary between photosphere and chromosphere. T.A. Clark, Rita T. Boreiko, and T. Cashion (Summer student, 1981).

(i) Atmospheric Physics

A serious commitment to the development of an atmospheric lidar probe has been made through the purchase of a tunable dye laser and associated optics. The lidar will be used in conjunction with atmospheric acoustic sounders, nephelometer, telephotometer and radiometer to study the effects of the Chinook and temperature inversions on the boundary layer. A field site has been established on high ground 15 km from the city limits of Calgary providing optimum viewing conditions over the urban area.

(j) Theoretical Plasma Physics

S.R. Sreenivasan and M. Schroeder have discussed the stability of a positive column carrying a current treating the effects of ionization and collisions in a partially ionized three-component fluid. A generalized Routh-Hurwitz criterion with complex coefficients in the dispersion relation was employed to isolate onset conditions for instability. The result predicts instability when the drift speed exceeds 5/6ths the electron thermal speed in excellent agreement with observations. This result has potential applications to the formation of double layers in space and laboratory plasmas, astrophysical plasmas and controlled thermonuclear fusion research. This paper has been accepted for publication in the Physics of Fluids.

A report summarizing the main phenomena observed during the five years of operation of the microbarograph array is being prepared.

9. University of Saskatchewan, Saskatoon, Atmospheric Dynamics Group; Medium Frequency Radar (J.B. Gregory, A.H. Manson, C.E. Meek and M.J. Smith)

The main emphasis of the research centres on the use of a 2.2 MHz radar, to measure winds at heights of 60-110 km and electron densities at 70-90 km. In September 1978 the real-time winds processing system had just begun to operate: now we have 3 years of continuous middle atmosphere data (60-110 km). Winds have been calculated every 5 minutes, at available heights, and stored on tape. Most subsequent analyses have used hourly mean profiles, for which 3 km height resolution is usually available. Providing 16 or more of the 24 hours is available, harmonic analysis provides the daily mean and daily 24-/12-h tidal oscillation characteristics. System reliability, and ionospheric variability, has allowed about 20 days per month (more in 1981) so monthly means and seasonal variations can be studied. The monthly mean winds (tidally corrected) have been compared with existing models (CIRA, 1972); it has been shown that these latter have tidal contamination above about 80 km, and do not reflect what appears to be a solar cycle trend (Gregory et al., 1981); and that the meridional flow over Canada does not follow the simple heat-engine pattern of winter poleward flow (Manson et al., 1981b). Also, comparisons with rocket winds (ROCOB) from Cold Lake (Alta.) have provided one of the best technique-comparisons; ROCOB winds above 60 km have been shown to contain an uncorrected ballistic effect - below, the agreement is excellent. 24- and 12-hr tides have been studied (Manson et al., 1981a,b) - the continuity of the data over 3 years has allowed a regularity of seasonal variation to emerge. During winter months vertical wavelengths are short (probably S 2/4, S 2/5, and S 1/1 modes), but during summer are long (S 2/2, S 1/-1): the seasonal transitions are unexpectedly rapid and yet regular in time. Additional features are the large daily tidal variability, and the existence of about 9, approximately 16-h oscillations (likely non-linear tidal interactions). Finally, daily mean winds for the 3 years have been analyzed for 26-, 12-, 6-, 3-mth oscillations (Manson et al., 1981c): results are consistent with, but more reliable and detailed than earlier studies.

Plans are to operate continuously through the years of MAP (1982-5), taking special part in projects involving the dynamics of the region from 60-100 km. J.B. Gregory, A.H. Manson, C.E. Meek and M.J. Smith.

10. University of Tokyo, Geophysics Research Laboratory, Tokyo 113, Japan (J.H. Meek)

It seems appropriate to report from Tokyo as so many of the researchers here have spent time in Canada doing research and observing in the fields of Aeronomy and Space research. They include T. Oguti, S. Kokubun, T. Tamao, and K. Hayashi from this laboratory and T. Obayashi, A. Nishida, K. Tsuruda and S. Machida from the Institute of Space and Astronautical Science (ISAS).

Several campaigns (1976, 1978, 1980) have been launched in Canada in recent years, with the help of T. Watanabe of U.B.C.

The ISAS has concentrated on the study of VLF wave transmissions from Siple station, Antarctica, observed at Roberval, Que. near the conjugate point. The transmissions as well as artificially stimulated waves generated by them were studied. The propagation paths of the transmissions were determined by the spatial distribution of the wave intensities by a grid of 9 stations spaced about 70 km apart.

The Geophysics Research Laboratory (GRL) carried out its third campaign to observe geomagnetic and ground pulsations, in cooperation with the Canadian Auroral Pulsation Campaign of Jan.-Feb. 1980. Five papers are included in the special issue of C.J.P. Vol. 59, No. 8, 1981. The following additional information is supplied by Prof. T. Oguti.

The study at GRL of observations made in Western Canada include the following:

1) Spatial and temporal variations of pulsating aurora (Yamamoto and Oguti). Pulsating auroras observed with TV auroral cameras occurring on Feb. 15 and 16, 1980 have been analyzed and the results will be published soon.

2) Relation between auroral pulsations and concurrent geomagnetic pulsations (Oguti, and Meek). Some examples of pulsating periods on Feb. 15 and 16, 1980 are being analyzed with a view to establishing the close relationship between auroral pulsation currents and magnetic field pulsations observed at the ground.

3) Spatial and temporal characteristics of the polarization of magnetic pulsations (Hayaski and Ishida). This study is quite involved requiring rather sophisticated analysis and is progressing more slowly. Some examples of polarization variations have been produced in a multicolour display.

4) Spatial and temporal relations between auroral pulsations and geomagnetic pulsations and VLF waves (Kokubun, in cooperation with Tsuruda-ISAS). The study of the relation between magnetic pulsations and VLF chorus is continuing. The analysis of the relation of VLF waves to auroral and geomagnetic pulsations takes a lot of effort for data analysis and results will require a little more time.

11. University of Victoria, Department of Physics; Atmospheric Airglow Emissions (H.M. Sullivan, R.E. Horita)

(a) Project CAMEO

The analysis of observations made during project CAMEO (Chemically Active Materials Ejected in Orbit) has now been completed. During this experiment 1.4 kg of lithium vapour were released by Nimbus 7 polar-orbiting satellite over northern Scandinavia at a height of 961.3 km on November 6, 1978. A weak enhancement of twilight lithium emission was observed at Victoria, B.C., 77 hours after the release. The maximum intensity after injection was approximately 50 rayleighs, falling to 15 rayleighs in about 7 days. Although very bright emissions were observed at Tromso and Skibotn as the cloud passed overhead, the zenith brightness at Longyear-byen was very much less than expected five minutes after injection. This effect may be explained if the cloud did not disperse as quickly as expected so that the emissions were unable to arrive at Longyear-byen before the cloud orbited poleward.

(b) Poker Flat Lithium Release

Two strong enhancements of twilight lithium emission were observed at Victoria following two rocket releases of lithium vapour in the height range 200-300 km at Poker Flat, Alaska. The first release took place on April 15, 1979, and the second one on April 18, 1979. An emission intensity of 192 rayleighs was observed 6 days after the first release, and an intensity of 272 rayleighs 5 days after the second release.

(c) Calibration of Optical Sources

A white light low-brightness source was taken to the Optical Calibration Workshop which was held in Aberdeen after the IAGA meeting in Edinburgh, in August 1981. Although a problem with light leakage in the wings of the 6574 A interference filter in the transfer standard photometer was encountered the effect has been minimized by interpolation of the response curve.

(d) Project TEFLON (an interesting acronym suggested at a meeting of the working group for a proposed rocket program - Tangential Electric Fields Located On the Nightside).

Construction of a wide-field high resolution scanning photometer is being undertaken to study the morphology of barium clouds to be released by a rocket which will be fired into an auroral arc in northern Manitoba in the spring of 1983.

(e) Plasma Waves

A.K. Gwal has recently arrived from India as a postdoctoral fellow and is investigating growth rates and stability criteria for various wave modes: whistler, magnetosonic and ion cyclotron, using data from the ISIS II satellite. He is also investigating VLF saucers, continuing the cooperative work with H.G. James of the Communications Research Centre.

The cooperative project with R. Shier of B.C. Hydro and T. Watanabe and D. Boteler of UBC has shown that the observed magnitudes and spectral characteristics of the recorded power system geomagnetically induced currents are consistent with the known spectral characteristics and the presumed spatial characteristics of the geomagnetic field. There

are a number of other cooperative projects underway including the study of the PiB phenomenon with R.L. McPherron of UCLA and J. Kangas of the Univ. of Oulu, Finland.

12. University of Western Ontario, Centre for Radio Science (P.A. Forsyth, J.A. Fulford, G.F. Lyon, J.W. MacDougall, D.R. Moorcroft, and J.K.E. Tunaley)

(a) Ionospheric Research

The purpose of investigating the effects of the ionosphere on radio signals propagating through it is twofold: (i) to achieve a better and more complete understanding of the physical processes occurring in the ionosphere and high atmosphere; and (ii) to determine the extent to which satellite communication system efficiency can be degraded by the environment. To these ends both satellite and rocket borne transmitters are utilized with ground based receiving stations at various locations to measure and record numerous parameters of the incoming signal.

A completely automated receiving station and data handling system which can handle either satellite or rocket transmissions has been built and has been in operation near London, Ont. for a six month period, observing signals from the NNSS (navigation satellites) and measuring phase, amplitude, doppler and angle of arrival. This has provided baseline data from a mid-latitude station which will be utilized in future studies. We plan to move the receiving station successively to Cape Parry, Churchill, and Cambridge Bay for both satellite and rocket observations to obtain data on the high latitude ionosphere which is particularly relevant in the Canadian communication context. Previous short expeditions to high latitudes with earlier versions of the equipment have indicated both the feasibility and necessity of this next phase.

The above system, known as a 'differential phase-locked system' yields the number of electrons present at various locations and various times in the ionosphere together with a measure of the smoothness of the electron distribution. An important additional piece of information required for a complete description of the physical phenomena is the presence and strength of ionospheric electric fields. Again, a completely automated system has been built to derive electric fields from the motion of the 'shadow' of ionospheric electron density fluctuations on the ground. This system, known as the 'long-line system', and utilizing signals from either geostationary satellites or radio stars has been operating at London, Ont. for some months. It is proposed to deploy the long line system simultaneously with the differential phase system for most of the high latitude expeditions.

(b) Radio Auroral Studies - Department of Physics/Centre for Radio Science

Continued mining of the mass of data obtained from the SR1 398 MHz Homer radar before it was shut down is providing material for a variety of studies. An analysis of the propagation of energy associated with plasma waves in the auroral E-region is nearly complete. The most surprising result is that although the propagation vectors for these waves are almost exactly perpendicular to the magnetic field, the group velocity is more nearly parallel to the magnetic field, except in the immediate vicinity of the height where the wave packet is reflected. Among other things, this may affect the height at which scattering is found to occur, since a given wave packet spends most of its time in the vicinity of the height at which it is reflected. Although studies of the doppler data from Homer are continuing, attention is now being given to the non-doppler data, which can be used to obtain echo heights, in an attempt to find evidence relating to the wave packet studies.

IV VOLCANOLOGY

Compiled by: B.N. Church

1. Introduction

Reporting based on a newly devised format has been fairly successful. Forty reports have been submitted from thirteen institutions including federal and provincial government groups and many universities. Most of these reports concern continuing studies of Precambrian and Cenozoic geology - fewer concern Paleozoic and Mesozoic rocks.

The investigations in progress focus mainly on the geochemistry and petrography of volcanic suites in support of mapping projects with special interest in komatiites and ophiolites and the REE elements. Structural geology has also received much attention with emphasis on plate tectonics. Ancillary studies include stratigraphy, geochronology, economic geology, paleomagnetic studies, gravity surveys, and physical volcanology.

2. Geological Survey of Canada (W.A. Baragar, S.S. Gandhi)

(a) Volcanology of the Circum-Superior Belt (Aphebian) in eastern Hudson Bay

The komatitic suite comprising low Mg (<13%), medium Mg (13-16%), and high Mg (>16%) flows underlies the Ottawa Islands and Smith Islands and extends into the Cape Smith Belt. Its most distinctive members are the layered flows among which are the spinifex-textured komatiites present only on Gilmour, Perley, and House Islands of the Ottawa group of islands. The layered flows may act as trunk distributors and settling chambers to the other flows.

Research plans are to complete detailed mapping of the Smith Island and adjoining mainland and collate with earlier studies of the Cape Smith Belt.

(b) Natkusiak basalts, Victoria Island, N.W.T.

Research plans are to assemble and publish paleomagnetic study of Natkusiak basalts with H.C. Palmer and assess the varying petrochemistry of the succession.

(c) Chemistry of Late Paleozoic potassic volcanic host-rocks of the Rexspar uranium-thorium deposit, British Columbia

Chemical analyses of 12 samples were completed, overcoming difficulties of high strontium in some samples. Highly potassic composition (K_2O, 8 to 12%; Na_2O, to 3%). Preliminary Rb^{87}/Sr^{86} ratios of 19 samples are between 0.04 and 2.3; isotopic analyses of 2 samples yield 0.7092 and 0.7028 ($\pm$4%).

Research plans are to produce a reasonable isochron with improved instrumentation and to publish the results.

(d) Reconnaissance geology of the Proterozoic and Devonian volcanics of northern Ellesmere Island (G.S.C. no. 70051)

It is now known that volcanics occur in at least 12 units of Ordovician to Devonian age and in at least 5 units of Cambrian and older age. A stratigraphic and tectonic framework for these units is being developed and it has become apparent that the peak of volcanic activity is related to a Wilson-cycle in the Ordovician. Petrographic and chemical studies are progressing.

Research plans are primarily to date the pre-late Middle Ordovician volcanics by zircon determinations.

3. Ministry of Energy, Mines and Petroleum Resources, Province of British Columbia
(B.N. Church, T. Hoy, G.E. Ray)

(a) Geology and gravity survey of the Tulameen basin (Tertiary age) south-central British Columbia

The Tulameen basin is a faulted sub-circular structure of possible caulderic origin. A gravity survey of 235 stations gives a profile of the Tertiary rocks delineating the basal felsic volcanics and overlying coal measures. Rhyolite ash bands in the upper part of the coal measures may be the result of a resurgent volcanic vent responsible for the relatively high (bituminous) rank of coal.

Further refinement of gravity and petrographic data is required.

(b) Gravity survey of the Leech River Fault near Victoria, British Columbia

The Leech River Fault is a profound dislocation trending east by southeast across the southern tip of Vancouver Island. It separates the Eocene Metchosin oceanic basalts from older metamorphosed and crystalline sialic continental crust on the north. A gravity survey in the Victoria area traces the course of this fracture below the Colwood delta showing a southwesterly dip on the fault plane - this information is important to plate tectonic interpretation for the region.

Extension of the gravity survey and additional modelling of the results is planned to determine more precisely the inclination of the fault.

(c) The Riddle Creek uranium-thorium prospect, Okanagan area, British Columbia

A large radioactive anomaly coincides with an Eocene volcanic centre near the headwaters of Riddle Creek. The principal radioactive rocks include trachytes and mafic phonolites of the Marron Formation and consanguineous igneous intrusions of the Coryell-type.

Further analysis of the volcanic structure and identification of the radioactive minerals is required.

(d) The Penticton Group - a new stratigraphic subdivision of the Tertiary, south-central British Columbia

The main objective of this study is to trace the various formations of the Penticton Group laterally from the Okanagan and Boundary regions mapping at a scale of 1:50,000.

(e) Stratigraphy, sedimentology, and mineral deposits in the Purcell Supergroup (Helikian), British Columbia

The distribution and character of andesitic lavas and related pyroclastic rocks in the Purcell Supergroup is being studied. Regional mapping, section measurements, petrography, and chemical analyses of these rocks are continuing. They have been formally named the Nicol Creek Formation.

Research plans are to relate the character and distribution of Purcell volcanic rocks to paleotectonic environments and related mineral deposits.

(f) Carolin Mine - Coquihalla Gold Belt Project near Hope, British Columbia (Triassic to upper Jurassic)

The area around Carolin Mine has been mapped in detail and the surrounding region at reconnaissance scale. Samples are currently in preparation for petrographic, chemical, and micro fossil studies. The volcanic zone forms an important stratigraphic division and possibly the source of gold mineralization.

Research plans are for additional mapping, chemical studies, and dating.

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

(a) White Lake - Mikanagan Lake Project (Early Proterozoic volcanic rocks)

Mapping at a scale of 1:15,840 was completed for a 110 km^2 area of Early Proterozoic volcanic rocks 15 kilometres east of Flin Flon, Manitoba. The objective of this mapping project is to develop a regional stratigraphy for the Amisk Group, the main rock formation of the Flin Flon greenstone belt. The geochemical and paleogeographic evolution of Amisk volcanism and the volcanologic control on deposition of massive Cu-Zn sulphide deposits are also under investigation.

In the study area, a series of major faults divide the Amisk Group volcanic succession into distinct fault blocks, each with a unique stratigraphic sequence which is not repeated in adjacent blocks. Thus, at this time it is not possible to develop a coherent regional volcanic stratigraphy for the area. Further detailed work planned for adjacent areas may identify repetition of some of the major units and permit the development of a regional stratigraphy.

Primary structures and textures are generally well preserved, allowing the identification of depositional mechanisms for most units. This will allow at least partial reconstruction of volcanic paleo-environments. Preliminary geochemical results indicate that individual units have unique or distinctive chemical characteristics and this, combined with tight stratigraphic control, will permit a meaningful study of the geochemical evolution of the Amisk Group.

5. Ontario Geological Survey (P. Thurston, A. Choudhry, T.L. Muir, M.W. Carter)

(a) Cyclical volcanism in the Confederation Lake area

(b) Geology of Keefer, Denton, and Thornloe area, District of Chochrane, Ontario (Archean supracrustal and felsic intrusive rocks)

Preliminary map and economic geology reports have been completed. Petrographic and final reports are in preparation involving microscopic investigations of about 80 thin sections and chemical analyses of 40 rock samples for 10 major and 15 minor elements.

(c) Bowerman-Belanger Township Area, 80 kilometres east of Red Lake, Ontario (Archean)

This is a mapping project to connect the Uchi and Red Lake volcanic belts assisted by radiometric dates and rock type determinations.

Research plans are for petrographic and lithogeochemical analyses included REE determinations.

(d) Study of the Onaping Formation, Sudbury basin (Proterozoic)

This is a mapping project of the Onaping north range to assist in evaluating the volcanic or meteorite origin of these rocks. Petrographic and lithogeochemical work is planned.

(e) Study of the Terrace Bay area (Lat 48°54'-49°03', Long 87°01'-87°15') (Archean)

This is a mapping project covering an area underlain by metavolcanic and metasedimentary rocks intruded by gabbroic and granitic rocks and diabase dykes. The metavolcanic rocks range from mafic to felsic composition with mafic rocks predominating and forming part of the Wawa belt. The metasedimentary rocks comprise wackes and minor arenites assigned to the Quetico belt. The regional trend is east-west and metamorphism attains the amphibolite facies.

6. Ministère de l'Energie et des Ressources, Gouvernement du Québec (M. Hocq)

(a) Synthèse géologique Joutel-Quevillon (Archean), Abitibi, Quebec

Following a broad reconnaissance in 1980, detailed mapping was carried out mostly in Dalet, Mazarin, Poirier, and Guyenne townships covering a region of 2500 kilometres^2 west of Harricana River. A cross-section of 18 kilometres in volcanic rocks is almost completed, including massive andesite lava flows, diabase sills, andesitic breccias, and ultramafic rocks.

Research plans include interpretation of the chemical evolution of the northeast part of the volcanic sequence and the stratigraphic and volcanological evolution of the Abitibi volcanic fold belt.

7. University of British Columbia (R.L. Armstrong, J.E. Harakal, K. Scott and Associates, W.H. Mathews)

(a) Petrology, geochemistry, and geochronology of Cordilleran volcanic rocks

K-Ar dating of late Cenozoic volcanic rocks in the Garibaldi, Anahim, and Stikine belts is continuing under contract to the Geological Survey of Canada (J. Souther scientific authority) and in the Stikine region for B.C. Hydro volcanic hazards research (P.B. Read, Geotex Consultants).

Doug Wood completed an honours thesis on the mid-Cretaceous South Fork volcanics of the Yukon which is in press with the Geological Survey of Canada.

Several recently completed studies have now been written up and the manuscripts are in review, or in press. A summary of the Cenozoic igneous history of the Cordilleran region has been written for GEOS.

(b) Cenozoic rocks of the middle Fraser area (Gang Ranch to Leon Creek)

Two seasons of field work have been completed on this project and laboratory work is now in progress. Some details remain to be completed.

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

(a) Petrology of Quaternary nephelinites of the Canary Islands, Hawaiian Islands, and British Columbia

Rocks are being analyzed by chemical methods and the constituent minerals using the electron-microprobe.

With this data and the methods of chemical thermodynamics, inferences about the conditions of origin can be made. Such conditions include the temperature and depths in the earth at which the lavas formed and the mechanism of separating the melt from the surrounding solid earth.

(b) Heat effects of assimilation, crystallization, and vesiculation in magmas

The objectives of this study are to examine the heat effects attendant on release of H_2O from magmas and to use energy balance to place constraints on hypotheses advocating

assimilation and/or crystal fractionation as a mechanism to explain the diversity of igneous rocks.

(c) Petrologic variation of historic eruptions of Mauna Loa

(d) Geologic and petrologic history of Diamond Craters, Oregon

9. University of Saskatchewan (E.G. Nisbet, G.A. Chinner, W.E. Cameron, M.J. Bickle, M.R. Stauffer, L.C. Coleman, N.T. Arndt)

(a) Early Archean komatiites Ruthwell, Western Australia; study of modern magnesian basalts; study of Rhodesian Archean craton

This is a study of Archean komatiites and their modern analogies with the objective of elucidating the thermal history of the crust and mantle and the chemical evolution of the mantle.

(b) Detailed mapping and geochemistry of part of the Aphebian Amisk volcanics, Flin Flon area, Manitoba and Saskatchewan

Detailed mapping has been completed in several localities near Flin Flon and the rocks have been extensively sampled. Petrographic study and major element chemical analysis are partially completed.

Research plans are to complete petrographic descriptions and major element analyses and to investigate trace element compositions of selected samples. Results will be evaluated in terms of magma source, geotectonic regime of volcanism and, possibly, the nature of the Aphebian upper mantle.

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

(a) Physical volcanology of Early Proterozoic greenstone belt volcanoes, Flin Flon area, Manitoba and Saskatchewan

The object of this study is documentation of the morphology and genesis of subaerial and subaqueous flows and fragmental rocks; volcano evolution.

Of nine kilometres examined to date in the Amisk Lake area of Saskatchewan, including seven kilometres of mafic lower Amisk Group and two kilometres of felsic to intermediate upper Amisk Group, all units were deposited either subaerially or in relatively shallow water. Two major subaerial-subaqueous transition zones, marked by distinctive, littoral flow-floot breccia, have been defined.

Research plans are for continuing documentation of: (i) the stratigraphy including comparative studies further east; (ii) morphology of subaerial and subaqueous basalt and dacite flows; (iii) morphology and genesis of subaerial and subaqueous dacitic debris flows; (iv) morphology and genesis of mafic tuff which forms 40-50% of the subaerial and subaqueous mafic sequence at Amisk lake; and (v) morphology of subaqueous rhyolite dome-pyroclastic complexes.

11. Carleton University (J.M. Moore, Jr., C.J. Rees, D.H. Watkinson, H.L. Gibson, J. McEwen, G.M. Ross)

(a) Stratigraphy and petrology of Helikian volcanic successions, Grenville province, Eastern Ontario

Mapping at a scale of 1:15,840 and bulk chemical analyses have demonstrated the existence of both a tholeiitic suite dominated by submarine basalt and a calc-alkali succession dominated by andesite. Despite upper greenschist-mid amphibolite facies metamorphism, chemistry is coherent and consistent with preserved primary features.

Research plans call for more detailed mapping of some localities to resolve facies relations and deposit types; further chemical studies will incorporate rare earth abundances and petrographic connections with associated plutons; the ultimate aim is a tectonic model for igneous activity.

(b) The boundary between the Omineca Belt (Hadrynian-Cambrian) and the Intermontane Belt (Upper Paleozoic-Mesozoic) in the Quesnel Lake area, east-central British Columbia

Field mapping was carried out in 1980 and 1981. Widespread mylonitic rocks and the absence of stratigraphic continuity suggests that the boundary in question is a major shear zone, and juxtaposes continental margin-type metasediments (Omineca Belt) with oceanic mafic and ultramafic rocks, argillites, and volcanics (Intermontane Belt). The youngest rocks affected by the shear zone are probably Early Jurassic.

Petrographic work is underway and another field season is planned for 1982. In 1981 samples were collected from Lower Jurassic volcaniclastics within the Takla Group for the purpose of paleomagnetic research under the direction of Dr. E. Irving.

(c) Relation of alteration of volcanic rocks, Noranda area, to Cu-Zn deposits, Archean geothermal systems

Silicification of mafic and intermediate volcanic rocks has been documented in the Amulet Rhyolite Formation. This is a result of geothermal activity in a block-faulted terrain with later, superimposed geothermal activity causing chloritic and sericitic alteration and volcanogenic deposits when faults were reactivated.

Research plans are for additional mapping, petrography, and chemistry of the Amulet Rhyolite Formation and other rhyolitic and andesitic rocks in the vicinity of the Amulet group of deposits, Gallen deposit, and in the Corbet mine. It is hoped to generate a model to explain silicification of mafic and other volcanics and relate this to superimposed alteration (chloritic, sericitic, etc.) and Cu-Zn.

(d) Narakay Volcanic Complex: mafic phreatomagmatic volcanism in a high energy shelf setting, Hornby Bay Group (~1.5 Ga), Dease Arm, Great Bear Lake

The object of this study is the documentation of the depositional environment of sedimentary rocks, eruptive and depositional mechanism of pyroclastic rocks, and dispersal of epiclastic debris.

During August 1981, the Narakay Volcanic Complex was mapped at a scale of 1" = 500' and more than twenty-five detailed stratigraphic sections were measured. The sedimentary rocks (siliciclastics and dolostones) were deposited on a storm and wave-dominated shelf with some periods of tide-dominated deposition. Inferred paleobathymetry ranges from subtidal (30 metres) to intertidal. Pyroclastic lapilli tuffs and tuff breccias were deposited on the flanks of subaerial, and in part subaqueous, phreatomagmatic tuff cones. The common occurrence of cored, fusiform, and ribbon bombs and bomb sag features suggest that the eruptions were dominantly subaerial. Morphology of pyroclasts indicates fragmentation by thermal quenching and steam explosions (e.g. hyalotuffs). The tuff cones were eroded by high energy wave attack. Epiclastic debris was swept off the cones by waves, rip currents, and storm surge and deposited as sediment gravity flow channel-fills (proximal) and thin-bedded turbidites (distal). Epiclastic material also occurs as thin sheets with an abundance of admixed clastic grains (quartz, feldspar, oolites, intraclasts). The entire sequence is cut by a rhyolitic dyke swarm that reflects the tensional stress regime which preceded formation of the conformably overlying Dismal Lakes Group Platform (see Kerans, et al., 1981).

Laboratory analysis of volcanic rocks is now underway to determine original composition of volcanic material and diagenesis of pyroclastic and epiclastic volcaniclastics.

12. University of Montreal (J.N. Ludden, G. Thompson, W.G. Bryan, L. Gelinas, S. Nadeau, D. Francis, R. Darling)

(a) Geochemistry of the volcanic rocks of the Kane Fracture Zone, Atlantic Ocean at 23°N

The objectives of this study are 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

The objectives are 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 region.

(c) Geochemical evolution of the Proterozoic volcanic rocks from the Cape Smith-Wykham Bay belt, Quebec

The objectives are trace element identification of petrogenetic 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

The objective of this study is to document wall-rock alteration and mode of formation of volcanogenic deposits.

13. Laval University (J. Belanger, R. Laurent, P.A. Bourque, M.J. Girard)

(a) Silurian and Devonian volcanism in the Gaspé Basin, Appalachians of Quebec

The volcanic formations are defined on the basis of four carefully mapped type-sections whose stratigraphic positions are well known. Based on petrographic, mineralogical and chemical characteristics, the volcanic rocks are classified as calc-alkaline.

The detailed mapping at the scale 1:20,000 of the volcanic formations of southern Gaspé Peninsula necessitates at least two more field seasons in 1982 and 1983. The petrological and geochemical study of the material collected is undertaken simultaneously by J. Belanger (full-time research worker) under the supervision of Dr. Laurent.

(b) The volcanic rocks of the Quito Rift near Tixan, Andes of Ecuador

This project is undertaken in collaboration with the "Politecnica Nacional" school of Quito. It is the subject of a Master's thesis by M.J. Girard, a student of Laval, under the supervision of Dr. R. Laurent. The field work was done during the summer 1981.

Research plans are to undertake a detailed petrological and geochemical study of the material collected by M.J. Girard and R. Laurent in 1982. Based on the results of present studies, continuation of the project is expected into 1983.

(c) Geology of the Appalachian ophiolites of Quebec

The objectives of this study are to determine the significance of ophiolites within the Appalachian belt, and the environment of formation and emplacement of these rocks. This project will be 10 years old this coming July and was centered on the mapping and detailed petrological study of the ophiolites of the internal zone of the Quebec Appalachians which extends from the U.S. border to the northern tip of Gaspé Peninsula. It resulted in two Ph.D. and five M.Sc. theses.

Detailed studies of the volcanic section will next include: (1) geochemistry of magmaphile elements such as the REE; (2) isotopic geochemistry of hydrogen (D/H) and oxygen ($^{18}O/^{16}O$); (3) distribution and origin of Cu-mineralization; (4) comparisons with present-day oceanic rocks.

14. Memorial University R.M. Easton, M.O. Garcia, F. Frey)

(a) Trace and REE geochemistry of recent sediments of Kilauea Volcano, Hawaii

The study of the trace and REE composition of recent sediments derived from a tholeiitic volcano will provide a basis for interpretation of Precambrian volcanogenic sediments.

Samples were collected in 1981 and analyses are underway.

(b) Stratigraphy and volcanic geochemistry of the Akaitcho Group: an initial rift sequence in Wopmay Orogen (early Proterozoic), N.W.T.

This is a study of the stratigraphy and geochemistry of the 1800-2000 Ma Akaitcho Group. The group consists of continental and ocean tholeiite basalt interbedded with continent-derived clastic rocks. These rocks are suspected to be related to the initial development of an early Proterozoic continental margin.

Field and geochemical data indicate that the Akaitcho Group is related to the initial development of a continental margin about 2000 Ma ago. The Akaitcho Group is similar to recent rift related sequences such as the southern Gulf of California.

(c) Trace and REE geochemistry of the Hilina Formation, Kilauea Volcano, Hawaii

This is a study of the petrology and geochemistry of the 20,000 year old and older lavas of Kilauea Volcano, Hawaii. Includes major, trace, REE, and Sr isotope geochemistry.

Major and trace element data was reported by Easton and Garcia (1981). REE results indicate older lavas similar to recent Kilauea tholeiites.

Research plans are for additional Sr isotope data.

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V. ISOTOPE STUDIES AND GEOCHRONOLOGY

Compiled by: A. Hayatsu

1. University of Alberta - Department of Physics (G.L. Cumming)

(a) Instrumentation

The 5" radius extended geometry gas source mass spectrometer for Ar isotope measurements is progressing rather slowly due in part to heavy use of machine shop facilities. We have finished the design work for the flight tube and source/collector housings and expect to commence construction of the major components in the new year.

We are currently spending most of the time available for construction, on the reassembly of the 9" radius, solid source, extended geometry instrument. We anticipate that testing of the instrument will be possible early in 1982.

(b) Radiogenic Isotope Studies

(i) Work is completed on a major study of the geochronology of the Midwest Lake uranium deposit. The isotope work was carried out as a research contract from Esso Resources Canada, the liaison being with Dr. J. Worden of Exxon Production Research. The project was a joint contract with G.L. Cumming and H. Baadsgaard of the Department of Geology. The final data set is one of the most extensive ever obtained on the isotopic variations in an ore deposit and its surrounding host rocks. We completed 93 Rb/Sr determinations on rock units surrounding the ore, 32 U/Pb measurements on the ore minerals, 30 Pb isotope ratio measurements on galenas and 15 on trace Pb in Ni-arsenides. The results indicate ore emplacement at about 1330 Ma, typical of other deposits in the area.

(ii) We have completed the first part of a cooperative study with V. Koeppel, ETH Zürich on the relationship of Pb isotope ratios in Ni ores of the Ivrea zone in northern Italy, with the isotope ratios of the ultrabasic to acidic host rocks of these small ore bodies. There appears to be a systematic relationship between the composition of the ore Pb and the rock Pb, indicating that at least part of the Pb in the ores comes from the surrounding country rocks.

(iii) A small project extending the work of Godwin and Sinclair of U.B.C. has been completed in cooperation with D.W. Morrow of the Geological Survey in Calgary. We have verified and extended their suggestion that the Pb-Zn ores of northern British Columbia and the Yukon may be divided into a very few classes of ore deposits which have characteristic Pb isotope ratios and isotope ratio patterns. Some deposits are extremely homogeneous, others show wide ranging but linear patterns which reflect variations in the source and mode of formation.

(c) Stable Isotope Studies

(i) A method for the determination of $^{17}O/^{16}O$ ratios in highly enriched nuclear reactor moderator water has been developed. This has yielded the somewhat surprising result that $^{18}O/^{16}O$ and $^{17}O/^{16}O$ ratios remain linearly related even at enrichments of 1200°/oo in $^{18}O/^{16}O$ in 99.8% D_2O.

(ii) S.J. Song has now completed work on the D/H and $^{18}O/^{16}O$ analysis of cellulose in tree rings. The general conclusions are that both $^{18}O/^{16}O$ and D/H ratios reflect the isotopic composition of averaged meteoric water used during photosynthesis. This means that temperature information may be readily obtained from stable isotope ratios of tree rings using both techniques.

A process which has been called the "juvenile effect" has been found which shows that the D/H ratios of trees in early stages of growth (15-20 years) are not reliable climate indicators and should be discarded.

(iii) Peat Studies. A program of detailed $^{18}O/^{16}O$ and D/H analysis of a peat core is now underway. A peat core supplied by B.H. Luckman is now being investigated isotopically. Pollen analysis has been carried out on this core (Luckman) and it is hoped the 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).

(iv) Speleothem fluid inclusions. 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). Interpretation of $^{18}O/^{16}O$ ratios in $CaCO_3$ deposits in terms of climatic variables are complicated by a lack of knowledge of the isotopic composition of the precipitating water. It is hoped to obtain unambiguous climate data for a time period up to 250,000 years B.P.

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

(a) Organic matter in Estuaries of the St. Lawrence

The objective of this study has been to examine the sources and sinks of the organic carbon in the St. Lawrence Estuary by stable carbon ratio method. The analytical aspect of this work is completed.

(b) Distribution of sea ice meltwater in the Arctic

Oxygen isotope ratios of selected water samples, collected during the Swedish Arctic Expedition (YMER 80) between Svalbard and Northeast Greenland, have been used to assess the importance of sea ice meltwater to the observed excess alkalinity in the surface layer. Our results indicate that $CaCO_3$ releases due to the melting of sea ice can only contribute a relatively small fraction of the excess alkalinity in the Transpolar Drift Stream-East Greenland Current. The principal source for this excess alkalinity is from the high alkaline river inputs to the Arctic Ocean. This is a collaborative project with Dr. D. Dyrssen of University of Goteborg, Sweden.

A large suite of samples collected from the Eastern Canadian Arctic during 1980 are being analyzed. The $\delta^{18}O$ will be used to evaluate the extent of glacial meltwater contribution in Melvills Bay and to examine year to year variation in sea ice meltwater distributions in areas that were previously investigated. Samples collected during cruise 80-028 in north-central Baffin Bay were analyzed. The sea ice meltwater distribution as estimated by the oxygen isotope method will be compared with the one estimated by the measurement of alkalinity. Water and ice core samples collected during FRAM III experiments will be analyzed and interpreted.

(c) Paleoclimatic studies

The purpose of this study is to examine climatic changes that occurred during the late glacial and Holocene. This is a collaborative program with scientists at Atlantic Geoscience Centre, BIO and the University of South Carolina.

(d) Sources of organic carbon in Pecks Cove ecosystem

Stable carbon isotope method has been applied to samples collected in Pecks Cove, Bay of Fundy for the determination of the relative importance of different potential carbon sources to the mud organisms. This is completed and a paper has been submitted. This is a collaborative project with Scientists at Marine Ecology Laboratory, BIO.

(e) Scotian Shelf ecosystem studies

An exploratory study on the use of carbon isotope method to examine the food chain in Scotian Shelf ecosystem is being completed. This is a joint project with Dr. E. Mills of Dalhousie University.

3a. University of British Columbia - Department of Geological Sciences
(R.L. Armstrong, R.R. Parrish, K.L. Scott, J.E. Harakal and associates)

(a) Coast Plutonic Complex

R.R. Parrish has completed his Ph.D. thesis on the uplift history of the Coast Mountains, based largely on fission track dating and quantitative thermal models.

P. van der Heyden has nearly completed writing of his M.Sc. thesis on the Tsaytis River area.

J. Gabites has started a thesis on an area east of Harrison Lake that will include varied geochron techniques to calibrate the metamorphic, structural, plutonic, and uplift history.

T. Heah is describing and dating volcanic rocks of the Gambier Group that are well exposed in the Sky Pilot area near Squamish for an honours thesis.

R.L. Armstrong, R.R. Parrish and K. Scott have completed Rb-Sr dating in a Coast Mountains traverse at Bella Coola and will soon finish at Alice Arm. Jurassic to Early Tertiary dates will be checked with U-Pb dates on zircon separates by R. Parrish.

Analysis of a suite of Bridge River schists for C. Potter of the University of Washington indicates a largely Jurassic protolith age and probable late Jurassic metamorphism (subduction?). One large tectonic block of gabbro gives a late Paleozoic age.

(b) Insular Belt

C. Isachsen has started a M.Sc. thesis on the West Coast Complex, concentrating near Tofino. Geochronometry of those rocks plus others from near Victoria will start soon.

(c) Omineca Belt

A large suite of samples (largely from P. Read and R. Brown) analysed for Rb-Sr have firmly established an early Precambrian age (~2.2 Ga) for both core and mantling gneiss of the Frenchman Cap and Thor-Odin gneiss domes. All granitic rocks of the Clachnacudainn Salient appear to be Paleozoic. Mylonites of the Columbia River fault zone are pre Late Jurassic (P. Read) but some brittle movement postdates Eocene dykes (L. Lane). Trail-Castlegar (P. Simony) and Valhalla (R. Parrish) gneisses appear to be largely Mesozoic, with no evidence of greater antiquity being evident in Rb-Sr and U-Pb data collected so far. Gneisses near Quesnel Lake (C. Rees) appear to be late Precambrian, ~800 Ma old. Zircon dating by R. Parrish is in progress on several of these rock suites.

(d) North Cascades

Papers concerning our geochron studies of late Paleozoic and Jura-Cretaceous blueschists are in press. Further work near Baker Lake (for P. Misch and P. Leggi) has confirmed a late Paleozoic, ~280 Ma metamorphic age for a large tectonic slice there.

(e) Pb Isotope Studies

Anne Andrew, working for C. Godwin, is carrying out ore-Pb isotopic analyses on our new Micromass 54R spectrometer.

3b. University of British Columbia - Department of Geophysics and Astronomy (W.L. Slawson)

(a) Radioactive isotopes

While on leave last year, W.F. Slawson began an experiment to test the efficacy of radon measurement as a local monitor of activity precursory to earthquakes. The hypothesis to be tested is that if radon emanation is enhanced in the neighbourhood of active faults prior to earthquakes then the soil through which the enhanced flow of radon occurs should contain an excess of radon decay products. Soil samples were collected along a 40 km traverse across the San Andreas fault. The samples are being analyzed by γ-ray spectrometry for U, Th, ^{226}Ra and ^{210}Pb. The few results available do not exhibit a clearly defined anomaly.

(b) Mass spectroscopy

P. Whaite working under the supervision of R.D. Russell is continuing the assembly of a highly automated oxygen-isotope mass spectrometer. This work brings together the results of Whaite's M.Sc. project and the Ph.D. thesis of T.K. Ahern.

4. Dalhousie University - Departments of Physics and Geology (P.H. Reynolds)

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

(i) Ages of paleomagnetic poles

Our study of selected intrusive rocks from the Northern Appalachians has continued, an attempt to define more clearly apparent polar wander paths for this region during the Paleozoic. Results of a study on the Mount Peyton Complex, Newfoundland, have been published in the Canadian Journal of Earth Sciences. Data obtained from an extensive suite of diabase dikes from Newfoundland's Gander Zone will soon be published; work in the Meguma Zone of Nova Scotia is continuing (with P. Lapointe, Earth Physics Branch; G.S. Murthy, Memorial University).

(ii) Metamorphic and intrusive events in southwest Nova Scotia

A paper summarizing results on intrusive rocks has been published.

(iii) The Indus suture zone

Results of an initial study have been published. Work continues on a second suite of samples collected by M.E. Brookfield, Guelph University.

(b) Stable Isotope Studies

A study of O, C and S isotope abundance patterns in the Gay's River (N.S.) deposit has been completed by graduate student S. Akande. A major investigation of selected marine sediment cores using oxygen isotopes is under way.

5. McGill University - Department of Geological Sciences (R. Doig)

(a) Rb-Sr Geochronological Study of the Gneissic Terrain North of the Cape Smith Fold Belt

The primary objective is to determine the age relationships between the Proterozoic Cape Smith Fold Belt and the complexly deformed and metamorphosed gneissic terrain to the North. All Rb-Sr geochronological work for the proposed basement gneisses between the Cape Smith belt and Hudson Strait has been completed. The various suites yield Archean ages (2580 to 2950 Ma) and low initial ratios of 0.701 to 0.703. Undeformed aplites and pegmatites have also been dated (1635 Ma) giving us a younger limit to tectonic events in

the region. Most of the 1981 field work consisted of mapping and sampling coastal sections west of Sugluk. The section includes potentially datable (metamorphic and model ages) high-grade pelites and arkoses. Metamorphic studies of the pelites and rare calc-silicate beds will enable us to better interpret the Rb-Sr isotopic data.

(b) Geochronological and Petrologic Study of Granitic Rocks Related to Hydrothermal Ore Deposits, Gaspé Peninsula, Quebec

The central Gaspé region extending from Mont Albert to Murdochville contains numerous granitic intrusives, some of which are closely related to major porphyry-copper-type deposits. A systematic study of the petrochemical characteristics and age relationships of all these intrusive bodies was initiated last year. Prior information on some of these units indicates that there may be differences between bodies that are related to significant ore deposition and those that are not. For example, some exhibit calc-alkaline petrochemical trends whereas others may be anorogenic. These differences may also be a function of age, and in any event, the Rb-Sr age data will also provide information on origin and effects such as contamination or hydrothermal alteration.

6a. McMaster University - Department of Chemistry (C.E. Rees and H.G. Thode)

(a) Stable Isotope Studies

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 minerals. 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.

6b. McMaster University - Department of Geology (R.H. McNutt)

(a) Winnipeg River Batholithic Belt

G. Beakhouse has been evaluating the evolution of this belt, in the English River subprovince of the Superior Province. Three distinct types of plutonic rocks have been identified and dated. The geochronological studies have extended the known distribution on orthogneiss unit that predates most of the volcanism in the Superior Province. The Rb-Sr whole rock analyses were done at McMaster and the zircon U-Pb work at the ROM in Toronto, in cooperation with T.E. Krogh.

Beakhouse has found small, but significant, differences in initial $^{87}Sr/^{86}Sr$ (= R_i) in the plutonic rocks.

(b) Grenville Province, Ontario

L. Heaman has completed his work on the Loon Lake pluton which gives a Rb-Sr whole age of 1063 Ma. The $\delta^{18}O$ values are high (9-11°/oo). This combination of high ^{18}O and low R_i indicates a lower crustal origin for these late stage intrusives. The Tallon Lake sill is an amphiholite with a syenitic phase, interpreted as a metamorphosed, differentiated basaltic sill. The Rb-Sr whole rock age is 1245 Ma, an age similar to other volcanic units in the area. A study of syenitic samples that have microfractures filled with secondary material, notably enriched in Rb, give a statistical isochron of 1025 Ma. He interprets the latter age to reflect the cooling of the Loon Lake pluton, i.e. the microfractures may represent passageways for escaping fluids. The Silent Lake granite, which intrudes the high grade gneisses and amphibolites of the Herman formation, has a Rb-r whole rock age of 1127 Ma, R_i = 0.711. He interprets this age to approximate

the zenith of Grenville metamorphism, and that the Silent Lake magma formed by anatexis of an arkosic phase of the Herman formation.

(c) Pampean Range, Argentina

L. Heaman and C. Rapela looked at suites of plutonic rocks from N.W. Argentina, and defined an older prekinematic group at 500+ Ma, a second synkinematic period at 475 Ma and two post-kinematic groups at 440 Ma and 340 Ma. The youngest group has high R_i (>0.710) indicating the reworking of older crust.

7. Université de Montréal - Département de Géologie (C. Brooks)

(a) Etudes géochimiques et isotopiques des assemblages volcanoplutoniques associés aux processus de subduction lithospherique (avec M. Boily et J. Ludden)

Projet de Ph.D. de M. Boily. Les analyses des isotopes radiogéniques du Sr et Nd et des isotopes stables de l'oxygène seront combinées à la géochimie des terres rares et des éléments en traces afin d'établir l'évolution pétrochimique de plusieurs séries volcaniques et plutoniques localisées au sud du Pérou. Les laves et les plutons étudiés sont directement reliés à la subduction de la plaque océanique de Nazca sous la croûte continentale péruvienne depuis le mésozoique. L'âge des échantillons recueillis (Jurassique à Quaternaire) permettra donc d'évaluer de façon temporelle, l'évolution géochimique de la croûte continentale et du manteau supérieur depuis le début de la subduction.

(b) Géochimie des complexes "granitiques" archeens (avec C. Gariépy, F. Lamarche et J. Ludden)

Les plutons "granitiques" archeens se divisent en deux groupes pétrographiques: un assemblage tonalite-diorite et un assemblage de granodiorites. Les Plutons de la suite tonalite-diorite sont des masses concordantes mises en place avant la période de plissement alors que les plutons de la suite granodiorite semblent être post-tectoniques. Du point de vue géochimique, les premiers forment une suite pauvre en potassium alors que les seconds sont enrichis en potassium.

Ce projet est basé sure l'étude de la distribution des éléments-traces et des isotopes de Sr, Pb et Nd, échantillons provenant de différents plutons. A l'aide des résultats analytiques nous espérons établir les caractéristiques chimiques essentielles de chacune des suites et déterminer l'origine de même que l'évolution pétrologique de ces magmas.

(c) Pétrogénèse des basaltes de plateau mésozoiques du Brésil (avec N. Machado)

L'étude des isotopes de Sr, Nd, Pb et O sur des basaltes des 3 plus importants bassins mésozoiques du Brésil (Parana, Parnaiba et Amazonas) nous renseignera sur l'interaction manteau-croûte dans la génèse de ces basaltes et l'hétérogénéité du manteau à grande (millier de km) et moyenne (centaine de km) échelles. Les données géochimiques nous permettront aussi de mieux comprendre les mécanismes de fracture et séparation du continent de Gondwana.

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

(a) Modifications to the analytical equipment (D.A.A., E.F.)

Through a capital equipment grant from N.S.E.R.C. we are rebuilding the argon fusion system. The new system is made of stainless steel and has a very low volume. Turret mounted samples will be fused by resistive heating and it is anticipated that up to 5 argon analyses will be completed per day.

(b) Metallogenic studies in the Cordillera Carabaya, Southeastern Peru (D.J.K., E.F.)

Investigations into the tectonic, magmatic and metallogenic evolution of the Cordillera Carabaya, S.E. Peru during the past two years 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, albeit tentative, to explain the distribution of rock types and ore deposits with respect to the surrounding Andean system.

(c) New Zealand (E.F.)

A literature review combined with new K-Ar dates (with C. Adams, D.S.I.R.) 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) Canadian Cordillera (D.A.A., E.F.)

Kootenay Arc

A study of the geology and geochronology of the southern Kootenay Arc, B.C., is continuing. The study comprises conventional K-Ar dating as well as $^{40}Ar/^{39}Ar$ and U-Pb (with T. Krough, R.O.M.) zircon dating of selected plutons. This study has succeeded in elucidating the thermal and tectonic history of the Kootenay arc and surrounding areas.

Selwyn Mountains

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 is being undertaken in cooperation with K. Glover of Union Carbide.

(e) Korea (D.A.A., E.F.)

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) Kapuskasing Structural Zone (D.A.A., E.F.)

A $^{40}Ar/^{39}Ar$ study (in cooperation 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) Antarctic Peninsula (E.F.)

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.

9. University of Waterloo - Department of Earth Sciences (P. Fritz and S.K. Frape)

Isotopic composition and geochemistry of saline ground waters in the Canadian Shield

Deep groundwaters in the Canadian Shield are very saline (200 $g\ell^{-1}$ TDS) and have isotopic compositions which differ strongly from modern waters. $\delta^{18}O$, ^{2}H and geochemistry suggest that these waters were generated in a marine environment and are thus almost certainly many millions of years old.

10. University of Western Ontario - Department of Geophysics (A. Hayatsu, J.P. Hodych, Memorial U., H.C. Palmer et al.)

(a) K-Ar isochron study of the Shelburne Dike, Nova Scotia

Whole rock samples from this dike also yielded a well defined isochron with an initial argon ratio of about 200. Thus, all the Mesozoic dikes in northeastern North America so far analyzed in this laboratory yielded the initial argon ratios lower than the present atmospheric ratio.

(b) K-Ar age of the Picton Lamprophyre, Ontario

This dike intrudes the Trenton Limestone and contains large amounts of carbonates. K-Ar analyses on whole rock and HCl-treated samples yielded 197 Ma and 175 Ma, respectively. The difference may not be attributed to incorporation of carbonates from the host rock because the latter's potassium and radiogenic argon concentrations are much lower than those of the carbonates in the dike samples.

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VI METEOROLOGY AND ATMOSPHERIC SCIENCE

Compiled by: E.J. Truhlar

1. Introduction

Research in meteorology and atmospheric science is maturing rapidly as Canadian scientists achieve world-class reputations in their areas of expertise. Evidence for this is indicated by the ever-increasing participation of Canadian scientists in such international joint undertakings as: the WMO Precipitation Enhancement Project field study in Spain; the UN Environmental Programme's report on environmental problems in the next century; the CCOPE field study in Montana to find out how precipitation is produced naturally in summer convective clouds; the STRATOPROBE flights in Texas (with FAA, NCAR, NOAA and the University of Denver) to measure stratospheric constituents and their variations; the major international Storm Transfer and Response Experiment; the Fifth Remote Sensing Campaign of the Commission of the European Communities investigating the SO_2 budget of the Ghent area in Belgium; the Canadian Arctic Air Pollution Program (part of an international effort with the United States, Norway, Denmark, Iceland and the United Kingdom) to study the trend and causes of Arctic haziness during winter.

The Canadian Council of Resource and Environment Ministers sponsored a seminar in Regina during March on "Climate Change and Variability in Canada and its Impact on Our Resources and Environment". This served as a forum where the Provinces could say how they perceived climate made an impact on their economies. As a result of this meeting CCREM accepted the meeting's recommendations and endorsement of a cooperative national Canadian Climate Program.

Considerable efforts have been expended in studying the long-range transport of air pollution and transboundary air pollution to assist the Canadian Government's vigorous political activity to ensure that meaningful action is taken to combat transboundary pollution under the terms of the Canada/U.S. Memorandum of Agreement. Because of the worsening North American recession, it is still not clear whether economic necessities will frustrate strategies to maintain acceptable air quality standards.

The Fifteenth Annual Congress of the Canadian Meteorological and Oceanographic Society was held on 27-29 May at the University of Saskatchewan in Saskatoon on the theme of Hydrometeorology. About 180 attended; altogether there were 125 papers including poster presentations. A new Special Interest Group was established on Hydrology. An Education Committee for Meteorology was formed to investigate Canada's future needs for professional meteorologists, the ways to meet these needs, and the types of training that might be required.

The Society prizes were awarded to: Paul LeBlond and Lawrence Mysak, President's Prize; Brian Barge and Bob Humphreys, the Dr. Andrew Thomson Prize in Applied Meteorology; Douw Steyn and John Loder, the Graduate Student Prizes in Meteorology and Oceanography, respectively.

2. The University of British Columbia - Department of Geography

(a) Assessing the Characteristics and Impacts of the Mesoscale Variability of Solar Radiation (J. Hay)

Two and one half years of observations of solar radiation with a 12-station network in and around Vancouver have indicated substantial variability in the distribution of solar energy. The significance of these variations is being assessed using numerical models of domestic solar space and hot water systems.

(b) Satellite Estimates of Solar Radiation at the Earth's Surface (J. Hay)

Numerical models that use satellite brightness data to estimate solar radiation at the earth's surface are being developed and verified using the above-mentioned mesoscale solar radiation data. The ability to earth-locate the satellite data and the impact of target size (i.e. spatial resolution) are amongst the topics of investigation.

(c) Continuing Studies (J. Hay, J. Knox)

Studies of the short-wave irradiance for inclined surfaces and of the circulation statistics for the Northern Hemisphere are continuing (See CGB, 1979).

(d) Sky Irradiance Distributions (J. Hay)

The distribution of sky irradiance in the short wavelengths is being investigated using a video camera equipped with a fish-eye lens and a video digitizer. The departure of the diffuse radiance from the commonly assumed isotropic distribution is being documented.

(e) Urban/Coastal Boundary-Layer Structure (T. Oke, D. Steyn)

A mathematical model of the mixed layer has been validated using field data from two coastal/shore environments where the effects of advection and mesoscale subsidence are evident. The data are from the UBC urban field program in Vancouver and the AES Nanticoke study (data kindly made available by AES). Agreement between modelled and observed features of the daytime mixed layer is excellent.

(f) Rural/Suburban Evapotranspiration Comparison (T. Oke)

The role of urbanization upon evapotranspiration is being investigated using simultaneous rural and suburban energy and water balance measurements.

(g) Urban Cooling Rates (T. Oke)

Nocturnal cooling of urban canyons under "ideal" radiation conditions is being studied using field and hardware model observations.

3. The University of Alberta - Meteorology Division and Institute of Earth and Planetary Studies

(a) Climatology of Destructive Winds (K.D. Hage)

Data collection on May to September destructive winds (including tornadoes) that occurred in Alberta and Saskatchewan between 1900 and 1960 has been completed. This time period was selected in preference to more recent data because it includes the decades of maximum rural population densities.

(b) Urban Valley Studies (K.D. Hage, P. Hopps, R. Wong)

A numerical model for estimating ground-level air pollutant concentrations from an urban area source was developed and tested, using emission and concentration data for carbon monoxide in Edmonton. The results were found to be superior to alternative surface area models, particularly for high concentrations.

(c) Biometeorology (A.S. Nursall and K.D. Hage)

Possible relationships between frequency and severity of migraine headaches and various weather parameters were studied. The results, though inconclusive, suggest that synoptic weather patterns were more important than individual weather elements, such as temperature and pressure.

(d) Atmospheric Physics (R.B. Charlton, E.P. Lozowski and E.R. Reinelt)

E.P. Lozowski has undertaken Monte Carlo simulations of the growth of rime ice, in order to determine growth angle and density. M.M. Oleskiw has developed a computer program that calculates the temporal variations of rime icing on an airfoil.

G. Strong has investigated the energy transfer between synoptic and mesoscale systems, with emphasis on the energetics of severe thunderstorms and their environment.

R.B. Charlton and C. Park completed a study of cloud, ice fog and precipitation caused by the industrial complex on the eastern outskirts of Edmonton. The "industrial" precipitation was analysed by using cooling-tower water treatment chemicals as tracers. The study was carried out on the coldest days of the past four winters.

J. Roessler is developing a model capable of simulating the statistical properties of turbulence, such as energy spectra. The model is based on bifurcation techniques applied to hydrodynamic equations, in particular the Navier-Stokes equation.

J. Freund is using hourly radiation data to determine the effect of particles (apparently originating in Europe) on the attenuation of solar radiation in the Canadian Arctic.

(e) Environmental Meteorology (R.B. Charlton, J. Roessler and J. Wieler)

The meteorological aspects of planned hazardous waste disposal sites and systems were studied for Alberta Environment, in response to increasing public concern about the fate of wastes from the petrochemical industries.

(f) Mesoscale and Satellite Meteorology (E.R. Reinelt, D. Phillips, and J.G. Wieler)

J. Wieler has completed a study on thunderstorms in Central Alberta. He developed a procedure for determining cloud-top temperature, cloud amount and cloud type from the combination of infrared and visible-range satellite images. His results compare favourably with measurements obtained by radar and research aircraft.

D. Phillips has continued his investigation into the mechanism of cyclogenesis in the lee of the Rocky Mountains. He is examining the effects of barrier size, height, profile and orientation on cross-barrier flow.

E.R. Reinelt has extended his work on the evaluation of operational cloud seeding in North Dakota.

4. Alberta Environment - Meteorology and Air Quality

Alberta Environment continues to support research and monitoring related to meteorology and air quality, e.g. studies of the chemistry of the rain and the snowpack over the Athabasca Oil Sands area; and of air quality over urban centres - studies of particulate matter and aerosols were successfully completed for Calgary and Edmonton.

A significant level of remote sensing, included an acoustic radar and ground meteorological monitoring network that compiled continuous data for Calgary. The resulting information will be used to study Chinooks and the possible relationships between Chinook events and air quality.

Modelling activities related to air quality and the valley effects in the Edmonton area were completed. Subsequently many aspects of this problem were considered but concentrated mainly on carbon monoxide from vehicles and more specific concerns about this pollutant.

At the request of The Alberta Petroleum Industry Government Environmental Committee, staff scientists and their private sector counterparts cooperated in the development of a multi-year multi-million dollar research program on acid gases in the environment. Modelling of compressor exhaust chemistry and wake diffusion was initiated. Equipment for measuring the dry deposition of sulphur dioxide by means of the combined concentration gradient/eddy accumulation method was assembled and tested. A mobile atmospheric pressure ionization mass spectrometer (TAGA 3000) was used to identify trace organic compounds at a number of sites in the province. A Gaussian Frequency Distribution Model for ground-level pollutant concentrations was completed.

5. Research Council of Alberta

During 1981 the Department was reorganized into four major projects, each subdivided into subprojects, whose activities are briefly reviewed below.

(a) Weather Modification Project

(i) Physical Assessment

To determine whether cloud seeding can alter the development of rain, hail or snow cloud physics aircraft data from the summers of 1978 and 1979 were analysed. Results indicate that seeding cumulus clouds with silver iodide or dry ice yields detectable effects, which are different for the two agents. Specific radar patterns could be attributed to such seeding.

Hailstones collected in previous years were analysed, showing a relation between hailstone concentration and size.

Major field activity included measurement of hailfall at the ground as a function of time, and collection of rain samples.

(ii) Quantitative Assessment

Several climatological studies aimed at eliminating the influence of climatic trends in assessments of weather modification experiments were completed, including one on rainfall and hail crop insurance data, another on hailfalls, hailswaths, and severe rainstorms.

Personnel participated in the Cooperative Convective Precipitation Experiment in southeastern Montana to determine optimum temporal and spatial measurements for prediction of areal precipitation from convective clouds.

To increase the ability to measure hailfall adequately, radar observations were related to ground observations of hailfall using a method developed by Swiss and French scientists. Results show high correlations between radar-derived and hailpad-derived hailfall energies.

A contract was made with the University of Québec to determine methods for eliminating errors in radar data during periods of rapid changes in storm intensity.

(iii) Cloud Seeding

Hailstorms were seeded with silver iodide by a fleet of six aircraft from June 20 to August 31, when aircraft were flown on 54 days (74%) and seeding was carried out on 40 days (55%). The seeding aircraft flew a total of 691 hours, down 32% from 1980, owing to a lighter than usual hail year within the project area.

(b) Dispersion of Aerosols Project

(i) Ground Generator

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. Ground generator effectiveness was tested at the Colorado State University Cloud Simulation and Aerosol Laboratory. The INTERA/ARC Atmospheric Sciences Research Aircraft flew several missions to detect ice nuclei originating from the Krick ground generators.

(ii) Sulphur-Precipitation

Analysis of hail insurance loss data statistics suggests that gas plant emissions of sulphur oxides may be having a local hail suppression effect. Samples of rain and hail collected from storms downwind of gas treatment plants contain high concentrations of sulphates. Such evidence has been used to plan a research study of the incloud effects of gas plant sulphate emissions on precipitation processes.

(c) Techniques Development Project

(i) Research Aircraft

A contract was made with INTERA Environmental Consultants, Ltd. to develop a cloud physics research aircraft (see b)(i) above). Development of software and hardware-based data acquisition system was started and is still continuing.

(ii) Software Coordination

Program documentation standards were developed enabling programmers to evaluate the efficiency of software development.

(d) Applications Project

(i) Flood Forecasting

A contract has been negotiated with Alberta Environment whereby ARC will provide the River Forecast Centre with radar-derived rainfall information in real-time on an operational basis by 1984.

(ii) Rainsat

The Rainsat subproject is funded by the Canadian Atmospheric Environment Service to investigate the physical mechanisms responsible for precipitation production in different storm conditions. This research supports the examination of real-time satellite and radar data to improve short-term forecasting.

Synoptic, radar, and TIROS-N data for 8 days have been reduced. Detailed case studies show that the synoptic index developed for the hail program relates well with radar and satellite data. Storms that track through a region with a maximum convective index tend to have maximum reflectivities in that region.

6. The University of Calgary - Department of Physics

A pulsed dye laser has been purchased and a simple optical transmitter/receiver has been designed as the first step toward implementation of a lower atmospheric lidar probe. In conjunction with this development an automatic all-sky scanning radiometer has been brought into use to measure both short- and long-wave sky/earth radiance. This instrument will be described in the Canadian Journal of Physics (1982).

A field station has been established on high ground outside the city from which radiometric and visibility observations are being made. The station is to be used for the study of Chinooks and temperature inversions.

An array of monostatic acoustic echo sounders has been operated to gather information on turbulence in the atmospheric boundary layer over Calgary and environs. In addition, a two-axis bistatic Doppler acoustic sounder has been constructed at the Springbank Airport to monitor the atmospheric wind profile up to 500 m above ground level. Measurements are also being made on the horizontal propagation of sound under various boundary-layer conditions.

7. Western Research & Development

Western Research supplied routine meteorological services to a wide variety of industries. Consultations related mainly to effects of terrain and buildings on plume dispersion. Observational and theoretical studies were undertaken on the characteristics of low temperature fog in Arctic Canada. Major research involved radiation studies in the neighbourhood of tailings ponds, sources of ammonia in Calgary's atmosphere, analysis of risk associated with sour gas pipeline ruptures and the development and testing of an atmospheric boundary-layer model for the Athabasca Oil Sands area. This model was developed from statistical correlations.

8. Saskatchewan Research Council

Research into environmental aerosol physics has continued, mainly in the field of aerosol and gaseous deposition rates of acid precursors with variations both in time and space within Saskatchewan. Studies centred on snow pack accumulation of sulphate and nitrate compounds in the North.

The emissions testing program has expanded from the potash industry to such others as: coal processing, gypsum and wood gasification plants. Diversification into laboratory and field procedures for determining emission rates of sulphur and nitrogen oxides has also been undertaken.

Micrometeorology programs have been established in conjunction with Agriculture Canada to determine the mass flux of field-applied pesticides to the atmosphere. A phenoxy pesticide was applied to a ten-acre field and volatilization rates to the atmosphere were determined. This research is being carried out together with other life scientists mainly to analyse total pathways of the most commonly used Prairie agricultural pesticide.

SRC continued the program of hydrometeorological data re-transmission, and added new sensors to measure total radiation (α,β,γ), pH of water, conductivity of water and dissolved oxygen. These sensors were used for a study of an abandoned uranium tailing pile.

9. University of Windsor - Department of Physics

Various processes involving the interaction of electrons with atmospheric species are being studied.

10. University of Waterloo - Department of Civil Engineering

(a) Hydrometric Network Design and Remote Sensing (Dr. S. Solomon)

A system involving the superimposing of mapped ground truth data on LANDSAT and GOES digital data is being developed, enabling classification of land-use data, moisture conditions and estimation of meteorological inputs as sensed by the satellites.

(b) River Flow Forecasting using RADAR precipitation data (Dr. N. Kouwen)

Various interpolation and smoothing techniques for processing RADAR rainfall data are being studied for their suitability in Flood Flow Forecasting.

(c) Pattern Analysis and Synthesis (Dr. T. Unny)

A characterization of pattern movements to further the understanding of time series.

11. McMaster University - Department of Geography

(a) Testing of solar radiation models

The performance of models for estimating solar radiation continues to be examined, as reported in the 1980 CGB. This project also includes the determination of cloud transmittances for Canada.

(b) Analysis of Woodbridge infrared data

Infrared radiation data recorded at the AES Meteorological Research Site are being compared with numerical model calculations.

(c) Aerosol effects on solar radiation

The study to estimate variations in bulk optical depths and single scattering albedos for aerosols, using ten years of Canadian cloudless sky radiation data, has been completed.

(d) Spectral measurements of direct beam solar radiation

The project has just been initiated.

12A. University of Toronto - Department of Physics (Meteorology)

(a) Cloud Physics

(i) Warm Rain Formation

Three-dimensional computer maps were produced to give detailed breakup fragment distributions resulting from the collision/breakup process; 1-D shaft models with the new breakup matrices show how raindrop spectra evolve. Further, the breakup results are being incorporated into the Clark-Hall 2-D cloud model.

A first set of breakup experiments at 50 kPa indicates no significant pressure effect when compared with 100 kPa.

(ii) Rain Concepts as they derive from hailstone growth and modelling studies

Studies of the shedding of drops from growing ice cylinders indicate that this liquid component represents an important fraction of the rain, with the mode of the distribution near diameters of 1 mm. The same numerical models also indicate that the warm rain should not be neglected and that this process is important in the hailgrowth region. Thus in the future, all three mechanisms need to be considered in parallel with interaction terms.

(iii) Cold Rain and Hail Simulator

This facility was assembled and tested. It is ready for experiments on the growth and melting of ice particles (snow, graupel and hail) at temperatures down to -25°C, wind speeds of up to 25 m/s (at 100 kPa), pressures as low as 20 kPa and any reasonable liquid water content.

(iv) Precipitation Enhancement Experiment, PEP, of the World Meteorological Organization

The group was heavily involved in the 1981 field season in Spain, the management of PEP, and the scientific evaluation of the data and findings.

(b) Ion Studies

Research tending to elucidate the catalytic action of ions on nucleation reactions in the gas phase continues. Gaseous ions of known species are introduced into the gaseous system and the nucleation produced is studied.

Experiments have been started to determine equilibrium constants and reaction rates for the clustering of molecules on hydrated ions. The results should be significant to the chemistry of atmospheric ions and possibly to reactions in solution.

(c) Atmospheric Waves

Studies of internal waves (Peltier) remain focused upon those forced by topography and those produced spontaneously in parallel shear instability. The collaboration between W.R. Peltier and T.L. Clark (of the National Center for Atmospheric Research) on the mountain wave problem has continued with the completion of new analyses of the self-resonance hypothesis advanced previously to explain the occurrence of severe downslope windstorms. The new work involves three-dimensional simulations. Analysis by G. Klaassen of the transition to turbulence in stably stratified parallel flows has conclusively established that the transition mechanism involves a broad bandwidth, shear-aligned convective instability. Work by Barbara Ley on internal waves and mesoscale dynamics has established that such disturbances are important in the explanation of a class of prefrontal rain bands and as a trigger mechanism for the generation of squall lines.

Work by I. Halevy is continuing on the problem of the dynamical mechanism of the solar-terrestrial weather correlation - if indeed such a correlation exists. Efforts are centred upon trying to explain the apparent connection of the process with the enstrophy-producing mechanism of baroclinic instability. Analysis uses the Matsumo model previously employed in studies of stratospheric sudden warming (Richard Chagnon).

(d) Climatic change

Using the model of glacial isostasy developed to study the phenomenology of postglacial rebound (see the section in this Bulletin on Seismology and Physics of the Earth's Interior), Peltier has developed a new theoretical model to explain the 10^5 year periodic oscillation of continental ice cover, which has characterized the macroclimate of the Pleistocene period. Using this model the long time-scale oscillation of the Pleistocene cryosphere is shown to be a simple relaxation oscillation driven by the Milankovitch forcing.

(e) Atmospheric Convective Processes

(i) Cloud-mean flow interactions

Dynamic effects of cumulus convective elements in large-scale weather systems are being studied, specifically, the influence of cumulus clouds on some mid-latitude weather systems, such as polar lows, and rapidly deepening cyclones. A study of the influence of convection on the vorticity dynamics of tropical easterly waves has been completed.

(ii) Forest fire induced air circulations

A coupled forest fire/mesoscale air circulation model is being developed to study the mutual interactions between air flow and fire behaviour.

(f) Dynamic Meteorology

A study of baroclinic and orographic instabilities of a baroclinic zonal flow and planetary waves has been initiated taking into account zonal (i.e. east-west) scale interactions. This is important because both instabilities occur at different zonal scales. These instabilities have been associated with atmospheric blocking events, and the dynamics of blocking is still not well understood.

A study of the meridional (i.e. north-south) scale interaction in the formation of baroclinic waves has been completed. The instability properties of a zonal jet with meridional structure is investigated. Owing to meridional asymmetries of the jet, the perturbation structure is described by a complete meridional mode spectrum. The spectra for different jets were examined.

Some calculations with a one-dimensional energy balance climate model have been initiated to examine the possibility of the model being governed by a simple extremum principle.

(g) Upper Atmosphere Composition

A balloon instrument is being constructed to measure the concentration of three stratospheric constituents, formaldehyde, carbon monoxide and methane, by sensing their thermal emissions in the stratosphere. The spectral selection of the gases will be achieved by using pressure modulator radiometers and the performance of the instrument, using helium-cooled detectors, will be near the background limit. It is hoped that the instrument will be flown for the first time in mid-1983.

Continuing research into the concentration of water vapour in the upper atmosphere shows that the concentration of water vapour near 80 km is about 1×10^{-6} v/v and decreases over that region.

A laboratory project to measure water vapour absorption in paths similar to those encountered in the stratosphere has commenced in order to verify the relationship between calculated and measured transmissions in, initially, the 6.3 μm band.

Research into atmospheric infrared fluxes in the 8-13 μm band is continuing.

12B. University of Toronto - Institute for Environmental Studies

The Institute for Environmental Studies undertakes interdisciplinary environmental research studies, many of which have an atmospheric component, with respect to acid precipitation, climate impact, perception, carbon dioxide and carbon cycle, snow and ice control-salt deposition, risk assessment and environmental monitoring.

In the joint Royal Society of Canada and United States Academy of Sciences Committee on acid deposition, the Institute is represented by Professor F.K. Hare as Co-Chairman, Dr. A.J. Forester as Scientific Director, Dr. P.M. Stokes and Dr. T.C. Hutchinson.

Several IES members have been involved in the United Nations Environment Programme's preparation for its Tenth Anniversary in 1982. In particular, Dr. R.E. Munn is preparing the report on the environmental problems of the next century. This will help us address the question -- where should we next be turning our attention?

13. Ontario Ministry of the Environment - Air Resources Branch

(a) Air Quality and Meteorology Section

Two models, one statistical, the other Lagrangian, have been developed for the Acidic Precipitation in Ontario Study and both are being evaluated using observed data. Research on quantifying uncertainties in the model results has been carried out.

A meteorological data acquisition and trajectory modelling system has been developed and is currently being used in meteorological analyses of precipitation chemistry events.

(b) Special Studies Unit

Wet and dry deposition monitoring continued across the Province, at more than forty locations, for acids and a number of related substances. Experiments were performed to evaluate deposition monitors, sample handling procedures, etc. Intercomparisons were made with other deposition monitoring networks in Ontario.

The precipitation washout study from plumes at the INCO smelter and the Nanticoke generating station was extended to November 1981. Air quality monitoring continued in the Nanticoke area, and the impact of the local industrial activities was assessed.

A study was carried out during the summer into ground-level ozone concentrations as a function of distance inland from Lake Erie.

14. MacLaren Plansearch Inc.

Activities during 1981 included:

(a) Non-AES wind and solar radiation Archives

A total of 37 sets of data were identified and archived in AES format, covering periods from 7 to 10 years.

(b) Environmental Assessments (including climatological studies and air pollution modelling) were made at: Come-by-Chance Refinery, Newfoundland; Saskatoon Chemicals Ltd., Saskatoon; Labrador Institute of Northern Studies, Labrador City; Handy and Harman, Toronto; Anchor Cap and Closure Inc., Toronto; Walker's Line Grade Separation, Burlington, Ontario.

(c) Meteorological and air pollution monitoring at Atikokan, Ontario (for Ontario Hydro)

This included wind monitoring of two stations, and air pollution monitoring (SO_2, TSP, NO_x, O_3) at 5 stations.

(d) Receptor Modelling

Comprehensive monitoring and fingerprint analysis of emission sources and ambient concentrations of dust in the communities of Labrador City and Wabush, Newfoundland.

(e) Long Range Transport of Air Pollutants

Application of current LRT models to emission sources in Ontario. Comparative studies.

15. Communications Research Centre

The influence of the Canadian Climate on radiowave propagation continues to be studied (see 1980 CGB).

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

The Flight Research Laboratory's Twin Otter atmospheric research aircraft was flown about 165 hours in atmospheric studies. The scavenging of airborne pollutants by cloud and precipitation was investigated in cooperation with AES in order to obtain a better understanding of the physical and chemical processes by which atmospheric pollutants, especially those contributing to acidic precipitation, are removed from the atmosphere and how they may inadvertently modify precipitation patterns. In March a series of flights sampled the Inco stack plume to test instrumentation installed on the Twin Otter to measure air quality, cloud physics and air motion. In the fall this instrumentation was flown over southwestern Ontario to study the scavenging by widespread precipitation of pollutants generated by distant sources.

For seven weeks in the summer FRL in cooperation with AES flew the Twin Otter in the Convective Precipitation Experiment (CCOPE) at Miles City, Montana. This $7 million program, organized by the U.S. Bureau of Reclamation and the National Center for Atmospheric Research, was designed to study the microphysics, electrification and dynamics of unseeded convective complexes from before birth to final dissipation.

Flights with the Twin Otter continued in 1981 to measure CO_2 fluxes in the boundary layer above vegetation (see 1980 CGB) using the Agriculture Canada open path CO_2 analyser. Low altitude flights were made over forest and corn fields to evaluate the resolving ability of the flux measuring system.

17. McGill University

(a) Department of Meteorology

A data study of the stationary planetary waves has been initiated. Analyses of level IIIb data from FGGE are used to evaluate the importance of wave-wave interactions versus wave-zonal flow interactions in the dynamics of the forced steady waves.

The forecast model of the Atmospheric Environment Service was used to investigate the effects of vertical resolution on the topographically forced planetary waves.

Large amplitude forced planetary waves have been investigated numerically using a time-dependent nonlinear Beta-plane model.

In cloud physics, studies were completed on the numerical simulation of an ensemble of cumulus clouds in three dimensions; cloud interactions on a particular day of the GATE experiment, based on combined radar data analysis and numerical cloud modelling; comparison of a numerically simulated hailstorm with radar observations of Alberta hailstorms.

A time-dependent numerical model of the evolution of raindrop size distribution below cloud base was completed, taking into account drop interactions and evaporation. It demonstrates the relative importance of the different processes in changing the size distribution. The model is now being extended to allow the study of the scavenging of aerosols by precipitation in a rainshaft.

Calculations are continuing to assess the effects of arctic haze on long- and short-wave radiative transfer.

There was an expansion of work on surface energy budget climatology. The detailed computer models that have been developed since 1965 were applied to case studies of man-made impact on the regional climate by surface modifications. In addition, the models were altered to be useful in detailed studies of climatic influence on vegetation growth. This has importance in defining the limits imposed on specific crops by climate, both as a general environmental control and as singular occurrences of such events as cold spells, drought, flooding.

Research continued in the application of radar data to short-term rain forecasting and to the assessment of rain effects on satellite communications.

(b) Macdonald Campus

A beta-gauging technique is being developed to determine the optimum timing of crop irrigation; its potential usefulness in semi-arid climates is being explored.

The feasibility of using aircraft-mounted sensors to measure CO_2 fluxes in the boundary layer (using eddy-correlation techniques) is under cooperative study with Canada Agriculture and NRC.

Pollutant transfer to pine foliage and lichens, at very low flow velocities, is being simulated electrochemically.

Energy-exchanges between leaves, buds and fruits and the environment, under conditions of radiation frost, are being studied theoretically.

18. Université de Sherbrooke - Département de géographie (J.J. Boisvert, G. Bousquet, J.M.M. Dubois, P. Goyer, R. Dallaire, A.M. Valton, B. Lauriol, F. Bonn, A. Champoux, M. Lacharite, C. Leroux, R. Brochu, A. Barcados)

(a) Recherches en 1981: Climatologie régionale des Cantons de l'Est (1941-1980); Les changements historiques de climat dans le sud du Québec; Le climat du golfe du Saint-Laurent; Les contraintes climatiques et la diversification agricole au Québec; Les fortes 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.

Etude de la couverture neigeuse de l'Ungava par télédétection, de 1967 à 1980.

Signification paléoclimatique des champs dunaires du sud du Québec.

Influence de la couverture végétale sur les relations entre rayonnement solaire incident, températures du sol et radiation thermique émise dans la fenêtre 9,5 - 11,5 μm.

19. Environnement-Québec - Service de la météorologie

(a) Les projets d'étude suivants ont été complétés: Climatologie du Parc Forillon; Climatologie des durées d'ensoleillement au Québec; Climatologie des vents et des classes de stabilité au Québec.

(b) Les projets d'études ou de recherches suivants ont été poursuivis:

- Transport à grande distance des polluants atmosphériques en relation avec les pluies acides. Le projet a donné lieu à l'implantation d'un réseau de collecteurs de dépôts humides (46 stations);

- Mise en oeuvre des recommendations de l'étude de rationalisation (B.C.G., 1979): modification et réorganisation des différents réseaux météorologiques québécois;

- Analyse des méthodes statistiques et stochastiques pour la détermination des pluies maximales probables.

20. Agriculture Canada - Agrometeorology Section, Ottawa

The main research and agrometeorological service activities included:

(a) A mathematical model of the stomatal mechanism was developed that shows how changes in the water status of a plant leaf affects the opening and closing of plant stomates; and how osmotic adjustment within the plant affects stomatal closure.

(b) A corn growth simulation model was developed and tested with three years of biomass and grain yield data at one site.

(c) Papers on the measurements of CO_2 exchange between various surfaces and the atmosphere and on carbon dioxide flux measurements from aircraft-mounted sensors were presented at scientific meetings.

(d) A protein yield model of hard red spring wheat in Western Canada has been tested for individual Crop Reporting Districts. The yield part of the model is very satisfactory but the protein calculations need to be refined before the model can be applied.

(e) Modification of the Williams' model to represent the yield weather relationship of the 1970's was completed resulting in a pilot operations project.

(f) Weekly yields were estimated for each Crop Reporting District in Western Canada. These estimates were close to the final harvest values available in October.

(g) Field measurements were undertaken as part of 5-year proposed program for modelling snow cover and frost components of a soil temperature regime.

(h) Image analysis procedures developed in North American spring and winter wheat regions indicate that growing conditions can also be appraised in selected analogue areas of Asia.

(i) In cooperation with the Winnipeg and Saskatoon Research Stations the requirements for modelling crucial environmental conditions of the grasshopper and Bertha Army worm habitat were assessed.

(j) Preparation of reports and procedures for developing agroclimatic resource maps on a 10-km grid for the Prairies was undertaken by the Land Evaluation Program.

(k) An instrument site for monitoring soil temperature and moisture was established. Data were collected on a snow-covered and a snow-cleared site. Frost penetration was measured on both sites using a frost tube, TDR (Time Domain Reflectometry) and thermocouple probe at 5-cm intervals.

(l) Soil bulk density and moisture data were used as input to the soil temperature model along with standard weather data; performance of the model was assessed using the observed data.

21. Canadian Forestry Service

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

Work continues on development of climatic diagrams for the national map of Canadian ecoregions, and on a dedrochronological study to correlate tree ring patterns with climate and fire history in central Newfoundland using Pinus resinosa. A new study was initiated on microclimate and mesoclimate as it relates to shelterbelt and energy plantation research studies.

(b) Maritimes Forest Research Centre, Fredericton

The study on the dispersion of spruce budworm moths was completed (see 1980 CGB).

Precipitation was obtained by the Sangamo collector at Acadia Forest Experiment Station (see 1980 CGB). Monitoring of rainfall, stemflow and throughfall has also been continued at Acadia FES and initiated at Kejimkujik National Park, under a variety of forest stands, as part of the acid rain program. Laboratory rainfall simulation apparatus has been constructed and tested, and is being used to determine the effects of simulated acid rain on seedling germination and growth, and soil microbiological activity.

Meteorological data for New Brunswick were further analysed to help develop an ecological forest site classification system for the Province.

(c) Laurentian Forest Research Centre, Ste. Foy

The climatological data from the Montmorency Experimental Forest in the Laurentide Provincial Park has been extended to 1980 for the needs of the LRTAP project. In December 1980 a Sangamo Type A automated daily precipitation collector was established on the Lac Laflamme watershed to provide information for the Air Pollution Network, and data on SO_4, NO_3 and major cations for a watershed nutrient cycling model that is to be developed.

Dr. A. Plamandon of Laval University is undertaking a detailed investigation (under contract) of the microclimate and energy balance within the balsam fir forest on the watershed. The purpose is to determine to what extent tree growth is controlled by climate, this to be subtracted from potential growth effects due to LRTAP. Extensive micrometeorological data are being collected; water is being analysed for major ions.

(d) Petawawa National Forestry Institute, Chalk River

A permanent open field site near Cobden, Ontario incorporates a complete weather station communication via GOES. A permanent 43-m forest wind mast plus seven 33-43 m masts were located across a narrow valley. Surface winds estimated from weather maps are being compared with those interpolated from surrounding stations. Mathematical modelling of wind flow over rough terrain has begun. A study of the predictability of area-burned using various fire weather indices and simple meteorological parameters continues.

Detailed area-burned statistics for 28 years have been computed. An attempt will be made to compare the rate of fire spread as measured using ARIES analysis of NOAA-7 data with that of fire spread models. Current knowledge about the simultaneous use of 10- and 5-cm radars to estimate precipitation rates is being reviewed. Two 20-m masts are being erected at two elevations in a natural frost pocket to follow temperatures at seven levels to relate to the frost damage of red pine flowers in the spring of 1982.

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

The summary provided in CGB 1979 requires no updating.

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

The Institute has an ongoing program to study: the meteorological factors affecting the drift and deposit of aerially applied sprays; spray application equipment; spray formulations; and the effect of weather on the behaviour of birds and other organisms in the forest ecosystem; and to set guidelines for the effective application of aerial sprays. The Institute has a mobile meteorological station with portable towers extendable to a maximum height of 35 m. The sensor systems are linked to a computer to analyse data for up to 37 parameters, with real-time capability. The project team worked in cooperation with MFRC and AES on the moth dispersion study in New Brunswick providing data for the layer from the ground to 25 m.

(g) Northern Forest Research Centre, Edmonton

The study to relate climatic variations to forest biomass productivity continued. The two ENFOR contracts listed in CGB 1979 should be completed by March 1982. In association with the tree-ring chronology study a second N-S transect of 5 samples was collected in Manitoba, with one of the locations in Saskatchewan.

Two reports on the interrelationship of trends of 21 defoliator insect populations and weather in Manitoba and Saskatchewan have been prepared. Climate data continues to be used in studies on forest hydrology modelling, fire behaviour and management, and air pollution injury to vegetation. A number of studies continued on: analysis of the effect of microclimate of clear-cut areas on pine and spruce seedling growth; development of an adjusted spring drought code used by all fire management agencies in the region; fire history reports for a number of national parks; a fire history atlas for Alberta; and methods of detecting frost injury in conifer seedlings. A study on the role of ice nucleating agents that mediate freezing in crops is about to begin. A preliminary investigation of aerial differences of selected microclimatological parameters was undertaken in a small man-made forest opening and the adjacent forest. A paper was published on surface wind structure in forest clearings during a chinook.

(h) Pacific Forest Research Centre, Victoria

Work on developing and using numerical models for studies of wind flow over forested mountainous terrain continues with particular emphasis on a small area 2-dimensional model. Climate and hydrological data have been collected and are being analysed for a study on the fate of fertilizer applied to snow. A new site is being established in the B.C. coastal region to study how rain on snow affects the movement of fertilizer. Heat unit requirements and threshold values for Douglas Fir bud flush and western spruce budworm development have been determined. Investigations of the effects of drought and topography on fire weather indices continue. Over one year of climate data have been collected and are being analysed as part of a study examining fire weather differences between thinned and unthinned stands of Douglas Fir. PFRC now has seven automatic data logging weather stations for supporting various studies. New instruments developed include a new type of sensitive cup anemometer, a minisonde receiver, and an integrator/pulse converter interface unit for scanning data loggers.

22. Atmospheric Environment Service

(a) Meteorological Services Research Branch (MSRB)

(i) General Program

The general program of the Meteorological Services Research Branch was outlined in the 1979 Canadian Geophysical Bulletin.

(ii) Detailed Studies

The driving model for the operational data-assimilation system was replaced by a 13-level, 31-wave spectral model with complete physics and non-linear normal mode initialization, resulting in a small but significant increase in forecast accuracy.

Specification of the geophysical fields required for surface flux computations in the spectral forecast model were further refined. Surface temperature and precipitation forecasts are quite sensitive to soil moisture and conductivity that are not observed and are subject to rapid changes. Their values must be computed or inferred from other observations.

Work was completed on the Beaufort Sea Winter Ice Experiment, which was described in the 1979 and 1980 Canadian Geophysical Bulletins. The data sets obtained were used to carry out sensitivity testing of a sea-ice forecasting model developed in the Experiment for winter Arctic conditions. Work was initiated for prototype implementation of an ice prediction model applicable to unconsolidated pack ice, in preparation for operational testing. Sensitivity tests were conducted on an ice thermodynamics model capable of predicting ice freeze-up, growth and ablation, and work was initiated on upgrading the model for incorporating growth rates into the sea-ice forecasting models. These models are being developed to provide a year-round ice prediction capability for any Canadian geographical location. Work was started to develop a model and system for predicting the mean daily drift of icebergs.

Products of an operational statistical procedure for predicting the probability of precipitation amounts were monitored and several deficiencies were corrected. Work was initiated on other statistical procedures for predicting meteorological parameters, mainly surface winds at airports. A package for carrying out regional meteorological analyses in isentropic coordinates was implemented at two Regional Weather Centres. This package has application for severe local storms and heavy precipitation forecasting. Development continued on a severe convective storm assessment procedure.

A fast-response marine oil spill trajectory forecast system was developed and delivered to a number of Regional Weather Centres for supporting AES responses to marines oil spill emergencies. A more complete system was developed, with predictions based on the AES oil spill trajectory model. The simpler system is capable of responding to new oil spill emergencies within a few minutes and, when implemented, the complete system should have a response time of a few hours.

Research studies continued on potential applications of SEASAT data, especially for supporting ocean wave forecasting, and on a Markov chain procedure for short-range aviation weather forecasting. Canadian participation ended in a project of the International Energy Agency to predict the local variability in regions of complex terrain: this involved the application of a mesoscale model for predicting surface winds. A comprehensive set of sensitivity tests on the mesoscale model are planned to establish its range of useful application.

The Aerospace Meteorology Division is continuing activities as reported in the 1980 CGB. However, in microwave sensing research and development, recently the emphasis has been shifted towards cooperative studies with United States agencies and the study of atmospheric effects on microwave sensing.

Activities in the Satellite Data Laboratory and in wind engineering research are as reported in the 1979 Canadian Geophysical Bulletin.

(b) Atmospheric Processes Research Branch

(i) Experimental Studies Division

UVB has been monitored since late 1980, and a year's data have been processed. Radiometric monitoring of long-wave fluxes and short-wave irradiances is continuing. The AES/Sonotek sunphotometer, of which ten have been manufactured, was subjected to an international calibration experiment and has been used to study city turbidity. Three production prototype AES suntrackers were tested and deployed and three are being built commercially. Over 200 pyranometers were calibrated. Pyranometer calibration experiments were conducted in cooperation with several other countries in an International Energy Agency program.

The Mark II ozone spectrophotometer has been put into commercial production. Two have been delivered and three more are under construction, including units destined for Greece and Sweden. They have been modified to permit monitoring the UVB spectrum as well as ozone and sulphur dioxide.

The ozone monitoring program, comprising daily surface-based measurements of total ozone and weekly ozonesonde ascents, continued at Toronto, Edmonton, Goose, Resolute and Churchill.

Stratospheric balloon flights were made in June and September from the National Scientific Balloon Facility at Palestine, Texas. In the June experiment, part of the international water vapour intercomparison experiment sponsored by FAA, various techniques for measuring water vapour where compared. Other groups participating were NCAR, NOAA and Denver University. AES modelling studies continue to indicate that hydroxyl concentrations in the mid-stratosphere are low, and analysis of the data from several flights confirms this. The September STRATOPROBE balloon flight in collaboration with NRC was undertaken to measure the time variations of NO_2 and to test for a solar-cycle variation in UV fluxes in the stratosphere. Such a variation would induce an 11-year component in trends of ozone concentration. Work on the correlative measurements for the LIMS and SBUV experiments on NIMBUS 7 continued.

(ii) Cloud Physics Research Division

Activities concentrated on the experimental and microphysical aspects of cloud and precipitation physics.

The Division was a major participant in the Cooperative Convective Precipitation Experiment (CCOPE) in Miles City, Montana. CCOPE was a single season multi-organization experiment designed to give a better understanding of how precipitation is produced naturally in summer convective clouds, ranging from small cumulus clouds to thunderstorms and squall lines. An instrumented NRC Twin Otter aircraft was used to make extensive microphysical, dynamical and chemical measurements in-cloud and in the cloud environment.

Studies of cloud and precipitation scavenging related to the "acid rain" problem, were made using the Twin Otter on flights over central and southwestern Ontario (see report by National Aeronautical Establishment).

Two projects were concerned with understanding the mesoscale structure of and precipitation processes within storms. In support of RAINSAT (a short-term forecasting technique utilizing satellite and radar data) a field project was conducted during November to gather data within cyclonic storms passing over southern Ontario. Sequential rawinsonde and special surface observations will be analysed in combination with standard observations. In support of the Storm Transfer and Response Experiment (STREX), data for several storm events over the northeast Pacific Ocean are being analysed.

Support continued to be provided to the radar program of the World Meteorological Organization (WMO) Precipitation Enhancement Project (PEP) in Spain for the final field season of this phase. The data collected were prepared and processed under contract with McGill University for distribution to all participant members for further analysis.

A study of the relationship between weather radar reflectivity factor measurements and rainfall rates in southern Ontario was completed. A single best-fit relationship was found to satisfy all synoptic and rainfall types. A study of 3 years of radar data produced an echo climatology for the area within a 140-km radius of Toronto. The patterns define areas affected by beam shading, reveal some minor effects of ground clutter and very few areas of preference for echo enhancement by orographic features.

The technology developed for real-time display of weather radar data on colour monitors was transferred to industry, and new subscribers are taking advantage of the direct access to the observations. A new digital video integrator and processor has provided better data averaging over shorter ranges.

New sferics lightning direction finding equipment responding only to cloud-to-ground discharges and providing information on time, azimuth, amplitude, and numbers of strokes per flash was successfully integrated with the real-time display of radar data. One season's data are being statistically analysed for patterns, frequency and radar echo relationships.

A study was begun to define a new radar system to replace the aging Woodbridge weather radar.

(c) Air Quality & Inter-Environmental Research Branch (ARQB)

(i) Long Range Transport of Air Pollutants (LRTAP)

A Memorandum of Intent (MOI) was signed by Canada and the United States on August 5, 1980, under which the Canadian government intends to: develop a bilateral agreement that will reflect and further the development of effective domestic control programs and other measures to combat transboundary air pollution; facilitate the conclusion of such an agreement as soon as possible; and, pending conclusion of such an agreement, take interim action available under current authority to combat transboundary air pollution.

Major AES activities in the Federal LRTAP Program are listed below.

a) Modelling Atmospheric Transport and Deposition

Main AES modelling efforts are focussed on applying a Lagrangian trajectory model to determine transboundary flows of sulphur compounds and source-receptor relationships, and to assist in data analysis.

MOI activities include: preparation of a unified and a more detailed pollution emission inventory; development of a short- to medium-range deposition model for sulphur compounds, and of statistical and analytical models for both sulphur and nitrogen chemistry.

The terms of reference and a program plan for the development and implementation of a Eulerian Air Pollution Model for North America have been defined.

b) Monitoring Atmospheric Composition and Deposition

AES operates the CANSAP network for precipitation chemistry across Canada (see Section (ii) below), and the event research network, APN, in eastern Canada. CANSAP and APN data have been published to December 1980 and June 1980, respectively. One additional operating APN station has been set up

(Baie d'Espoir, Nfld.) the next one (Cree Lake, Sask.) should start operating by late Spring 1982.

c) Research and Development

Research and development projects are aimed at improving: the understanding of important physical and chemical processes; and the measurement methodologies and gathering of field data.

Methods are being developed to measure the direct flux of sulphur dioxide and ozone to the surface using the eddy correlation technique in order to provide a better understanding of the dry deposition on natural surfaces. Instrument development has concentrated on the methodology of measuring ambient nitric acid and hydroxyl radicals.

Precipitation scavenging processes are being investigated theoretically and experimentally. Aircraft-based studies are being undertaken to better estimate the role of clouds in cleansing the atmosphere.

d) Liaison and Scientific Coordination

In response to the requirements of the expanded fedeeral LRTAP program, the LRTAP Scientific Coordination Office (LSCO) was established on January 1, 1981 for: ensuring coordination of scientific efforts within the Federal Government and in a Federal/Provincial and international context, advising appropriate federal committees and officials about the program, and providing information through a draft document "Canadian Federal LRTAP Scientific Plan".

(ii) Environmental Monitoring

AES operates air quality monitoring networks dealing with regional and global air pollution and precipitation quality. For a description of the Canadian Network for Sampling Precipitation (CANSAP) and the WMO background CO_2 monitoring program see the 1980 Canadian Geophysical Bulletin.

As a result of a review (of CANSAP operations) a new network known as the Canadian Air and Precipitation Monitoring Network (CAPMON) will comprise monitoring instrumentation situated at regionally representative, rural locations across Canada. Initial attention will be given to substances related to the "acid rain" problem, but sites will be chosen so as to be suitable for monitoring other substances such as toxic organics, ozone and carbon dioxide. The network's objectives are:

a) To measure temporal variations and long-term trends (daily to decades) in the chemical composition of air and precipitation, and wet and dry deposition in all regions of Canada;

b) To determine regional-scale concentration and deposition fields of atmospheric trace constituents;

c) To provide data for developing and verifying long-range transport models, and for phenomenological and process studies;

d) To set up standard monitors in all regions to ensure the compatibility of Canadian air and precipitation measurements.

(iii) Toxic Chemicals Program

The Branch contributes to the Federal Environmental Contaminants Program established under the Environmental Contaminants Act (1976), to investigate the behaviour of atmospheric inorganic and organic contaminants interacting with the biosphere (see 1979 CGB).

Major initiatives have been undertaken in three main areas:

a) Implementation of a Toxic Chemical Atmospheric Deposition Network that will eventually consist of 18 sampling stations in Canada (3 in each AES region).

b) Research into the atmospheric pathways and characteristics of toxic substances.

c) Development and testing of atmospheric mercury monitors

In support of the Network (see a) above), the Branch has been involved with site selection criteria and installation guidelines. Interlaboratory testing and comparison of two commercial types of environmental mercury monitors was completed. This utilized EPS laboratory facilities.

(iv) Oxidants Research Program

The ozone and peroxyacetyl nitrate (PAN) (collectively termed oxidents) and nitric acid gases produced by industrial activity are deleterious to important cash crops (O_3+PAN), or are eye irritants (PAN) or contribute significantly to the "acid rain" problem (nitric acid and nitrogen oxides). Research relating to oxidants includes:

a) the compilation of cause-effect data on the effects of (i) nitrogen oxides and (ii) ozone.

b) research into the effects of mixtures of oxidants (O_3 + SO_2 + NO_2) on crop plants

c) micrometeorological measurements of ozone dry deposition rates

d) a survey of the spatial distribution of ozone over southwestern Ontario and the dose-response relationship for white bean

e) preparation of standards on the measurement of ambient ozone and nitrogen oxides for the Canadian Standards Association

f) A new Gas Chromatograph will be acquired to identify and quantify low molecular weight hydrocarbons (paraffins, olefins and simple aromatics) in ambient air.

(v) Environmental Impact Assessment (EIA) and Modelling

In direct support of the Departmental EIA program and other agencies, the Branch reviewed about twelve EIA documents and reports: several dealt with oil explorations; some, with radionuclide releases (such as from uranium mining developments), and liquid natural gas shipping on the east and west coasts. Preview of the B.C. Hydro Hat Creek thermal power plant EIA led to a numerical modelling study of the acidic deposition in the snow pack and the snowmelt shock potential of the proposed power plant. A formal report of the modelling results was presented to the regional Hat Creek Task Force and the model was transferred to the AES Pacific Region Scientific Support Division so that further model assessment could be done regionally.

Research continued on numerical model development for various applications. A Snow Melt Shock Potential model for Eastern Canada has been finished under contract. It is a hydrometeorological model that examines the surge in acidity of the runoff during melt periods in the spring when acid-forming pollutants are released from the snow. A North American Mixing Height Study is also being made under contract, to produce a program to carry out several analyses of upper-air profiles over an 8-year period. Work continued on a Climatological Dispersion Model (CDM) to estimate the maximum concentrations expected during the year, and on a Mixed

Layer Statistics Model (MIX), to calculate the range of average hourly concentrations. The MIX model can output values for 46 Canadian and other Northern American radiosonde stations. A Nighttime Mixed Layer Height model was developed to calculate the minimum mixed layer height as a function of wind speed, surface roughness, length, and latitude. These models will eventually be incorporated into the Atmospheric Interactive Modelling System.

A Branch representative, as a member of the Analysis Group of the Provincial Nuclear Emergency Committee, participated in two separate nuclear accident exercises related to the Pickering and the Bruce nuclear stations. An interactive Gaussian puff dispersion model was used in the exercises.

A presentation was made to the Railway Transportation Committee of the Canadian Transportation Commission on the hazards associated with heavy gas spills.

(vi) Technology Transfer Activities

For the first time, the Air Pollution Meteorology Course was given in French at the Université du Québec à Montréal to federal, provincial and industrial representatives. The course was organized by Branch staff and meteorologists of the Scientific Services Division, Quebec Region.

A limited edition of a seven-volume set of Canadian Mixing Depth Statistics has been prepared on maximum mixing height, wind direction, wind speed, and ventilation coefficient. Each volume corresponds to a climatological region of Canada.

A package of environmental emergencies programs was written for HP-1000 minicomputers that is designed to give timely advice to AES personnel in case a hazardous chemical is released into the atmosphere.

(vii) Boundary-Layer Modelling and Field Studies

A major field study at Kettles Hill near Pincher Creek, Alberta, in February provided detailed observational data to define the influence of that terrain on airflow. Results showed remarkable agreement with predictions of the AES boundary-layer airflow model, MS3DJH, which has been amended to improve the realism of the predicted vertical structure. Agreement has been reached with the International Energy Agency for AES participation in a major international field experiment, to take place in the Outer Hebrides of Scotland; a pilot study is scheduled for September 1982; the experiment, in September/October 1983.

In cooperation with the Canadian Climate Centre, the National Research Council and Hydro-Québec a project is underway to evaluate sites for the installation of prototype 10-m vertical axis wind turbines for project AEOLUS. Three 60-m towers in the lower St. Lawrence Valley where instrumented and have collected wind and temperature data since early September.

The Branch participated in a major international field experiment, the Storm Transfer and Response Experiment (STREX) late in 1980 (see 1980 CGB). Intensive atmospheric and oceanographic data taken in the vicinity of Ocean Weather Ship PAPA have been checked for quality and given preliminary analysis. Ongoing case-study analyses are defining the dynamics and interactions for important synoptic events that should aid in improving process parameterizations. Studies of the radiation regime during STREX are expected to produce improved parameterizations for large-scale models.

A model has been developed to examine the atmosphere-ocean interfacial gas transfer. This model, combined with one for underwater sound generation by breaking waves, suggests that air-water gas transfer can be measured acoustically.

A model using the Monte Carlo method to predict atmospheric pollution dispersion and deposition through detailed knowledge of the governing atmospheric flow properties was extended to treat dispersion throughout the entire depth of the neutral boundary-layer. Model results were interpreted in terms of parameters in the widely used Gaussian plume model. Developments of the technique were applied to various non-neutral surface layers, to rapid assessments of agricultural fertilizer losses to the atmosphere, and to assessment of forest insecticide spray deposition to the forest canopy.

(viii) The 5th Remote Sensing Campaign of the Commission of the European Communities (CEC), Ghent, Belgium

On an invitation by the CEC, the Branch sent a two-person team to participate in the Ghent Project, whose aim was to provide an overall SO_2 budget for the Ghent area taking into account the complex pollution source configuration in the area. The team employed two Barringer Correlation Spectrometers (COSPEC) for measuring overhead burdens of sulphur dioxide (SO_2), a Meloy flame photo-metric sulphur analyser for ground-level SO_2 and associated data collection equipment.

(ix) Saint John Study

In response to an invitation by the New Brunswick Ministry of the Environment (ENB), the Branch participated in the Saint John air pollution study during July and August. The main purpose of the study was to determine the meteorological conditions that give rise to episodes of high ground-level SO_2 pollution concentrations in east Saint John and to identify the SO_2 emissions sources. Minisonde temperature and wind profiles were obtained by three teams (from the Branch, AES Atlantic Region and the University of New Brunswick). SO_2 ground concentrations were obtained by two mobile units, one from AES and one from EPS, as well as by the automatic network of ENB. Dispersion of the plumes aloft, tracking of the plumes and plume rise were obtained by using Branch COSPEC and LIDAR units.

On several days the combination of sea-breeze circulations and low mixing heights from the marine advection inversion caused poor air quality. The data for these days are being analysed.

(x) Canadian Arctic Air Pollution Programs and Arctic Dispersion Studies

The Canadian Arctic Air Pollution Program (CAAPP) (see 1979 and 1980 CGB) is into its third year of operation at three sites in the Canadian high Arctic: Igloolik, Mould Bay and Alert. High volume filter samples are obtained at each site, and integrating nephelometer measurements of light scattering at the first two sites. First results were published in Atmospheric Environment (Barrie et al). The program has shown that relatively high levels of sulphate and other anthropogenic aerosols are reaching far into the Arctic from mid-latitude sources. Siberian and North American sources dominated results from December 1979 and January 1980; European sources, in early spring 1980.

In addition to CAAPP, a short-term dispersion program is being conducted from November 1981 to February 1982, inclusive, to measure soluble/insoluble fractions of aerosols in the Arctic, their size distributions and SO_2/SO_4 ratios; scattering will also be measured aboard a Twin Otter aircraft to determine the vertical distributions (and dispersion) of the aerosols.

(d) Canadian Climate Centre

The Canadian Climate Centre (CCC) provides a central focus for climate activities in Canada relative to research, data management, information services, applications, impacts, monitoring and prediction.

(i) Canadian Climate Program Office

Draft submissions to senior government officials on the Canadian Climate Program (CCP) were prepared by CCC staff and reviewed by officials in several departments and agencies. A companion to these documents is a 20-minute audio-visual presentation, "The Canadian Climate Program - A National Need".

On March 17, 1981, the Canadian Council of Resource and Environment Ministers (CCREM) sponsored a climate change seminar in Regina on the theme: "Climate change and variability in Canada and its impact on our resources and environment". The seminar was designed to provide an opportunity for the Provinces to outline their perceptions of the impacts of climate on their economies. The most significant outcome of the seminar was a full endorsement of the concept of a cooperative national Canadian Climate Program. At their annual meeting in September, CCREM accepted the recommendations that came out of the Regina seminar.

Both English and French editions of the Agriculture, Tourism and Recreation, Climate Research, Oceans and Fisheries, and Forestry Workshops and the CCREM Seminar Proceedings were published, amounting to more than 2500 pages.

(ii) Data Management Division

Two feasibility studies on automated methods were completed. The first produced an automated quality control program to discover and edit erroneous data and to permit direct entry into the archive using remote CRT terminals. The second study dealt with archiving high volume data from satellites and radar.

Other activities included development of a marine data base for coastal waters that was stored by grid area and updated to 1979, the implementation of a remote user direct access capability and an update of the annual archive file.

(iii) Climatological Services Division

After 3 1/2 years of planning and development work, processing began on the new 1951-80 climate normals for radiation, temperature, precipitation and wind. Nearly 1500 pages of temperature and precipitation data were published in regional booklets. Information is available in booklet form, on microfiche and on magnetic tape. For the first time, simple computer methods were used to adjust data from stations operating for less than 20 years by using records from long-period nearby stations.

Canadian Climate in Review - 1980, was published and contains 12 essays on the economic and social impacts of significant climate events in 1980. Development work was started on a new edition of the climatic atlas of Canada and a reformatted hourly data summary (HDS).

Climatological data were supplied in response to more than 14,000 requests; over 400 requests were received for magnetic tape copy or custom computer statistical analyses of digital data retained in the National Climatological Archive. Approximately 5500 pages of historical data were published in regular periodicals, and 5000 pages of other publications, reports and minutes were produced. Over 1,000,000 pages of climate documents were microfilmed.

(iv) Hydrometeorology Division

The collection and initial analyses of data for the Lake Okanagan Evaporation Study were completed and showed the usefulness of thermal imagery for mapping lake surface temperatures and for estimating lake evaporation. Research studies began on using both active (SAR) and passive (SMMR) microwave data for determining snow cover properties. An investigation began on hydrometeorological sensors for data collection platforms.

In the Canadian Prairies drought project, streamflow and meteorological data were analysed to identify, define and rank historical droughts. A study was completed on a statistical technique to indicate monthly precipitation trends. Maps of water budget components were produced each week in near real-time for all of Canada.

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 northwestern area of Newfoundland (Cat Arm River area). Radar data from five SCEPTRE sites continue to be received and archived. Satellite-derived maps of snow cover in the Saint John River Basin were provided to the New Brunswick flood forecast centre.

A grid-point climatology of geostrophic winds was developed for the Northwest Atlantic and comparisons made with observed surface winds. Development began on the statistics of the freezing spray potential based on ships' observations. Water surface temperature maps of the Great Lakes and the Scotian Shelf/Bay of Fundy area were prepared bi-weekly from digital infrared satellite data.

(v) Applications and Impact Division

Much of the activity was a continuation of initiatives described last year, particularly in climate applications to agriculture, solar and wind energy, industry, construction and northern development. New work included: a study of the implications of carbon dioxide related warming to the North; a joint project with Health and Welfare Canada on the climate-related aspects of heat and cold stress and, more generally, on linkages between weather and certain diseases; development of a climate reference book for solar and wind energy applications, and of national maps of solar and wind energy potential; evaluation of different types of anemometers for wind energy and other uses; a study of the feasibility of better integrating climate parameters into biophysical land classification; and a review of material available for reconstructing past climate in Canada.

(vi) Monitoring and Prediction Division

Development of systems for real-time climate monitoring consisted mainly of the implementation of a pilot system based on the APL language for data retrieval and analysis and ongoing development of an on-line climate data base management system. New designs for improving the content of Climatic Perspectives were prepared.

Monthly temperature forecasts have been produced on an experimental basis using statistical time series models. Research is continuing in the transformation of deterministic model outputs into probabilistic forecasts.

Diagnostic studies are being carried out to study the relationships between interannual variations in horizontal heat fluxes in the lower troposphere and deviations from long-term mean circulation statistics at 500 mb.

(vii) Numerical Modelling Division

A simulation over the annual cycle was carried out using the AES/CCC multi-level spectral General Circulation Model (GCM). The various physical parameterizations have been modified to correct a number of deficiencies. Three new schemes are being developed and tested; these are an explicit cumulus parameterization, a new moisture formulation conserving total water amount, and an interactive mixed layer ocean model.

Numerical experiments have been made using a two-dimensional time-dependent radiative-photochemical transport model of the stratosphere. Several scenarios of possible future emissions of chlorocarbons have been used to predict the potential long-term changes in the stratospheric ozone and its climate.

Other modelling efforts involved the possible effects of stratospheric ozone reductions on solar UV-B radiation reaching the earth's surface, experiments to examine the radiative-photochemical coupling between the stratosphere and the troposphere, and the impact of ozone changes on surface and tropospheric temperatures.

Diagnostic studies were also conducted. Minor changes were made to the diagnostic program to permit analysis of a 14-month simulation over the annual cycle. Monthly circulation statistics were computed and global budgets were calculated for the potential and kinetic energies for January and April 1979. Several data sets were archived to assist in other on-going studies, including twelve months of data from the Canadian Meteorological Centre's (CMC) Objective Analysis; one month of 24, 48, and 72-h forecasts from the CMC forecast model; 5 months of FGGE level III-a data; and 6 months of level III-b data as grid point values and as spherical harmonic coefficients.

(e) Central Services Directorate - Ice Branch

An unusually mild ice season in the Gulf of St. Lawrence and a generally good ice year in the Arctic provided for an uneventful operational ice support season. Highlights included the implementation of the joint Canadian/Danish NOAA satellite receiving station at Sondre Stromfjord, Greenland, for coverage of northeast Arctic waters, increased ice reconnaissance coverage in the Arctic archipelago during late freeze-up, and the support of the m/v Arctic and CCG icebreaker St. Laurent during a late season probe into the Strathcona Sound. Climatological studies completed include compiling ice atlases for the Arctic and the Eastern Seaboard and publishing several of the annual Ice Summary and Analysis series.

A series of special projects were undertaken during the year in support of research and development in ice modelling, remote-sensing applications, and iceberg surveillance. The Branch participated in a spring experiment on winter ice dynamics in the Beaufort Sea (WIEBS 81), played a lead role in a fall RADARSAT experiment in Mould Bay, and performed a series of monthly iceberg surveillance flights along the Labrador Coast during the summer.

(f) Field Services Directorate

The Field Services Directorate role of providing weather information and service to the public is supported by the research activities of other AES units as well as by a wide range of studies carried out internally to improve operational procedures and products. These studies include: on-going efforts to improve the statistical and dynamical methods of predicting weather elements from the more abstract fields of standard numerical weather prediction (Canadian Meteorological Centre); integration of animated satellite imagery into an operational forecast program (Pacific Weather Centre); processing and analysing drifting buoy data transmitted via TIROS polar-orbiting satellite (Arctic Weather Centre and PADS project); and developing data management and analysis programs for the forecast centres' mini-computers (by all forecast centres).

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VII OCEANOGRAPHY

Compiled by G.T. Needler

1. Memorial University

(a) Centre for Cold Ocean Resources Engineering

Iceberg scouring and the nature of seabed stability are being examined from Lancaster Sound to the Grand Banks in collaboration with the Atlantic Geoscience Centre. Iceberg, wave, and current stresses have been investigated using a submersible. Surficial cores may soon be obtained using a seabed-deployable geotechnical corer developed by C-CORE. The International Ice Patrol data has been used to develop a probabilistic iceberg flux map for the northeast Newfoundland Shelf.

A skywave HF doppler radar program in collaboration with the Communications Research Centre has produced wind vector plots for the Labrador Sea. Detection of the pack ice edge appears to be feasible. Evaluation has begun of a U.S.-designed ground wave HF doppler radar (the CODAR system) for application to sea ice and iceberg detection, measurement of surface currents and other ocean variables. HF propagation over sea ice will be examined in the Arctic. A low-cost analog video processor, for use with a standard radar, is being developed for enhanced real-time analysis of small targets in the presence of clutter.

Laboratory tests of a laser-thermal imager system for airborne discrimination between oil and other contaminants of pack ice have demonstrated its feasibility. A solid-state disposal anemometer for currents between 1 and 1,000 mm/sec is now being developed for production by INSTRUMAR Limited.

Returns from 1979-80 drift cards released from east coast oilwell sites have exceeded expectations. Releases in the Beaufort Sea in 1980 have also been returned. C-CORE has also participated in oil dispersant trials in the Arctic and off Newfoundland.

(b) Ocean Engineering Group

The Ocean Engineering Group in the Faculty of Engineering and Applied Science consists of approximately 30 professors who undertake applied research in the ocean-related areas of geotechnology, acoustics, communications, ice and icebergs and ocean engineering.

Acoustic sensing is being used to determine geotechnical properties of ocean sediments and to identify subsurface layering with emphasis on computer models and algorithms. Core data and impact penetrometer calibration are being analysed. Work continues on an underwater digital telemetry system, a feasibility study of a Tsunami detection system, and of electromagnetic wave propagation over waves.

A sonar azimuth positioning device is being developed with industry, to obtain iceberg shape and drift. Iceberg-related projects also include laboratory scale studies

of melting, stability, hydrodynamic characteristics, and modelling of iceberg drift and scour. The main effort on ice has been in ice mechanics, including work on creep, fracture, and fracture toughness and of ice friction as it applies to ships.

Experimental and theoretical work, including use of the 60 m wave tank includes analysis of the response of moored semi-submersibles, offshore platform foundation shakedown, fatigue behaviour of monopod tubular joints, and structural integrity. Theoretical analysis work on optimal ship forms for minimum total resistance and of three-dimensional flow and wave resistance of a ship continues. The hydroelastic responses of plates and propeller blades vibrating in a fluid is being experimentally investigated.

2. Dalhousie University

(a) Chemical Oceanography

R.C. Cooke continued his studies of the marine carbonate system. The N. Atlantic surface seawater has been found to dissolve calcite at a pH near 8.16, contradicting the conventional view that the surface oceans are supersaturated with calcite. It was also discovered that the first and second dissociation constants of carbonic acid in seawater are regular functions of the carbonate system composition in seawater. Work on gas diffusion, organic matter separation, and phase change in thermally perturbed sediments has proceeded.

R.M. Moore is working on the role of atmospheric dust in marine trace metal and aluminum marine geochemistry while D. Wallace is measuring freons in seawater by gas chromatography in order to estimate the age of subsurface water masses.

P.J. Wangersky has grown three phytoplankton species in the Turbidostat, a device for the culture of phytoplankton at constant population density. A diatom, Phaeodactylum tricornutum, is now being used for nutrient stress experiments. A second Turbidostat has been put into operation.

R.M. Gershey has defended his thesis on natural marine surfactants. Brian Whitehouse is studying the effects of dissolved and particulate organic matter on the partitioning of polyaromatic hydrocarbons in seawater. C. Parrish is quantitatively separating lipids in organisms and in the dissolved fraction of the organic matter in seawater.

(b) Physical Oceanography

Research interests cover a broad range of topics, mainly in nearshore and continental shelf processes but with interests also in large-scale circulation and deep-ocean mixing. Thanks in part to the NSERC strategic grants programme, the group has grown to the point where more fruitful interaction can take place between researchers with different background experience. Close ties with Bedford Institute of Oceanography have continued.

Studies of the interaction of waves and beaches continue. Graham Symonds, with Tony Bowen and David Huntley, is investigating the role of wave breaking on the generation of low-frequency forced waves using a theoretical study and data collected on Prince Edward Island in 1980. Results suggest standing waves shoreward of the breakpoint and progressive waves seaward. Collaborative work with Rob Holman (Oregon State University) concerns the extension of models to three dimensions in order to study the forcing of edge waves by the breaking waves.

Tony Bowen, also working with Rob Holman, has taken a further look at mechanisms whereby oblique bars and even irregular sand bars may be formed. Basic questions about the phase locking between nearshore free and forced long waves are being addressed. The dynamics of turbidity currents, including the role of sediment settling in a turbidity current, is being studied by Mike Stacey for his Ph.D. thesis. Data from an extensive survey of Navy Fan, off Southern California, are being used to reconstruct a turbidity current event.

Because of interest in the nature of boundary layer turbulence and its importance in determining sea bed stress and sediment dynamics, David Huntley, Terry Chriss, and Liz Bedell are beginning a research programme to relate directly-measured Reynolds stresses to suspended sediment concentration and to stresses as measured by profiling thermistor probes in the viscous sublayer, within millimeters of the sea bed. Initial data are being analyzed, and further experiments are being planned, hopefully in the vicinity of the Hibernia oil field.

Barry Ruddick joined the Faculty in August and is continuing his work on double-diffusively driven interleaving at deep-ocean fronts. He hopes to expand this study to some oceanographic fine structure data, and to extend his interests to tidal fronts, tides, and mixing.

Cross-isobath exchange processes on Georges Bank have been studied by Dan Wright and John Loder (now at BIO). Rick Marsden is looking at current meter data from the northern slope of Georges Bank taken during the larval herring patch experiment.

Keith Thompson, Dan Wright, and Rick Marsden are examining the large-scale, low-frequency wind stresses on the North Atlantic using surface barometric pressure maps. These are being related to observed monthly fluctuations of North Atlantic coastal sea levels.

Chris Garrett and Bechara Toulany continued their study of the Strait of Belle Isle and the northeastern Gulf of St. Lawrence relating sea level data to meteorological forcing. Chris Garrett is on sabbatical leave at the Department of Applied Mathematics and Theoretical Physics, Cambridge University, and the NATO SACLANT ASW Research Centre at La Spezia, Italy, during 1981/82.

3. Bedford Institute of Oceanography

(a) Ocean Circulation

A heat budget study with AES (Toronto) and IOS (Sidney, B.C.) of an arctic polynya has yielded accurate bulk formulas for calculating the heat exchange between open water and the atmosphere in the arctic winter. An international workshop was held to define the experimental work required to improve humidity flux bulk formulas to the level required for large-scale climate modelling. Data from OWS Bravo are being used in a heat budget analysis of the mid-Labrador Sea. Similar data available from weatherships and ships-of-opportunity are being examined for their accuracy and applicability to large-scale oceanic heat budgets. The development of an iceberg drift model appropriate to the needs of offshore industry continues. Microstructure data from the mixed layer collected during the JASIN experiment were analyzed to provide information on the relationship between dissipation and wind forcing.

An examination of the mean circulation of the deep and intermediate waters of the Newfoundland Basin continued with the deployment and recovery of eight deep-sea moorings and an extensive CTD survey. Data from deep-sea moorings that were located in a joint Program with WHOI near the Gulf Stream at 50°W and 55°W are giving information on the zonal changes of eddies near the Stream. A major field program with the Scripps Institution of Oceanography will be held in March/April 1982 to observe the deep water formation in the Norwegian Sea.

The long-term (10-year) monitoring of the current near Hamilton Bank is now well established. Current meter moorings were deployed south of Hamilton Bank in a joint program with industry (PETROCAN) to examine the small-scale structure of the flow. Work on the seasonal circulation on Flemish Cap in support of a fisheries program is near completion. Work is progressing on a steady-state diagnostic-numerical model before development of a time-dependent numerical model for the Labrador Sea.

A number of process studies are underway. Non-linear tidal models are being used to predict rectified flows around banks and are being compared to field observations of the tidal boundary layer observed near Cape Sable. A numerical model for the estuarine circulation of the Gulf of St. Lawrence will be evaluated by field observations in the

coming year. Internal bores and solitons observed during a study of tidal mixing processes at the edge of the Scotian Shelf are believed to be important for mixing nutrient-rich water upward into the surface layers.

Work continues on the nonlinear baroclinic adjustment that occurs at locations such as the upper slope region or shelf edge along continental margins. Examples have been found where convection in an enclosed cavity with appropriate boundary conditions have analogs with the Stewartson problem in rotating homogeneous fluids. Progress has been achieved in numerically solving problems with a boundary in a rotating system which has non-uniform heating with particular interest in the role of spatial oscillations in the interaction between the boundary layer flows and interior flow.

(b) Coastal Oceanography

Data from Scotian Shelf Break experiment continues to yield information on low-frequency processes such as the radiation of topographic waves by Gulf Stream rings, seasonal and transient response to wind forcing, and the exchanges between shelf and offshore waters. Data from the Scotian Shelf off Cape Sable are being used to study the seasonal advective transport into the Gulf of Maine and to model the tidal boundary layer.

Data from varied sources have been analyzed to produce a quantitative description of the circulation on the Newfoundland Shelf. Analysis of ice floe movement in Baffin Bay and Davis Strait enabled estimates of the strength and variability of surface currents. Studies of the impact of freshwater on the surface water mass in the Labrador Sea are continuing.

A box model of the Gulf of St. Lawrence has led to the conclusion that variations in freshwater discharge and surface heat flux have more profound effects on vertical stratification than do changes in the estuarine-type circulation. Measurements of deep flow in the Laurentian Channel are being analyzed. The need for more winter data in the Gulf is apparent. The development of the numerical model of tides in the Bay of Fundy/Gulf of Maine continues and an atlas of the strength and variability of tidal currents has been published.

An estimate of interannual variability of wave climate in the North Atlantic is nearing completion and the wave climate at the Hibernia site is being addressed. The results of a program designed to measure the oil distribution on the Scotian Shelf after the Kurdistan incident have been published in an atlas. An improved drifter for oil spill tracking in offshore regions is being tested. The dispersal of dredge sediments at major dumpsites, with special emphasis on the Miramichi, is being analysed. Studies of circulation and bottom sediment movement in Saint John Harbour have been concluded and indicate that the dumping of dredge spoils has not significantly changed the sedimentary regime in the outer harbour and adjacent regions. Studies of the behavior of suspended particulate matter are concentrated on flocculation processes.

A program to obtain a long-term data series for bottom water temperatures at selected sites throughout the Atlantic Region has been expanded. Three data reports giving degree-day values for selected sites important for benthic productivity have been issued and over 79 sites had temperature gauges installed in 1981.

(c) Chemical Oceanography

The examination of the vertical distributions of metals in the Sargasso Sea, the Caribbean Sea, the northeast Pacific Ocean and the Arctic Ocean has continued with increased emphasis on the role of suspended matter. Continued study of the processes controlling estuarine and nearshore transport and removal of metals have led to better understanding of the flux of metals into the North Atlantic.

As part of an international SCOPE initiative, and in conjunction with OSS Quebec, monthly samples of riverine organic material are being collected to determine the nature of the organic material discharged. Carbon isotope techniques have been used to assess the relative importance of different organic carbon reservoirs in Bay of Fundy mudflat ecosystems and food chain relationships on the Scotian Shelf.

Data from Baffin Bay and other regions have been used to construct a budget for salt, freshwater, nutrients, and alkalinity for the region. Samples have been collected on the FRAM III Ice Camp Experiment north of Svalbard and stable oxygen isotope techniques used to assess the relative contributions of river water and sea-ice meltwater to alkalinity in the Svalbard area. As part of the program to identify the natural organic constituents of the lipid fraction of dissolved organic matter we are examining the nature of the coloured base-soluble organic matter in seawater. A laboratory study of the influence of salinity and temperature on the Henry's Law constants of three organic compounds of differing volatility has been carried out.

Examination continues of the baseline levels of low molecular weight hydrocarbons and petroleum residues in waters and sediments off the east coast of Canada and in the Arctic with studies on the continental shelf of southeastern Baffin Island and on the Grand Banks, focussing on the Hibernia and South Tempest exploratory drill sites and a natural seep off Scott Inlet.

Environmental monitoring at the Point Lepreau nuclear generating station in New Brunswick was continued in anticipation of the reactor start-up in 1982. Fallout radionuclides and their stable analogues are being measured throughout the terrestrial, atmospheric, and marine phases to identify potential pathways for the transport of any radionuclides released from the reactor.

Sediment-depth profiles of Cs-137, Pu-238, and Pu-239,240 in the unbioturbated sediments in the Saguenay Fjord, Quebec, have been used to define the atmospheric inputs of fallout radionuclides, during the past thirty years, and to determine their residence times in the soil and water of the drainage basin.

(d) Ocean Technology

Recent developments include new and faster sensors for CTD's and the Batfish, construction of a profiling pump system, and the use of light transmittance for estimating suspended solids in admixture with chlorophyll and dissolved organic matter. Attention is being given to the dynamics of CTD cables and instrument packages and shipboard handling systems for this equipment, and improved methods of handling long electromechanical cables. Studies of corrosion problems and motion of current meter moorings are underway.

Applications of acoustics and signal processing techniques to the improvement of echo sounding methods and location of oceanic microstructure and biota are being explored. Research is also underway on acoustic positioning methods in the solution of oceanographic and geological problems, the objective being to simplify field operations. Improvements are being made to an electrically-powered hard rock coring drill to extend its ability to sample a wider range of rock types and its depth of operation.

4. Université du Québec à Rimouski: Département d'Océanographie

L'équipe de messieurs J. Lebel, N. Silverberg, et B. Sunby a développé un programme de recherche sur la biogéochimie de la couche limite benthique. Les projets spécifiques suivants sont inclus dans le cadre du programme: mesure directe du taux de sédimentation à l'aide des pièges à sédiments dériveurs; mesure du taux d'accumulation du sédiment à l'aide des techniques radiométriques de datation; écologie benthique en relation avec la chimie des sédiments; mesure du coefficient de mélange biologique du sédiment (biodiffusion) à l'aide des radioisotopes de courte vie; la stoichiométrie de la diagenèse de la matière organique; mesure et calcul des flux à travers l'interface eau-sédiment à partier des données provenant des pièges à sédiment et des profils de distribution dans les eaux interstitielles du sédiment; étude des équilibres des carbonates, des sulfures et des phosphates dans les sédiments; le cycle de soufre dans des sédiments bioturbés; diagenèse de Cu, Zn, Cd, Co, B, Fe, et Mn dans des sédiments estuariens; cinétique de la dissolution et le transport de silice dans des sédiments bioturbés; modelling du flux de maganese entre la colonne d'eau et des réservoirs sédimentaires.

5. Pêches et Océans, Region du Québec

(a) Océanographie physique

En mai 1981, sous la direction de S. Peck, l'étude de l'influence du débit des rivières sur le milieu marin côtier dans le nord du Golfe s'est poursuivie avec une campagne océanographique réalisée entre Sept-Iles et Blanc-Sablon.

La division a également participé cette année à deux évaluations environnementales pour le Projet pilote de l'Arctique, sur les impacts possibles de la construction et de l'opération d'un terminal méthanier à Gros Cacouna, situé à quelque 200 km en aval de Québec. Il faut maintenant attendre les recommendations de l'Office national de l'énergie quant au choix du site du terminal, soit à Gros Cacouna ou à Melford Point, en Nouvelle-Ecosse.

(b) Océanographie chimique

Sous la direction de D. Cossa, l'analyse des données de trois campagnes océanographiques conjointes avec INRS - Océanologie a permis d'évaluer l'état de la pollution par le mercure dans le fjord du Saguenay. Entre autres, certains résultats ont servi, dans le case de la crevette, à préparer une modélisation sur l'évolution des concentrations en mercure dans la chair consommable.

Les résultats préliminaires d'une campagne océanographique effectuée en 1980 ont permis de dresser un premier inventaire de la distribution du mercure dans les eaux de l'estuaire moyen du Saint-Laurent.

Des analyses du 3,4-benzopyrène ont été effectuées sur sept carottes provenant du fjord du Saguenay afin d'évaluer la pollution par les hydrocarbures cancérigènes. Il appert que les couches sedimentaires les plus récemment déposées sont plus riches en 3,4-benzopyrène que les couches sous-jacentes. De même, un gradient décroissant amont-aval a pu être observé. Ces observations portent à croire qu'une source de contamination par les hydrocarbures cancérigènes existe en amont du fjord. L'analyse d'autres composés se poursuit actuellement.

En septembre 1981, une campagne a été réalisée dans l'estuaire maritime du Saint-Laurent et la Baie-des-Chaleurs. Des échantillonnages d'eau ont été effectués afin de mesurer la teneur en mercure total. De plus, des sediments ont été prélévés pour des analyses de mercure, d'hydrocarbures polyaromatiques, de PCB et d'autres organochlorés.

Enfin, en avril 1981, J. Piuze et D. Cossa ont participé aux travaux de l'Institut de recherche avancée de l'OTAN sur les métaux en traces dans le milieu marin. A cette occasion, ils ont présenté un modèle, élaboré en collaboration avec D. Pouliot, décrivant la variabilité des teneurs en métaux traces chez la moule: le modèle tient compte de l'influence des facteurs physiologiques sur le contenu en métal de ce bivalve et permet une nette amélioration de l'usage de cet organisme comme espèce indicatrice de la pollution par les métaux.

(c) Océanographie biologique

En 1981, sous la direction de J.C. Therriault, se sont poursuivis plusieurs projets de recherche sous le thème général de la variabilité estuarienne. Des études ont porté sur la variabilité de la productivité primaire et secondaire, à plusieurs échelles spatiales et temporelles, dans l'estuaire maritime du Saint-Laurent. D'autres études nous ont permis d'améliorer nos connaissances sur la succession photoplanctonique, sur les processus hétérotrophiques et sur le phytoplancton des glaces. Un nouveau projet a été entrepris afin d'etudier les variations endogènes du phytoplancton estuarien. Les variations saisonnières les lipides, glucides, et protéines du zooplancton ont également fait l'objet de recherches (R. de Ladurantaye). Enfin, le rapport sur le homard des laguenes des Iles-de-la-Madeleine a été publié.

6. Institut National de la Recherche Scientifique, Océanologie, Rimouski

Les activités du programme de sédimentologie littorale ont été largement dominées durant l'année écoulée par la demande d'Hydro-Québec d'une étude de l'estuaire St-Jean et du chenal de Mingan de la basse Côte Nord du St-Laurent. Cette étude a nécessité la préparation et la réalisation d'une mission importante pour laquelle le navire MV Rigolet a été utilisé. Des travaux de géophysique et de sédimentologie et des relevés de faunes benthiques ont été effectués sur l'avant côte de la rivière St-Jean, et le chenal de Mingan. De plus une étude du débit liquide et de la charge solide de la rivière St-Jean a été réalisée ainsi que la confection d'une carte morphosédimentaire de cette même rivière. Le projet d'étude de la stabilité du littoral des Iles-de-la-Madeleine a conduit à la présentation d'une publication au cours des la conférence des côtes du Canada à Burlington.

7. McGill University: Institute of Oceanography (R.G. Ingram, S. Lepage, C. Anderson, S. deMargerie, E.R. Pounder, M.P. Langleben, B. d'Anglejan, J.P. Savard, M. Lucotte, J. Basmadjian)

(a) Physical Oceanography

Field study and modelling of the Eastmain River (James Bay) for both open water and ice-covered conditions continued in 1981. Modifications to the estuarine circulation and salt intrusion characteristics following a major reduction of fresh water input from July 1980 to July 1981 have been analyzed. Studies of the plume dynamics of the Great Whale River (Hudson Bay) and circulation of the St. Lawrence Estuary were continued in 1981. This included new field work and analysis of previous data. A new program of studies concerning coastal circulation in the area of the Avalon Channel (Newfoundland) was begun in 1981.

A field program directed towards ice research in Austin Channel (Arctic) was completed in spring 1981. Data was collected using moored and profiling current meters and a CTD and turbulence probe.

(b) Marine Geology

A benthic system to monitor in situ the fluctuations of suspended sediment concentrations (turbidity) near the seabed, in response to changes in tidal velocities, winds, and runoff gave several weeks of continuous data at a location near Gros Cacouna in June and July.

A study of the chemical partition of phosphorus in sediments and seston in the St. Lawrence upper estuary was completed. Absorbed iron hydroxide bound to "apatitic" phosphate was identified and the relative proportions of total inorganic to organic phosphorus in the sediments measured.

A baseline study of the sediments of the Eastmain estuary (James Bay) was completed early last summer prior to the river cut-off (July, 1980). A large collection of gravity cores, seston samples, shallow reflection seismic profiles and current velocity observations was obtained.

8. Ocean Science and Surveys, Central Region (B. Bennett, N. Watson, N. Freeman, P. Budgell, S. Prinsenberg, L. Muir, S. Baird, D. Brooks, E. Lewis, G. Boyd, W. Haras, J. Shaw)

(a) Oceanography

The first of several multi-disciplinary field surveys in Barrow Strait was completed in early 1981 in order to gain understanding of the short- and long-term variations in the physical, chemical, and biological properties. These are being used to distinguish the components (origins) of flow through Barrow Strait. Changes in the vertical structure of currents density, nutrients, and biota are being documented over month-long periods. Data from year-long and six-week current meter moorings, together with data from a specially-designed current meter profiler are being collected.

Numerical techniques are being used to predict changes in the characteristics of the plume in James and Hudson Bays when river runoff rate is changed due to hydro-electric development. Other work concerns the tidal-induced variation in salinity distribution in a narrow estuary, the variability of the oceanographic parameter in Hudson Bay, and the present and future circulation in James Bay.

A Ph.D. thesis (University of Waterloo) investigated the use of stochastic-deterministic modelling for estimating tides in branched estuaries. Results from related research programs and on the identification of internal tides in tidal current records observed in the middle estuary of the St. Lawrence have been presented.

(b) Ocean Technology

The unmanned through-the-ice current profiling system used in James Bay was redesigned using a gyroscope (realigned before each profile) for the high Arctic and has been successfully used. Two more systems are now being built. A small submarine is being used to transfer lines under the ice and special embedment anchors, to deploy through-the-ice current-meter moorings with fixed orientation. Further mooring and retrieval technique developments are planned.

The ice radar program collected data in Lancaster Sound with various radar types and operating techniques for the study of the interaction of signals with various ice types. A transportable ice physics laboratory was constructed and instrumentation procured to collect data on ice and snow.

(c) Shore Properties Studies

Monitoring of erosion along erodible shores of Canadian Great Lakes was reduced to the essential, yet viable, number of stations. Data have allowed updating rates of erosion and accretion, and classification of the shore zone into four distinctive groups. The Section provided the secretariat to the Coastal Zone Subcommittee. The estuaries of four major rivers in James Bay are being monitored to provide understanding of the physical processes controlling erosion in a sub-Arctic estuarine environment.

9. 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 hydrodynamic and transport numerical models. Work has continued on the physical limnology of special lake systems such as fjords and reservoirs. The coastal and shore dynamics of nearshore waves, currents, diffusion, sediment movements, and shore development 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.

10. Fisheries and Oceans, Ottawa: Marine Sciences and Information Directorate

The Marine Sciences and Information Directorate carried out its national and international functions and responsibilities through its three branches: Ocean Science Affairs Branch (OSAB); Marine Environmental Data Services Branch (MEDS); and the Scientific Information and Publications Branch (SIPB).

Ocean Science Affairs Branch (OSAB) helped prepare papers for OSS in fields such as ocean climate, sea ice research, Arctic marine science, marine transport, remote sensing, and ocean information services during the year. Activities during the year include participation in the environmental aspects of the Arctic Pilot Project and offshore drilling.

The Scientific Information and Publications Branch (SIPB) publishes most and indexes all Fisheries and Oceans scientific publications including the monthly Canadian Journal of

Fisheries and Aquatic Sciences. It also inputs relevant Canadian literature to Aquatic Sciences and Fisheries Abstracts, an international abstracting service, which is searchable online or available in printed form, and covers most aspects of ocean science and technology. In 1983 it will be merged with Oceanic Abstracts to form the most comprehensive database for marine and freshwater science.

MEDS is Canada's national marine data centre, archiving oceanographic data collected in the ocean areas around Canada, including the northeast Pacific, Arctic, and northwest Atlantic Ocean north of 35°N latitude.

MEDS retrieves data from its archives on request, largely for Canadian technical and scientific users, but also to a limited extent for foreign nationals. It provides a number of data services and products designed to provide data in a form and format well suited to individual needs.

As a forerunner to long-term plans to expand holdings to include more chemistry, biology and pollution data, MEDS is rapidly developing a national inventory system to track all oceanographic data sets of interest to Canada, both of Canadian origin and data collected by other countries in the area. The system is called CAMDI, the Canadian Marine Data Inventory. This activity has a very high priority in MEDS. Data scrutiny for inventory information was done in OSS regions and the information is now in various processing stages. At mid-October, more than 530 CAMDI entries were in the computerized system. They include more than 5,163 various data sets or six million characters. An on-line inquiry program exists and a data catalogue will be published shortly to provide the information to the various scientists and engineers.

MEDS is also participating in the evaluation of the oceanographic uses of the proposed Canadian radar satellite.

11. University of British Columbia: Department of Oceanography

(a) Physical Oceanography

S. Pond deployed three cyclesondes (internally recording profiling current meter/CTD systems) in the central Strait of Georgia in late February for three months, in Knight Inlet for two weeks in August, and in the central Strait of Georgia at the end of September, continuing until mid-1982. T. Yao, a research associate of L.A. Mysak, is analyzing the Strait of Georgia data. Open-ocean measurements of momentum flux, with W.G. Large, have been published in JPO; papers on heat and moisture fluxes and on synoptic estimates of air-sea fluxes (with R. Marsden) are in preparation.

L.A. Mysak is developing theoretical models for the generation and topographic scattering of baroclinic Rossby waves for application in the North Pacific. G. Mertz and L.A. Mysak have used a maximum likelihood spectral method to analyze current and temperature fluctuations in the source region of the Somali Current to test a three-layer, viscous, wind-forced model. L.A. Mysak, G. Swaters, and W.A. Perrie are developing a model for topographically-induced eddies near a coastal boundary, which may apply to the eddy observed near Sitka, Alaska. H. Hukuda, working with L.A. Mysak, has completed a non-linear baroclinic instability (subharmonic destabilization) study of the California Undercurrent off Vancouver Island which may explain why two different wavelengths are observed in infrared thermal satellite images of this region. M. Ikeda, working with L.A. Mysak and W.J. Emery, is developing analytical and numerical circulation models of the flow and eddies off Vancouver Island. The results will be compared with satellite images and with current observations obtained in IOS's CODE study. W.W. Hsieh, working under L.A. Mysak, has used novel data analysis techniques (rotary spectral analysis and model fitting) to show that about half the subinertial horizontal kinetic energy on the Oregon-Washington shelf is attributable to shelf waves. L.A. Mysak, W.W. Hsieh, and T.R. Parsons have shown that a 5-6 year signal observed in coastal sea level, temperature, and salinity fluctuations off B.C. is highly coherent with the 5-6 year fluctuations found in the Sockeye salmon catch and herring recruitment in this region.

T.R. Osborn and R.G. Lueck are continuing their work on ocean turbulence, particularly the measurement and interpretation of small-scale fluctuations of velocity

shears and temperature gradients. Measurements were made in September in a warm core ring (81-D) as part of the Warm Core Rings Experiment, and two more cruises are planned for next year. Development work has been completed on CAMEL III, an internally-recording profiler that dives to 3000 meters, and on a relatively inexpensive expendable dissipation profiler (XPD) that operates to 500 meters of depth. The analysis of data collected during FRONTS-80 is completed and the analysis of the data collected with the U.S. submarine DOLPHIN is in progress.

P.H. LeBlond and W.J. Emery have continued the elaboration of a model of the coastal circulation off the B.C. coast driven by freshwater inputs; long-term time series of the B.C. coastal runoff and precipitation have been assembled. T. Nicol, a M.Sc. student, has completed a numerical model of the oceanic response to fresh-water sources at specified coastal inputs. Y. Gratton, working with P.H. LeBlond, is completing a study of low-frequency oscillations in a basin with order-unity topography, aimed at elucidating the long period motions in the Strait of Georgia. Preliminary studies of the relation between salinity and runoff in the St. Lawrence estuary have been undertaken by P.H. LeBlond and K. Dyck.

The study of transport and deposition of tailings in Rupert Inlet has been completed by A.E. Hay, working under R.W. Burling. A numerical modelling study of Burrard Inlet and Indian Arm is underway, involving D. Dunbar and R.W. Burling.

W.J. Emery has completed an atlas of TS, SZ, and TZ curves for the North Atlantic and North Pacific, soon to appear as an issue of Progress in Oceanography. Studies of frequency-wave number spectra of wind and sea-surface temperature in the eastern North Pacific, as well as an evaluation of expendable CTD devices have recently appeared. In collaboration with D. Krauel of Royal Roads, W.J. Emery has initiated a program of multi-ship XBT surveys using Canadian Forces destroyer squadrons. Five such surveys have so far been conducted: four between Honolulu and Esquimalt, one between England and Halifax. Keith Thompson is working on a Ph.D. thesis based on this sampling program and its application to a study of the effects of mesoscale phenomena on acoustic propagation.

In collaboration with S. Pond, W.J. Emery and L. Royer (Ph.D. student) have been collecting surface salinity data from the Strait of Georgia using B.C. ferries. Time series studies of Fraser River plume positions and characteristics have been made; they show correlations with wind, tide, and river discharge. These data are being supplemented by monthly cruises taken in the central Strait of Georgia between the ferry routes. In a separate program, AXBT data from the northeast Atlantic are being examined to document the development and evolution of the subsurface temperature minimum.

W.J. Emery, in collaboration with T. Royer of the Univ. of Alaska, is carrying out a study of the recirculation of the Alaskan Gyre. In July-August, a CTD cruise was completed, along with the deployment of five satellite-tracked drifting buoys.

W.J. Emery has been a prime mover in the development of an excellent image processing facility at UBC for the study of satellite imagery. Efforts are underway to host navigation and registration software for image analysis. Recent agreements with AES and CCRS have helped to establish supplies of image data.

(b) Chemical Oceanography

E.V. Grill, in cooperation with R.L. Chase, has been studying the geochemistry of sediments from the Juan de Fuca and Explorer Ridge spreading centres located off the B.C. coast. T.F. Pedersen and E.V. Grill are examining the post-depositional chemical changes occurring in mine tailings which are being discharged from a copper-molybdenum mill into Rupert Inlet. Studies on the kinetic and thermodynamic factors controlling manganese concentrations in oceanic waters (E.V. Grill) and on the chemical behaviour of manganese in the estuarine zone of the Fraser River (S. de Mora with E.V. Grill) were completed.

Research in R. Andersen's group in 1981 focused on the study of structures of biologically-important secondary metabolites produced by marine invertebrates and phytoplankton. Two sesquiterpenes were isolated from the dorid nudibranch Cadlina luteomarginata and were shown to possess potent antifeedant activity. Luteone was shown

to be the metabolite responsible for the pleasant odor of C. luteomarginata. Two new steroids were isolated from the dorid nudibranch Aldisa sanguinea cooperi and shown to have antifeedant activity. Triophamine, an unusual diacylguanidine derivative, was isolated from the dorid Triopha carpenterii. We have shown that the fragrant odor of Melibe leona is due to 2,6-dimethyl-3-heptanol. We continued to study the production of a Gaky positive metabolite (Siderophore) by the dino-flagellate Prorocentrum minimum and we are investigating the physiological controls on the production of Lumichrome by Ohisthodiscus lutens.

(c) Geochemistry

S.E. Calvert has continued his studies of the geochemistry of the sediments of B.C. coastal inlets with a view to determining the role of organic association and sulphide precipitation in controlling the trace metal chemistry. The compositions of modern phosphorites from the Namibian Shelf are being studied in a collaborative project and a new investigation of the chemistry and mineralogy of manganese nodules and associated sediments from detailed surveys in the northern equatorial Pacific has started. A new automatic wavelength-dispersive X-ray emission spectrometer has been installed and is now heavily used for the geochemical work.

T.F. Pedersen's research has been considering 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, characterized by substantial biogenic, terrigeneous, and hydrothermal inputs; (ii) in British Columbia, Rupert Inlet, where sedimentation is dominated by tailings discharged from a large open-pit copper mine; (iii) Powell Lake, a meromictic former fjord, containing permanently-anoxic saline water and Lake Nitinat, a stratified, shallow-silled permanently-anoxic fjord which is subject to intermittent incursions of adjacent Pacific Ocean water.

12. Royal Roads Military College - Coastal Marine Science Laboratory

(a) Water Mass Studies (D.P. Krauel, F. Milinazzo, W.W. Wolfe & M.J. Press)

These studies are concerned with the dynamics of estuaries and harbours, with special emphasis on circulation, mixing, water level oscillations, and the relative importance of environmental forcing at various time scales by the wind, freshwater runoff, tides, and barometric pressure. Data from the Miramichi were used to calibrate and verify a numerical model used to separate the influences of the freshwater runoff and the wind. 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 a computer model using wave data hindcasts, and historical aerial photographs.

(b) Sea Bottom Studies (P.J. Schurer, H.J. Duffus, W.T. MacFarlane, J.M. Gilliland, and M.J. Press)

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 accessible for coring study. A profiling system was successfully applied in less than one meter of water in three different intertidal zones in Tsehum Harbour, showing the location of bedrock and penetrating approximately 30 meters into the sub-bottom. Forty-five 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 has been defined, and several offsets in the magnetic pattern perpendicular to the Fault's trend have been identified with topographic features.

(c) Sea Surface Studies (M.J. Press and H.J. Duffus)

An extension of the Fraser River Plume water has been traced into the Strait of Juan de Fuca using digital analysis of LANDSAT I imagery. Lapse rate photography of the Mt. Helmcken ship control UHF radar screen has been used to study tidal currents and fronts, internal waves, and radar sea clutter statistics in the Strait of Juan de Fuca.

(d) The other research projects at RRMC are less closely related to geophysics. However, all the projects are described in some detail in the Coastal Marine Science Laboratory Annual Report for 1981, Royal Roads Military College, FMO Victoria, B.C., V0S 1B0.

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

(a) Offshore Oceanography

With the termination of the Canadian Weathership program in June 1981, over 25 years of time series oceanic measurements at Station P and along Line P came to an end. A modified version of this program, initiated in August 1981 using research vessels at the Institute of Ocean Sciences, consists of two-week oceanographic surveys on a bi-monthly basis. The STD/hydro data are being used to determine steric contributions to mean sea levels, to delineate sub-surface fronts and to calculate baroclinic transports. An edited version of the data collected over the past 25 years is being prepared for use by organizations studying the role of the ocean in climate variability.

A study of wind-generated near-inertial internal waves in Queen Charlotte Sound and Hecate Strait has been completed. These motions were found to be spatially coherent over a distance of 300 km, considerably more than previously observed, and in certain regions to be subject to Doppler frequency shifting by mean flows. Monthly mean sea levels and atmospheric pressures were examined for the west coast of North America. With the exception of central-northern California, the sea level response to pressure differed appreciably from the standard inverse barometric effect ($\sim$1 cm/mb), steric effects being important. A significant sea level variability peak was found centred at 5.7 years, corresponding to a northward propagating signal with phase speed of 25-30 cm s^{-1}.

An analysis of the CODE (Coastal Oceanic Dynamics Experiment) data collected between May 1979 and September 1980 revealed strong (15-20 cm^{-1}) diurnal currents over the shelf-slope region off Vancouver Island. These are associated with northward propagating continental shelf waves. A theory has been developed to explain the presence of these waves in terms of a forced response to tidally-induced bottom Ekman dynamics.

An analysis of the Storm Response Experiment (STREX) data collected in late fall of 1980 at Ocean Station P is underway. Work continues on interpretation of the movements of 300 satellite-tracked buoys bunched in the southern oceans for the FGGE.

(b) Coastal Zone Oceanography

A new narrow angle transducer was built for sonar experiments and successfully tested in Knight Inlet. Velocities were sensed remotely using the range gated Doppler scheme, while the ship on which it was mounted slowly traversed the sill. Results demonstrate the potential of the device for measuring complex flow patterns associated with stratified flow over topography.

Analyses of pressure sensor and density data from Knight Inlet have been used to determine the internal pressure field and the balance of forces in the surface layer of the inlet. It has been shown that in contrast to assumptions implicit in various theoretical models, the principal balance is between the horizontal pressure gradient and the wind stress. Short-term fluctuations in the pressure gradient were shown to be well correlated with wind stress but not with fluctuations in river discharge. The baroclinic adjustment occurs close to the surface and is therefore hard to resolve with submerged pressure gauges, but produces significant sea surface slopes during the summer when there is a net up-inlet wind component.

A new program was begun in the Observatory Inlet, Alice Arm area, following widespread concern over environmental factors associated with the dumping of mine waste at Kitsault. In addition to an intensive monitoring programme, some detailed hydrographic measurements were taken extending to the mouth of Observatory Inlet. Together with acoustic measurements, these demonstrate that many of the energetic processes known to occur over the Knight Inlet still also occur in Observatory. Several recording instruments have been moored in the area as part of a study of deep water exchange and estuarine circulation.

Analysis is continuing of data collected between spring 1979 and spring 1981 on the southern Vancouver Island continental shelf. A description is emerging of a zone of persistent upwelling which is strongly coupled to biological processes in the area. The upwelling is driven by an interaction between quasi-steady current systems and a deep, narrow canyon that cuts the continental shelf. One of the moorings has been left in place to acquire statistics on interannual variability on the continental shelf, and as part of Super Code.

A related program extends from Barkley Sound into the Alberni fjord system. The shelf water appears to play a major role in the renewal of deep basin water resulting in more or less complete replacement on an annual basis. A decrease in oxygen content was observed, as dense water continued to flow into the fjord. About sill depth, strong and frequent exchanges of water between the fjord and the shelf were observed during the late fall and winter months apparently controlled by the offshore wind field.

An array of moorings is being maintained at five locations between the U.S./Canada border and the Queen Charlotte Islands. These moorings comprise the northern end of a very large array deployed by Mexican, U.S., and Canadian oceanographers to study the large-scale alongshore coherence of coastwise current systems. This experiment began in the spring of 1981 and will terminate in September 1982.

Preparations are underway for an intensive study of a small region of the ocean off new South Wales, Australia. The experiment is called ACE (Australian Coastal Experiment) and will attempt to determine whether or not continental shelf waves really do play any part in propagating signals alongshore. The experiment is cooperative between I.O.S. (Canada), Oregon State University, and CSIRO (Cronulla, Australia).

(c) Numerical Modelling

Through 1981 to 1982, observations of surface layer thickness, density, and circulation are being made to adjust and verify the performance of a vertically-integrated upper-layer buoyant-spreading numerical model. This is a joint project with industry to simulate the motions of the Fraser River discharge over the deeper dense water in the southern Strait of Georgia.

A three-dimensional (7 level) numerical model of the barotropic tides and density-driven circulation in the Georgia-Fuca system is being developed in collaboration with the University of Hamburg. A WMO-sponsored study of tidal aspects of storm surges in the Bay of Bengal was completed. Work is in progress on development of an irregular triangular grid finite difference model for the Dixon Entrance-Hecate Strait-Queen Charlotte Sound system.

(d) Remote Sensing

The program of remote sensing of water colour at IOS has shown that natural chlorophyll fluorescence, stimulated by direct or scattered sunlight, provides a distinctive signature in near surface waters. This can be used in airborne surveys of primary productivity. Results of a feasibility study of a fluorescence line imager, a sensor capable of detecting fluorescence from an aircraft, or from space, recommended that an instrument should be constructed. The project to build and evaluate a prototype has received support from the interdepartmental Committee on Space, and construction will start in 1982.

Analysis of water colour observations from an existing space sensor is continuing at IOS for producing chlorophyll maps of the west and east coasts of Canada. There is also a potential use for fisheries science and operations. Planning has begun for the Canadian Radarsat project involving a more detailed analysis of the U.S. Seasat data, and projects of the Convair 580 research aircraft, modified to include a new (c-band) radar frequency. IOS will be involved in both the analysis and the airborne experiments.

(e) Arctic Oceanography

The main components of the 1981 field season included a joint oceanographic survey project with the University of Washington covering Long. 0°-30°E, Lat. 81°-84°N, north of Spitzbergen, and a survey of the Beaufort Sea continental shelf between Tuktoyaktuk and Banks Island. Both of these utilized a specially-developed airborne CTD system based on the Twin Otter aircraft. Work is proceeding on the analysis of data collected during the 1980 Dundas polynya experiment. Planning of the NW Passage study is at an advanced stage for a major field effort to be mounted in 1982.

Further studies have been completed on the effects of gas hydrate formation on the behaviour of oilwell blowouts in deep water. A study is currently being made into the feasibility of subsea collection of an oilwell blowout, a joint program involving Scandinavian and U.S. interests.

The new practical salinity scale '78 has been accepted as the standard for reporting salinity measurements by the major international bodies and journals.

(f) Ocean Chemistry

Ongoing research continues to concentrate on the marine carbon cycle, hydrocarbons, trace metals and ocean enclosed experiments to understand marine processes so as to provide expertise and advice for environmental problems of mine tailings, disposal, oil pollution, ocean dumping, arctic and fjord chemistry, and environmental contaminant transfer.

The Marine Carbon Research Centre, created as a focus for marine CO_2 studies, has three programs in place to substitute for the Canadian Weather Ship program, terminated in May 1981: (1) Line P CO_2-chemical oceanography in N.E. Pacific Ocean between Victoria and Station P (50°N, 145°W), (2) west coast lighthouse CO_2 sampling program, and (3) ships-of-opportunity between Tokyo, Japan, and Vancouver, B.C. and between Sydney, Australia, and Vancouver, B.C. to collect air and sea CO_2 samples. Analysis of atmospheric CO_2 data at P and sea surface temperature over the N. Pacific suggest a correlation between CO_2 lows in 1976 and 1977 with colder than normal sea surface temperature in NW Pacific (40-45°N) which might be a major CO_2 sink.

Ocean pollution work was concentrated on marine environmental problems associated with disposal of mine tailings into Alice Arm by AMAX Mines. The chemical programs included measurements of metals (lead, zinc, copper, cadmium) in the coastal fjord, in particular using lead isotopes to distinguish the metal input from tailings and natural river particulates, study of tailings sedimentation by sediment traps and monitoring of sediment tailings accumulation and effects on pore water metal chemistry. Hydrocarbon studies at IOS included baseline surveys of petroleum-based compounds in sea water, sediment, and mussels in Saanich Inlet related to an oil tank farm proposal and histopathology work on mussels collected in clean and polluted environments. Participation in the Baffin Island Oil Spill (BIOS) project involved management of contracts on the chemical fate and effects of oil spilled experimentally in the arctic.

The SEAFLUXES program continued (sediment/ecosystem/atmosphere fluxes enclosure study) with participation of scientists from the University of Tsukuba, Japan, Qingdao College of oceanography in Peoples Republic of China, and Institut fur Meereskunde at Kiel University, F.R. Germany. Transfer of metals and copper complexing with organics were studied using large enclosures of sea water.

Deep-sea oceanography was studied on the HUDSON-81-003 leg between Puntarenas, Costa Rica, and Victoria, B.C. during April to early May 1981. Programs carried out included: air-sea exchange of CO_2 in the upwelling areas off Baja California to B.C., study of a geothermal vent on the East Pacific Rise, and sampling of trace metals in open-ocean and marine carbon cycle in the productive coastal waters.

(g) Tides and Currents Section

The current survey off the west coast of Vancouver Island, completed in 1980, revealed strong diurnal currents. These are now explained as shelf waves, driven by the tide, and modified by the stratification and alongshore average flow. During the summer, when northwest winds generate currents to the southwest over the shelf, we found a northwestward current very close (about 15 km) to shore. This current may be driven by the density gradient caused by fresh water input near shore.

(h) Ocean Ecology

The study of the planktonic ecosystem on the continental shelf off the west coast of Vancouver Island concluded with two cruises in 1981 during which a survey of the benthos was also carried out. Results obtained suggest a counterclockwise current gyre centred over the head of a tributary canyon to the Juan de Fuca submarine canyon as being responsible for drawing nutrient-rich deeper offshore water up the canyon and onto the shelf. This is where a large region of enhanced primary and secondary production is located. The benthic survey is aimed at determining whether the spatial distributions of bottom organisms correlate with the zone of high plankton productivity.

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VIII GLACIER STUDIES

Compiled by: R.M. Koerner

1. Introduction

Glacier studies in Canada in 1981 showed an increasing move toward applied, rather than academic, studies. The Ocean Engineering group at Memorial University of Newfoundland completed many studies on icebergs which have an important relevance to the oil industry working offshore in that province, and EM&R continues its work on ice cores with leanings towards understanding past climates and monitoring the present in order to see into the future. ETH Zurich drew its field work to a conclusion after many years in the north, but the mass balance measurements will hopefully continue under some other sponsorship. NHRI of DOE and Karl Ricker Ltd. concentrated on the Cordillera with mass balance/hydrology oriented studies, although cores were obtained by NHRI from the Mount Logan area. Memorial University, Department of Geography, began a study of hitherto unknown glaciers in northern Labrador and the University of British Columbia maintained its important glaciological program previously concerned with glacier surges and radio echo sounding. The University of Minnesota's long-continuing work on the Barnes Ice Cap was in the form of analysis of previously collected data while the Université du Québec à Montréal developed equipment for studying CO_2 in ice core gas bubbles. The Scott Polar Research Institute of Cambridge, England successfully tested very high resolution radio echo sounding equipment in northern Ellesmere Island. Altogether a fairly successful year.

2. Energy, Mines & Resources Canada - Polar Continental Shelf Project (R.M. Koerner, D. Fisher, B. Alt, M. Parnandi, and J. Bourgeois)

(a) Laboratory Investigations

Under contract J. McAndrews (Royal Ontario Museum) completed pollen identification in the 1973 Devon Island ice core from 200 slides. A similar study of the northern Ellesmere 1977 core, which is very low in pollen concentration, is now underway. Analysis of the 1977 Agassiz core δO^{18} and microparticle distribution was completed and a preliminary report written. A study on increasing acidity in the snows of northern Ellesmere was submitted for publication. A comparison between ^{14}C productivity and δO^{18} records from the Camp Century and Devon Island cores nears completion. The ice texture of the northern Ellesmere ice core was studied and the by now characteristic nature of fine ice deposited during the last ice age was recognized. A study of about 20 years of Canadian High Arctic glacier mass balance results in terms of climatic trends and value as a "climate-watch" indicator was begun. An investigation by the University of Portland, Oregon into iridium concentrations in several levels of the ice nears completion. From detailed analysis of summer synoptic conditions for extreme positive and negative mass balance seasons during the period of record, synoptic analogs were developed for periods such as the Little Ice Age and Medieval Warm Period, and Climatic Optimum. The effect of fluctuations in the ratio of winter to summer accumulation as the apparent annual temperature as represented by δO^{18} were investigated.

(b) Field Work

The mass balances of the Meighen, Melville, Devon (northwest side), and Agassiz (northern Ellesmere) northern ice caps were measured. In the northern Ellesmere boreholes drilled from surface-to-bedrock in 1977 and 1979, down-the-borehole photography, closure rates, total vertical strain and temperatures were taken to compare to measurements made each year since the original drilling. Core samples to a depth of 20 m (age approximately 1910) on Agassiz ice cap and 10 m near Mount Oxford on northern Ellesmere were drilled to study the acidity trends in the snow.

3. Environment Canada - Snow and Ice Division, NHRI (S.J. Jones, Acting Chief)

(a) Glacier Studies - General

(i) Glacier Inventory of Canada (C.S.L. Ommanney, M.M. Strome and J.W. Clarkson, S&ID, NHRI, EC)

Glacier inventory work was limited to the Iskut River basin of British Columbia. Over 2000 glaciers have been identified and partial measurements made. Bibliographies of Ellesmere Island glaciers and ice islands have been completed.

(b) Glacier Studies - Yukon

(i) Mount Logan Ice Core Studies (G. Holdsworth, S&ID, NHRI)

An operation (supported by the Arctic Institute of North America) was carried out to retrieve the electro-mechanical ice core drill and 75 m of ice core from the 103 m hole. This was carried out successfully, as was the relogging of the hole for temperature, vertical strain rate and tilt. The top of the borehole was also resurveyed for movement. G.K.C. Clarke (UBC) over-flew the area with the airborne radar and obtained additional ice depth profiles. This concludes the Mount Logan operation.

(c) Glacier Studies - Cordillera

(i) Mount Edziza (B.C.) and Mount Waddington area (Tellot col) (B.C.) (G. Holdsworth, S&ID, NHRI)

Reconnaissance site surveys were carried out at these locations as to suitability for future ice coring. Both sites are temperate and 10-12 m cores are being analysed for oxygen isotopes. The work is being supported by B.C. Hydro.

(ii) Iskut River glaciers, B.C. (O. Mokievsky-Zubok, S&ID, NHRI)

Studies of three glaciers in two watersheds draining into Iskut River to determine their mass balance and assess glacier influence on proposed construction of river dams were continued. Accumulation and ablation were average. Yuri and Alexander glaciers lost ice at the terminus vertically 2.2 m and 2.0 m, respectively. Andrei Glacier lost 4.4 m of ice vertically and retreated 29.5 m.

Two small ice dammed lakes, Natavas Lake in the More Creek watershed and an unnamed lake in the Forest Kerr Creek watershed, were observed to partially fill and discharge in the course of the summer.

(iii) Mass balances, SW Coast Mountains, B.C. (O. Mokievsky-Zubok, S&ID, NHRI

Measurements of winter and summer balances, meteorological variables and meltwater flow continued on two former IHD glaciers, Sentinel and Place. Mass balance only was measured for Helm glacier.

(iv) Jokulhlaup of Flood Lake, B.C. (O. Mokievsky-Zubok, S&ID, NHRI)

Observation of ice dammed Flood Lake in northern British Columbia continued. It flash flooded in mid-August as predicted discharging about 200 x $10^6 m^3$ of water into the Stikine River raising its level by 2 m.

(v) Bridge River, B.C. (O. Mokievsky-Zubok and S. Fogarasi, S&ID, NHRI

Studies of the Bridge River headwaters glaciers to determine the effect of glaciers on basin runoff and to evaluate seasonal and operational forecast models for a downstream hydropower reservoir (with J.R. Gordon, B.C. Hydro) were continued. A Data Collection Platform is in operation again to provide hydro-meteorological data.

(vi) Tiedemann and Bench Glaciers, B.C. (O. Mokievsky-Zubok, S&ID, NHRI)

Studies began on these two glaciers in the Mount Waddington area to determine their mass balance, their response to climatic change, and their potential influence on the proposed construction of river dams. Vertical ice loss during the summer at the termini was 8.1 m and 5.3 m, respectively.

4. Karl E. Ricker Ltd., Vancouver, B.C.

(a) Wedgemount Lake and Glacier, B.C. (W.A. Tupper, BCIT, K. Ricker, K.R. Ltd.)

The glacier was visited in early autumn and lower velocity profile and snout position were fixed using stereo-pair, photo-theodolite imagery. Velocity was, as for the previous year, 12 km y^{-1} with convergent flow of stations. Snout advanced 5-8 m except for no change at margins.

Scribing of the 1:10,000 map of the glacier basin was completed. Volume of the ablation zone ice loss is being computed using terrain digitizing methods (with B.C. Hydro facilities).

(b) Upper Clendenning and Snow Cap, creeks, lakes and glaciers (W.A. Tupper, BCIT, and K. Ricker, K.R. Ltd.)

No further progress on these areas last year and work will not be resumed until student enrollment in photogrammetry at UBC reaches the requisite level.

5. University of British Columbia - Vancouver, B.C. - Department of Geophysics & Astronomy (G.K.C. Clarke, M.G. Maxwell, B.B. Narod, R.D. Russell, B. Prager, E.D. Waddington, D.A. Waldron)

(a) Ellesmere Island (G.K.C. Clarke, B.B. Narod, and B. Prager)

The UBC 840 MHz radar has been modified by B.B. Narod to include sampling and magnetic recording systems. In June, 1981 the equipment was used to take 2000 line-km of soundings over the Ayles, Milne, M'Clintock and Ward-Hunt shelves, the Milne and Disraeli glaciers and the highland glacier near Mount Oxford. The digitized sounding data are now being computer processed and plotted.

(b) Glacier Studies - Yukon

(i) Glacier Surging (G.K.C. Clarke, M.G. Maxwell, D.A. Waldron, UBC/GPHYS, D.E. Thompson, Jet Propulsion Laboratory & S.G. Colling)

Field studies in preparation for the next surge of Trapridge Glacier were continued in 1981. The flow marker network was resurveyed and 10 holes were drilled to the glacier bed in the vicinity of the wave-like bulge.

(c) Glacier Studies - Cordillera

(i) Outburst Floods (D.A. Waldron, GPHYS/UBC)

The likely magnitude of outburst floods in the Iskut and Stikine River basins of British Columbia is being appraised and a computer model for the Flood Glacier outbursts has been developed.

(ii) Flow Modelling (E.D. Waddington, UBC/GPHYS)

A doctoral thesis on accurate modelling of glacier flow has been completed. The thesis gives a very thorough analysis of the many sources of instability and inaccuracy in finite-difference models.

6. University of Minnesota - Minneapolis, USA (R. LeB. Hooke, P.J. Hudleston)

(a) Barnes Ice Cap

No field work was undertaken in 1981. Analysis of previous years' results is underway, the most interesting of which is the identification of a layer of isotopically ($\delta^{18}O$) less negative ice beneath the white ice, previously shown to be of Pleistocene age, near the base of the ice cap. This isotopically-less negative ice is also white (due to a high bubble content), but it contains morainal material, in contrast to the isotopically-more negative white ice. The less negative isotopic composition of this dirty white ice is interpreted as indicating that the ice was once at the pressure melting point, and that water produced during sliding was lost either to groundwater or to a subglacial stream system.

7. Université du Québec à Montréal (Jean-Claude Hilaire Marcel and Pierre Pagé)

Equipment capable of determining the percent of CO_2 present in air bubbles in glacial ice was designed and built. It will be used to determine the CO_2 content of ice from High Arctic cores obtained by the Polar Continental Shelf Project on northern Ellesmere.

8a. Memorial University of Newfoundland (St. John's, Newfoundland, Geography Dept.)

(a) Torngat Mountain Glaciers - Labrador (R.J. Rogerson)

The Torngat Mountains in northern Labrador host the only glaciers in eastern Continental North America and the southernmost glaciers in the eastern Canadian Arctic. The largest group of glaciers is concentrated in the Selanuit Range, south of Nachvak Fiord, an area overlooked in previous surveys of Labrador glaciers.

Four cirque glaciers (about 1.6-2.4 km^2) were examined in the summer. Mass balance, ice movement and terminus position measurements were started and will be continued in subsequent field seasons. Snow depth at 400 points in mid-July was 1-2 m, densities were generally more than 0.5 g cm^{-3} with thick ice lenses. Snow melt was at a rate of about 0.5 g cm^{-2} a day with slush flow on steep slopes. Melt ended by late August with the maximum snow line altitude at 1300 m. The geomorphology of avalanche-type medial moraines was studied. There is good evidence for a recent increase in the activity and extent of these glaciers. A stake network was set up for future strain rate, velocity surveys, and terminus changes. Future work will expand on glacier stratigraphy and climate and the definition of neoglacial and Late Wisconsin ice limits.

8b. Memorial University of Newfoundland (Ocean Engineering Group, Faculty of Engineering and Applied Science)

(a) Iceberg Dynamics (D.B. Muggeri, W.E. Russell, N.P. Riggs)

Theoretical and laboratory studies have been initiated on the stability and hydrodynamic drag characteristics of icebergs of different shapes.

(b) Iceberg Drift (R.T. Dempster and C.C. Hsiung)

Field data on iceberg drift have been analyzed and further work on the short-term drift of icebergs is in progress. A study of the effect of wind and waves and a detailed parametric analysis are in progress to determine the relative importance of the various environmental parameters.

(c) Iceberg Scouring (T.R. Chari, A.S. Reddy, G.R. Peters, H.P. Green)

The mathematical model for iceberg scour has been generalized to account for cohesion and internal friction of the sediments. Sea trials were conducted jointly with the Bedford Institute of Oceanography to study the seabed characteristics in the Hibernia and Ben Nevis areas of the Grand Banks. Laboratory tests are in progress with pipeline models, in order to interpret the effect of scouring icebergs on buried installations.

(d) Iceberg Decay (B.D. Bowen and C. Dutton)

Laboratory experiments are in progress to identify the major parameters affecting the melting process of icebergs. Measurements of velocity, temperature and salinity profiles are being made and interpreted.

(e) Iceberg Impact Probabilities (D.V. Reddy, M. Arockiasamy and P.S. Cheema)

Impact probabilities of icebergs with offshore structures are being investigated using the Monte Carlo method. Iceberg shapes are simulated based on observed data.

9. E.T.H. Zurich (A. Ohmura and H. Blatter)

The mass balance of White Glacier on Axel Heiberg, which began in 1959, was measured (giving a 22-year record) as were the balance of a glacier and an ice cap on Coburg Island. Englacial temperatures to bedrock were made in holes by a steam drill. These results together with those from previous years give a line of temperature profiles down the White Glacier allowing work on the thermal regime of that glacier to be completed.

10. Scott Polar Research Institute - Cambridge, England (C. Neal and M. Gorman)

In May of 1981 a joint SPRI/BAS team, with logistic support from PCSP, carried out high resolution radio echo sounding along short track sections on the Agassiz ice cap, Ellesmere Island. The aim of this work was to try to obtain a direct experimental correlation between radio echo internal layers and ice core stratigraphy. To this end the echo sounder had a resolution in firn of under 15 cm and was able to detect layers to a depth of 20 m. Core stratigraphy was assessed at points along the radio echo tracks by hand coring 11 m holes from the base of 3 m pits. Preliminary analysis indicates a strong correlation between density fluctuations and radio echo layers.

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IX HYDROLOGY

Compiled by: G.J. Young

1. Introduction

This report has been compiled from information gathered through members of the Associate Committee on Hydrology. Since the Committee is composed of members from the four member categories (federal, provincial, university and professional association), the report is representative of hydrological activities in Canada but the overall national coverage is not as even as was desired. Hydrological activities in glacier studies and hydrometeorological studies are reported separately under the chapters on Glacier Studies and Meteorology and Atmospheric Science respectively.

2. National

A study group was established to investigate the future of the National Research Council of Canada's Associate Committee on Hydrology and provide to the Committee the coordinated views of the membership. Recommendations will be submitted to NRCC when the present ACH mandate terminates in mid 1983. The Canadian Council of Resource and Environmental Ministers have agreed to support the preparation of an ACH Flood Hydrology Guide and Alberta Environment is assigned the task of playing the lead role of canvassing all governments to secure financial commitment to the work. Dr. V. Klemes of the National Hydrology Research Institute, Environment Canada conducted an ACH/CSCE National Lecture Tour, visiting 11 cities across Canada, speaking on a variety of topics relating to stochastic modelling.

Agriculture Canada undertakes and supports hydrologic research in the near surface zone such as drainage, desalinization of soil, return flows from irrigated lands and water conservation in agriculture. Research in agrometeorology includes improving water use efficiency, crop yield prediction from soil water and weather data, and modelling of water use by crops. The soil-resource inventory program includes research in soil water processes, and studies of the impact of shallow groundwater processes on soil properties and uses. An improved approach for characterizing the soil water regime is under development for use in the soil resource inventory program. Farming systems' impact on hydrology especially on the water quality aspect is receiving increased support. The needs for research in agriculture will be addressed at a forthcoming research planning meeting.

The National Hydrology Research Institute (NHRI) continued its research activities in the three broad areas of surface water, ground water, and snow and ice. Activities in the surface water area include modelling of precipitation-runoff relations, peak discharge-mean daily flow relations, regional evapotranspiration and streamflow from glacierized basins. Studies in remote sensing include the application of gamma ray and synthetic aperture radar to snowpack observation and measurement as well as the use of time domain reflectometry in tracking the freezing plane in the soil. In northern environments, research is being carried out on lake dynamics and flooding in the Mackenzie Delta, on ice-breakup of the lower Mackenzie River and on hydrologic processes affecting highway and pipeline construction. More emphasis is being placed on studying ice jam dynamics and ice jam floods because of the many Canadian rivers that are subject to their effects.

In the field of ground water, the increasing importance of contaminant related problems has led to increased emphasis being placed on two areas; the migration of toxic materials away from toxic waste disposal sites and the influence of ground water in ameliorating the impacts of acid rain on water bodies. Other important activities include a continuing major investigation of the hydrogeologic aspects of deep disposal of nuclear wastes in the Canadian Shield and a preliminary study of the impacts of land drainage practices on streamflow. The Institute is also responding to steadily increasing demands for hydrogeological input to environmental assessments and clean-up projects such as uranium mine tailings developments, gas pipeline developments, chemical spills, etc.

Snow and Ice studies continued in various areas. A core was obtained from Mt. Logan and analysis commenced to obtain proxy climate data. Snow hydrology experiments continued, with emphasis placed on a study of snow metamorphism. Mechanical tests on frozen sand, clay, and permafrost have been started with a view to obtaining data on the amount of unfrozen water present in frozen ground. Electrical measurements and structural calculations on ice were continued in an effort to see if it would be possible to discriminate between frozen ground and gas-bearing clathrates by some remote method.

The National Water Research Institute (NWRI) is conducting a number of research activities in hydrology. Theoretical and experimental calibration curves were produced for the Tipping-Bucket Rain Gauge Study in which recorded intensities were found to underestimate the actual ones by as much as 10%. The ILLUDAS model, which was originally developed for mainframe computers, was modified for implementation on a desk-top computer and verified in an urban test catchment. An exploratory study of persistent toxic substances in urban runoff was carried out in several Ontario cities. Significant concentrations of heavy metals, organochlorine pesticides, polychlorinated biphenyls, and polyaromatic hydrocarbons were found. Effects of urbanization on water resources in the Waterford River basin are investigated through a cooperative effort involving Newfoundland Environment, the Inland Waters Directorate, Atlantic Region, and NWRI. Urban runoff quantity and quality are monitored in two urban test catchments with commercial and industrial land use. Observed data will be supplemented with data obtained earlier for residential areas. The variation of rainwater quality during storms is monitored in the field using a newly-developed sampler. The results will be used for the modelling of urban runoff quality. A numerical simulation model of groundwater flow through an anisotropic unconfined aquifer has been developed and published. The results are being applied to the Port Granby radioactive waste disposal test site. Ancillary field work is also in progress.

3. Provincial

(a) Alberta

Alberta Research Council is studying river ice hydraulics on a continuing basis. In particular, river ice processes, such as ice jams and frazil generation and aufeis are being examined for their hydraulic implications. Long term hydraulic and geomorphic processes of Alberta rivers are subject to documentation and analysis at about 100 sites in the province as is research into improvement of analytical methods for predicting the effect of flooding on channel formation near engineering works.

Two projects are active in sediment transport: RMD 80-73 (Hydrology and Sediment Yield of the Muskey River Basin) and RMD 81-22 (Laboratory and Field Investigation of Gravel, Braided Stream Morphology). In addition, project RMD 80-34 (Scour and Transport of Coarse River Bed Material) is in publication. The planned outcome from these three projects is a state of the art sediment transport model suitable for use in both steep, gravel bedded streams and in the variable fine and coarse grained bed found in the Athabasca deposit.

A satisfactory hydrodynamic flow model has been constructed for the outlet channels from Lake Athabasca by Alberta Environment. It is driven by water surface elevations taken from the Crackingstone Point gauge on Lake Athabasca. Because of the complexity of the Athabasca Delta, no satisfactory model has been derived for the relationship between the gauge of Embarras Airport and the elevation of Lake Athabasca. Further, little has been published on the nature of currents in the western basin of Lake Athabasca and on the nature of mixing between shield derived waters in the eastern basin and plains water in the western basin. These issues are being addressed by project RMD 81-23 (Modelling the

Circulation and Sediment Distribution in the Athabasca Delta Region). When the mechanics of Lake Athabasca are better understood, it would be useful to attempt a model of the distributary channels downstream from Embarras Airport to the mouths of the channels. University of Alberta has carried out a theoretical analysis of the fluid mechanics of the distributary channels using plane jet theory that looks promising. If that system can be modelled quantitatively, then a distributary channel model would represent its input function. The next logical step would be a model of the mainstem between McMurray and Embarras Airport. Some preliminary work on the mixing characteristics of this reach was carried out for AOSERP (Mixing Characteristics of the Athabasca River Below Fort McMurray - Winter Conditions, Report #40, 1979), (Regional Analysis of Low Flows: A Cold Region Example, in preparation). The current work by Hudson (project RMD 81-22) would complement this work.

In 1981 Alberta Environment installed 5 Handar GOES DCPs. Minor problems occurred with one platform to date. Currently, 8 Handar DCPs are operating successfully in the field and no problems have occurred with any one of these platforms since they were installed. An additional 22 Bristol DCPs are on order to be delivered before March 31, 1982. Installation will commence in the spring of 1982. Assuming the network proceeds as planned, Alberta Environment will have approximately 40 DCPs operating by the fall of 1984. These installations are part of the real-time data gathering network which was designed by the Alberta River Forecast Centre, with flood forecasting and water management as the main consideration.

The Alberta Research Council has been contracted to design and implement the systems required to transmit digital weather radar (precipitation) data from Penhold to Edmonton, and display the data in several useful formats in the offices of the River Forecast Centre. This project will take three years to complete and the systems will be fully operational by the spring of 1984.

Alberta Environment completed arrays of monthly flow estimates for 60 hydrometric stations in the Battle River and South Saskatchewan Basins for the historical period 1912-1978 and published arrays of monthly lake evaporation estimates for 23 climate sites.

Alberta Environment completed the near total coverage of all urban flood plains in Alberta by maps showing areas subject to flooding at 1% frequency of occurrence.

(b) British Columbia

The Ministry of Environment is conducting a peak flow regionalization study in which peak flow frequency analyses are carried out for all gauged streams in the province with suitable data. On the basis of hydrologic zones, regional graphs and maps are derived relating unit peak flows for a range of return periods to appropriate physiographic and climatic factors. Analysis of related variables such as date of occurrence and ratio of instantaneous to daily peak flow is also carried out. The results are used to provide estimates of return period peak (or flood) flows for the design of culverts, bridges, spillways and floodplain protection works. The data base is updated annually and new estimating methods are continuously being developed.

The Ministry of Environment is also involved in a study of the land-use impact on community watersheds. Increasing pressure for development (especially timber harvesting) in small watersheds used for community water supply has prompted a program of monitoring and analysing a range of biophysical and hydrologic parameters in selected watersheds. An attempt is made to predict impacts of land use change on water quantity and quality. On the basis of this assessment, limitations on the extent of development are prescribed to minimize detrimental impacts.

At the University of British Columbia, the Department of Bio-Resource Engineering is studying (i) the effects of subsurface drainage and/or subirrigation on ground movement beneath agricultural lands, and (ii) the water balance in agricultural fields.

In the Faculty of Forestry, effects of clearcutting and slashburning on watershed nutrient budgets and on nutrients in streams are studied on four gauged watersheds at the UBC Research Forest: one watershed is scheduled for clear cutting in 1982. Effects of

herbicide application on nutrient movement into streams is also being studied. Study of effects of logging continues on the Jamieson Creek Experimental Watershed (Greater Vancouver Water District Reserve), road construction and logging having begun in 1980. Study of water repellency in soils after slashburning has been completed and a study of snowmelt during rain-on-snow events has been initiated.

In the Geography Department field investigation is under way of the relations among precipitation, ground water level and movement in large scale earthflows composed of overconsolidated, low sensitivity materials. A study of the hydrometeorology of a suburban area includes measurements of evapotranspiration and evaluation of the surface water budget. At Miller Creek Representative Basin (Pacific Range of the Coast Mountains) variable runoff, solute and sediment sources are being examined. Natural hydrophobicity of the soil has been identified as an important factor in runoff generation; atmosphere, soil and groundwater are distinctive solute sources in this alpine environment; surface wash is a significant source of clastic sediment.

In the Department of Geological Sciences, studies include (i) the role of groundwater flow in the genesis of stratabound ore deposits; (ii) multiple seepage faces on heterogeneous slopes; (iii) worth of data in rainfall-runoff modelling; (iv) stochastic modelling of mass transport in groundwater systems; (v) design of monitoring networks for predicting groundwater contamination; and (vi) interpretation of geothermal gradients in regions of active groundwater flow.

In UBC Department of Soil Science, research continues in the Courtenay-Campbell River area (Vancouver Island) on hydrometeorological processes on thinned and unthinned Douglas-fir stands, emphasis being placed upon the role of understorey vegetation in the water balance. A water balance model, developed for these stands, is currently being tested. The mechanism of streamflow generation on mountain slopes is being investigated in a West Coast watershed. Research continues on the hydrologic behaviour of agricultural lowland soils, emphasis being given to the mechanism of ponding on the organic soils of the Nicomekl- Serpentine area.

At Simon Fraser University, two studies assessing the hydrological impact of urbanization have been completed: one utilized Greater Vancouver Regional District streamflow data; the other, three specially instrumented watersheds. A small on-campus watershed (1500 m^2) on dedicated land is under development for experimental work. A recently completed study examined streamflow production of Douglas Fir in relation to crown volume and canopy architecture.

At the University of Victoria, the Department of Chemistry is studying water purification by osmosis through artificial membranes; electrochemical removal of heavy metals from water; and the generation of electrical power by reverse electrolysis at freshwater/salt water interface. The Department of Geography is studying the possibilities for leachate treatment as an application of the second topic.

(c) Manitoba

On March 31, 1981 an Agreement Respecting Flood Forecasting was signed by the governments of Canada and Manitoba. This Agreement is subsidiary to the General Agreement of Flood Damage Reduction (FDR) signed by these two parties on December 20, 1976. The Sub-Agreement will result in a five year study designed to improve the flood forecasting procedures on the Red, Assiniboine and Souris Rivers. The first phase of the study will consist of a Pilot Project on the Boyne River, a tributary of the Red River, to select or design a suitable deterministic runoff model.

A Technical Sub-Committee has been established to direct technical aspects of the Study and to carry on liaison with the Steering Committee. Installation of real-time data systems will be a significant aspect of this project.

Concurrently with the study Manitoba is continuing to develop and improve forecasting procedures for various other locations in the province including the Churchill River System.

The Domain Drain and the adjacent Mannes Drain watersheds have been instrumented with seven standard rain gauges, a recording rain gauge and two stream gauges. The objective is to determine the effects of drainage installation and land use on the runoff regime. The intention is to make changes in one watershed while leaving the other intact to act as a statistical "control". Data have been collected since June, 1981.

Research continued in the Wilson Creek Experimental Watershed with the collection of new hydrologic data, analysis of previously collected data, and, the monitoring of a series of energy dissipating rock-filled weirs.

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 are being planned for aquifers within the Red River Valley southwest of Winnipeg.

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 "blow outs" in the bottom of drainage channels has been put in place and appears to be functioning effectively in the Ross Creek Drain just north of Winnipeg.

(d) New Brunswick

A major concern of the New Brunswick Environment has been to find mechanisms for protecting the Government's recent investments in public water supplies to ensure that they are properly granted and maintained. The fourth Regional Resource Evaluation Report was completed on the Fredericton area and the fifth is drafted with two remaining. The SSARR Flood forecasting model is well established and attention is being directed to the snow course network and to the possible provision of year round flow forecasting for the Power Commission. An ad hoc Committee on Ice has been actively looking at ice jam prediction problems and the problem of providing flash flood warnings is being considered. The Flood Risk Mapping Agreement has been extended and maps are nearly completed for Sussex and the remaining area near Fredericton. In another context the Department is exploring methods of bringing about "creative sentencing" where the courts may be enabled to ensure that damages done to the water resource will be made good or alternative supplies found for those affected at the expense of the defendant.

The University of New Brunswick, Faculty of Forestry is directing the hydrological aspects of the Nashwaak Experimental Watershed Project. The main contributions are related to the distribution of snowcover over the basin and the evaluation of the change in response of a small basin to clearcutting.

The Department of Civil Engineering has directed a field study related to flow under ice on a reach of the Nashwaak River; is directing a laboratory study of resistance to flow in a partially covered channel; is directing a field and laboratory study of flow in natural channel bends; and is directing a study to estimate the relative contribution of suspended sediment from the banks of channels and from the land (sheet, rill and gully erosion).

(e) Newfoundland

Memorial University of Newfoundland is involved in the following research studies: C-CORE (Centre for Cold Ocean Research) continues with instrumentation in ice research; the pathways of pesticides, used in forestry for the control of spruce budworm, through water and soils is under investigation; a study of mass balance and terminal dynamics of cirque glaciers in Northern Labrador is underway; in conjunction with Newfoundland and Labrador Hydro, studies are being undertaken toward the economic scheduling of integrated hydro and thermal power generation; limnology studies of large deep lakes in Newfoundland have been initiated; offshore tide gauging is underway at four stations; biological research in two sea bays continues; a water quality balance has been completed for a small catchment stream near St. John's; studies of the pollution of coastal and deep sea water by crude oil and its derivatives are being undertaken; in conjunction with Provincial Departments, the effect of a peak mining operation on the local environment (water flow,

quality, wildlife, vegetation) is being assessed; the run-off response from an area including a peat bog has been measured; site work will commence soon for the NRCC (Arctic Vessel and Marine Research Institute) on land adjacent to M.U.N. Engineering Building; and offshore investigations into atmospheric conditions (fog, weather, etc.) and into iceberg movement and behaviour continue.

(f) Nova Scotia

A Storm Water Quality and Quantity Research program was organized at the Technical University of Nova Scotia in mid-1980: to form a focus for research in departments of Civil and Agricultural Engineering; to identify an area of research activity that the university is prepared to encourage and support; and to establish and maintain communication with representatives of all three government levels and the private sector, through an Advisory Panel, to identify research needs and potential sources of support.

With the support of the Tech Research Program, the Provincial Department of Environment, and the County of Halifax, a Workshop was held in March 1981 to solicit opinions from engineers and municipal officials across the province on Storm Water Policies and Criteria, prepared for the County, that will provide a model for other municipalities.

Current research at the Technical University of Nova Scotia includes: urban surface water quality and quantity - emphasis on sources and processes; field experiments expected to improve model algorithms; rural runoff-process of nutrient runoff from animal manured surfaces; arsenic in ground water - in cooperation with NSDOH; acid rain - in cooperation with NSDOE; rain water cistern systems; and lake response to urbanization effects - construction and nutrients.

(g) Ontario

Within the Ministry of the Environment a number of established areas of programs have been continued. There have been basin management studies for the Stratford-Avon area, Thames, Rideau, South Nation and the Grand watersheds. A Drainage Basin Inventory has been conducted for the Holland-Black watershed and a report is in preparation. The inventory on the Credit watershed is in the data collection phase.

The Ministry is also involved in studies on urban drainage, storm drainage and remedial measures for rural areas for erosion and sedimentation control.

With the present emphasis on atmospheric pollutants, a great effort has been put into acid rain studies and lake studies to determine the effects of changes in pH. Also, there is involvement in the Toronto region waterfront plan which includes the quantity and quality of river inflows as well as an industrially polluted Keating Channel.

At the Ministry of Natural Resources a number of programs have been continued and some new ones initiated. Within flood protection, a new province-wide flood plain policy defines the level of protection. A mechanism for co-ordination is now being developed for land use planning in flood plains. In order to standardize the methodology of flood frequency analysis, studies have been carried out that have narrowed the models to either the three parameter log normal, or log Pearson type III. The previously used model, Gumbel, has been rejected because it is a special case of the other two. Also, a study has just been completed of the regional analysis of skewness. The principal problem here has been the lack of sufficiently long records for analysis.

In the field of Streamflow Forecasting, a contractor has been working to develop a real time forecasting system based on the NWSRFS model. The contractor is to supply development software and lease the mini-computer system. Principal new features of the system are the manipulation of digital precipitation radar data to obtain accumulation from intensities and the use of mean basin precipitation from the radar data as input to the model. There have been ten DCPs installed in remote areas for data collection purposes.

In the area of the Great Lakes coastal zone management, a guide has been prepared with the intention of aiding land use planning, coastal engineering, environmental and economic components in a comprehensive shore management plan.

In the area of model development, a watershed model calibration study has been initiated. Also, work has been done on the development of a fast HEC-2 processor and studies have commenced on an ice jam management program.

Under the Federal/Provincial program for flood damage reduction, $1.44 million was spent on 19 jurisdictions in 1980/81.

A number of ministries of the Ontario government have also been involved in programs such as erosion and sedimentation control.

Research in hydrology and water resources at Queen's University is ongoing in four distinct areas: experimental studies to determine the effect of an ice cover on open-water head-discharge relations for various types of structures; field studies on the mechanics of ice jams on large rivers; experimental and theoretical studies on the stochastic aspects of sediment transport; and hydrologic modelling of streamflow including the development of a stochastic/deterministic method for real-time streamflow forecasting and the development and calibration of a deterministic model for simulating the outflow from tile-drained agricultural fields.

(h) Saskatchewan

Saskatchewan Environment and Environment Canada jointly commissioned a study of the channel degradation downstream of Gardiner Dam in 1979-80. The results of that study led to Saskatchewan Environment commissioning a supplementary study of the impact of degradation on the Gardiner Dam spillway. This study placed emphasis on potential erosion problems and on hydraulic performance during major flood events. The study indicated that although erosion during major floods will be very large, the high flow tailwater will not be lowered sufficiently to endanger the project.

The Water Pollution Control Branch, Saskatchewan Environment, is planning to investigate the water quality of the North Saskatchewan River in Saskatchewan as part of the 1981 summer program. Because the North Saskatchewan River is a major water supply and an important effluent disposal system, the Branch is interested in describing more fully the baseline conditions, the types of effluents entering the system and their effects on the river.

A Regina-Moose Jaw Water Supply Study consists of a long-term (to the year 2030) two-phase assessment of the water supply needs for the cities of Regina and Moose Jaw and for the surrounding region. The first phase of work, costing some $75,000, extended throughout 1981 and consisted of the compilation of existing information, the identification and evaluation of a range of alternatives and the selection of preferred systems. Some new water quality information was generated during 1981. Phase two of the work will extend to 1983 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.

Commissioning of an Acid Rain Study, jointly by Saskatchewan and Alberta Environment Departments and Environment Canada, occurred in early July, 1980, for the purpose of determining the potential effects of acid rain in northern Saskatchewan and in northeastern Alberta. Later, the study area was expanded to include the four western provinces.

The work is being done by the Saskatchewan Research Council (SRC) according to the following terms of reference:

(i) Review and summarize existing studies of air quality and ecosystem effects.

(ii) Provide an inventory of industrial atmospheric emissions and an estimate of future emissions.

(iii) Identify areas where the aquatic environment, soils or vegetation may be susceptible to acid rain or snow.

(iv) Recommend further studies that will help identify potential impacts on water, soil, fish and wildlife.

(v) Recommend a monitoring system that will help show changes in precipitation chemistry, air quality and ecosystems.

The report by SRC was due in 1981. Preliminary reports indicate that acid rain is not a problem yet.

The expanded Technical Committee is currently assigning priorities to monitoring and research projects for the year in relation to: precipitation event sampling network; snow surveys; dry deposition monitoring network; water quality and fish sensitivity map; soils and geological sensitivity map; and atmospheric modelling of SO_2 emissions to determine acid rain impacts.

A three-year federal-provincial interim subsidiary agreement on water has been in effect for about two years and the implementation of programs is progressing satisfactorily. Under the Agreement, work has been divided into three sectors.

Sector A - involves Drought Proofing Studies to evaluate the impacts of droughts on the Saskatchewan economy and to develop long-term strategies to alleviate the impacts of drought. Work is well under way and contractual arrangements have been finalized for a good portion of the work. The studies are estimated to take 42 months to complete. Also, under Sector A, there is a Water Management Investigations Program to investigate and evaluate ground water resources in the province. Three projects are under way and scheduled for completion this fiscal year.

Sector B - is a water supply program for the investigation, evaluation, design and construction of community water supply projects. Implementation to date has included three water supply projects. Three more projects are to be implemented.

Sector C - is a flood damage reduction component involving a number of programs aimed at alleviating and protecting both urban and rural areas from flooding in the Souris River basin. This program is a result of recommendations that were put forward in the Souris River Basin Study Report. Progress to date has been limited to the design of programs and works.

The Drainage Control Act, proclaimed on January 1, 1981, prohibits the construction or use of drainage works by any person unless a permit has first been obtained. The issue of a permit will be considered after a review is made of the proposed drainage works to assess impacts they may have on the watershed. The Act also provides powers to deal with drainage and flooding problems related to drainage works, including ordering works to be closed or altered. Steps are under way to appoint a Drainage Appeal Board which will hear appeals against decisions and orders made pursuant to the Act. The Act enables the Minister to establish watershed areas and appoint a local Watershed Commission in each area to carry out some of the responsibilities and powers under the Act, including issuing drainage permits and dealing with drainage complaints and disputes. Until Commissions are put in place during the next several years, Saskatchewan Environment will administer the Act.

Regulations under the Act are being prepared for consideration by the government. In addition to prescribing forms and procedures, the regulations will exclude certain classes of drainage works from the requirement to obtain a permit.

The new Environmental Assessment Act in Saskatchewan ensures that proposals for developments in the province which could cause adverse environmental, social and economic impacts undergo an environmental assessment. The administration of the Act is the responsibility of the Environmental Assessment Secretariat of Saskatchewan Environment. The Act applies to both public and private developers and requires that the cost and responsibility for preparing and submitting an Environmental Impact Statement (EIS) be

borne by the proponent. Proponents are encouraged to obtain public input both before and during the preparation of an EIS.

The Department of Northern Saskatchewan (DNS) is proposing to construct a concrete weir across the Bigstone Cutoff of the Saskatchewan River at Cumberland House. The effect of this weir will be to raise the level of water in Cumberland Lake. Several alternative weir elevations are being considered, which will result in average lake level increases ranging from 0.3 to 1.2 m. Construction is scheduled to start in about 18 months. This will require satisfaction of environmental, water rights, budgetary and PPWB requirements in the interim.

Saskatchewan Power Corporation plans to construct a hydro power generating facility, with an ultimate generating capacity of 252 MW, on the Saskatchewan River some 4 km upstream of the Town of Nipawin. The reservoir full supply level will be at the elevation of 348 m. Construction should be completed by 1986.

X MINING GEOPHYSICS

Compiled by: Norman R. Paterson

1. Introduction

Returns from 25 organizations show a further increase in mining geophysics research activity in 1981. As requested, a number of organizations provided figures for staff employed and dollar expenditures.

In industry, companies report about 110 scientists/engineers involved full or part time in R&D. Expenditure is estimated at approximately $4.0 million. More than one half the total staff and expenditure stems from activities at Scintrex Limited and McPhar Geophysics, both of Toronto.

Incomplete returns and difficulties of identifying "mining geophysics" research complicate the problem of estimating staff and expenditure in the government sector. The GSC, however, reports 15 scientist-years and $757,000 of activity.

The bulk of the activity in the university sector is at IREM-MERI/Ecole Polytechnique, Montreal, where an in-house staff of 18 and a total expenditure of $1 million is reported. This includes sub-contracts. Probably a total of about 50 staff and graduate students are involved in mining geophysics research at universities.

As in the case of 1980, the main emphasis in industry appears to be toward the development of more sophisticated field data processing and interactive interpretation hardware and software. Nine companies report activity in this area and the compiler knows of others who failed to send in reports. The effective handling of large quantities of multi-channel data is becoming a problem of considerable proportions. The problem will increase in severity as still more sophisticated instruments make their appearance in the next few years.

Increased activity in borehole measurements and interpretation techniques is seen in all three sectors. This stems from two requirements:

(1) the desire to explore to greater depths;
(2) a need for better in-situ physical property measurements in order to interpret surface and airborne geophysical data.

As in previous years the shortage of scientific manpower for R&D is to be the limiting factor rather than funding. Over the past three years the Federal government has funnelled an average of about $1.5 million per year into industrial research for mining geophysics. In 1981 the Ontario government initiated its Exploration Technology Development Fund (ETDF) with an annual budget of up to $1 million. All funding agencies report a shortage of worthwhile applications and the creation of new funding programs to try to stimulate additional R&D.

It is the compiler's personal view that an expenditure of $4.0 million by the private sector constitutes a remarkably high proportion of total earnings which probably do not exceed $28 million. A degree of saturation may be taking place.

INDUSTRY

2. Phoenix Geophysics Limited, Toronto

The company continued research on some fundamental aspects of multi-frequency IP. William H. Pelton improved the EM coupling removal software, including the modelling of negative EM coupling, which occurs over buried conductors. The coupling data is now interpretable in terms of the conductivity structure so that multi-frequency surveys can produce information similar to that derived from EM surveys. IP spectra can be broken down into contributions from different grain sizes with the use of combinations of multiple Cole-Cole dispersions. This development allows more accurate dilution corrections to be made in the presence of responsive host rocks.

J.D. Klein conducted electrochemical studies using rotating disk electrodes in order to investigate the mechanism of the IP response. Laboratory studies have led to procedures for correcting data obtained with chip samples to obtain estimates of the whole-rock response.

The company also undertook an evaluation of the application of multi-frequency IP to hydrocarbon exploration. This research is being sponsored on a proprietary basis by a number of Canadian and U.S. oil companies. The program consists mainly of field studies over a number of oil and gas fields using a newly developed 100 Kw transmitter. The field results will be supplemented with geochemical studies to prove, or disprove, the hypothesis that microseepage occurs above the hydrocarbons.

Publications consisted of Case Histories I, II and III for the IPV-3 multi-frequency IP receiver.

3. Scintrex Limited, Toronto

The company continued an active research program involving a staff of 45 and a budget of $1,600,000.

Areas of activity included: IP, EM (airborne, ground and borehole), proton magnetometers, borehole loggers, radiometric sensors, and analytical instruments such as atomic absorption spectrometers, fluorescence analysers and laser-induced fluorescence.

Some completed research projects are mentioned in the February 1982 CMJ article by P.J. Hood.

4. EG & G Exploranium/Geometrics

The parent company EG & G Geometrics, of Palo Alto, California, reported continued work on high resolution magnetometer development and applications. The Geometrics group has an R&D budget of between $1 and $1.5 million and a research staff of 10.

No R&D is reported by the Canadian affiliate.

5. Sander Geophysics Limited, Ottawa

The company conducted research directed toward the optimization of inertial navigation methods in both fixed-wing aircraft and helicopters. In particular, methods were developed to correct for cross-track drift.

The stability of spectrometer crystals under varying field conditions was investigated and feedback methods were developed utilizing LED's as a light source. It was necessary to find very stable light sources to make the method work successfully.

Progress was made in improving the reliability of cassette recording of geophysical data. A new recording system is under design incorporating a microprocessor for memory and calculating purposes.

Basic research is underway on a new high resolution magnetometer with very fast reading capability. This project is supported by an NRC grant.

The annual R&D budget of the company is approximately $200,000 and a staff of 4 scientists and several technicians is employed.

6. Kenting Earth Sciences Limited, Ottawa

The company completed the development of the KDSS-5 airborne digital data acquisition system.

The development of an airborne magnetic gradiometer was initiated in 1981 under a program sponsored by the Ontario Ministry of Natural Resources and DREE. During the year a twin-boom platform, with the lower boom retractable, was designed and tested. Work is continuing on the design and installation of sensors and a compensation system, with completion scheduled in 1982.

The company continued to develop improved methods of multisensor data processing and presentation.

7. Geoterrex Limited, Ottawa

The company continued to participate with Barringer Research and Elf Aquitaine in the development of the COTRAN airborne EM system. Work included airborne testing, improved bird and coil design and real time processing. Research continued in the development of post-time processing. Principal investigators were Bernard Kremer, Grant Mervyn and Don Wagg. Research was conducted in the interpretation of 3-frequency, 2-coil helicopter EM data, using layered earth, dyke and sphere models. This work was conducted by Mike O'Connel and Kevin O'Neill. Ground geophysical test surveys were conducted at the company's test site at Calabogie and at Hawkesbury for the purpose of improving interpretation techniques. Programs are being developed for the Lamontagne computer to process, plot and interpret data acquired by the Geonics EM-37 TEM system. New gravity data processing and interpretation software is being developed.

Approximately 12 scientists were involved in R&D throughout 1981 and the company spent about $400,000 on research related activities.

8. Barringer Research Limited, Toronto

Work continued on the COTRAN airborne EM system in conjunction with Geoterrex Limited and Elf Aquitaine (see Geoterrex above). The system has produced measurements of the step function responses of the ground and these results are presently being evaluated to assess the system's capability to determine subsurface conductivity structures.

The company introduced an additional product line in 1981, comprising the Hand Held Ratioing Radiometer (HHRR). This is an electro-optical device, designed for measuring the reflectance ratios of pairs of wavelengths (filters) in the visible and infra-red region, from 0.4 to 2.5 micrometers. The method is seen to have application in identifying clay minerals and vegetation stress for mapping and for following-up targets of interest selected from satellite imagery.

In conjunction with the work on reflectance, the company has been working on a complementary ratioing radiometer. The Field Reflectance Spectrometer measures the spectral reflectance characteristics of surface soils and vegetation. Through signal processing, this information provides a continuous digital readout of the target reflectance to solar radiation.

The company employed 5 full-time personnel and spent approximately $280,000 on unfunded R&D during 1982.

9. alphaNUCLEAR Company, Toronto

Under a contract from CANMET, Mining Research Laboratories, Elliot Lake, the company is developing a "Quasi Continuous Radon Daughter/Thoron Daughter Monitor" to analyse the radioactive content of air in uranium areas.

Work has also started under a contract from the Ontario Geological Survey to develop a field portable measuring system to determine low concentrations of helium in soil, gas and ground water.

The company also introduced the alphaCARD system for determining radium levels in soil. The system uses methodology developed by K. Bell and J.W. Card of Carleton University under an Ontario Ministry of Natural Resources OGRF grant.

10. Questor Surveys Limited, Toronto

The company developed and installed a high power INPUT transmitting system on one of its DC-3 aircraft. A large loop of novel design allows the transmission of a 2ms pulse at double the previous power, resulting in considerable data quality improvement.

Work continued on the airborne magnetic gradiometer system, including test flying of a twin boom installation on one of the company's Trislanders. This testing was supported by the Ontario Ministry of Natural Resources and DREE.

Work also continued on the development of a helicopter version of the INPUT system.

Research continued into the interpretation of INPUT data in areas of conductive overburden. Under the direction of Alex Becker, this work is being carried out in collaboration with the University of California, Berkeley.

Questor's R&D is under the overall direction of Peter Lazenby; instrumentation development was conducted by H. Jantsch and D. Leggatt.

11. Huntec ('70) Limited, Toronto

Most of the company's R&D was in the area of marine geophysics, and has been reported on in the Oceanography chapter.

Research in mining geophysics was directed primarily at IP product development. Work also commenced on the development of software for GeoDataBase, a field computer to be used for data reduction and interpretation of IP, EM, gravity and magnetic surveys.

12. Paterson, Grant and Watson Limited, Toronto

The company initiated a program to enlarge its software library in all areas of geophysical data processing and interpretation for mineral exploration. The work was supported by an ETDF grant from the Ontario Ministry of Natural Resources.

Efforts during 1981 concentrated on the development of specialised software for interpreting airborne magnetic gradiometer data. This included the development and testing of an inverse magnetic modelling technique for 1-D, 2-D and 3-D models, as well as research toward the direct calculation of apparent ground susceptibilities from gridded airborne gradiometer data.

In addition, the company developed and tested a variety of techniques for 1-D forward and inverse modelling of multi-frequency EM data.

13. Geonics Limited, Toronto

The company continued R&D in transient EM, concentrating in 1981 on the development of a microprocessor-controlled, large capacity data storage system (DAS-40) with cassette recorder for the EM-37 TEM ground EM system. Software programs were developed for field processing and interpretation, based on the HP85 micro-computer.

R&D was continued also in engineering and groundwater applications of ground EM.

14. Lamontagne Geophysics Limited, Toronto

R&D was commenced on a borehole TEM system with fibre-optic link, designed for depths up to 2 km. This system is expected to provide advantages in weight saving and noise suppression.

Work was continued in the development of software for use with the company's field computer. Emphasis has been given to interactive interpretation software and the graphical presentation of results.

15. Geotech Limited, Toronto

Work commenced on the development of a 4-frequency helicopter EM system operating in the frequency range 350-4500 Hz. This program is supported by the Ontario Ministry of Natural Resources ETDF program.

Parallel development work is underway on interpretation software for the proposed system.

16. Urtec Limited, Toronto

Under the leadership of Bob Pavlik, the engineering team developed additional software programs for the company's field data processing system. Additional software operational features were also added to the UG-180 Survey Combination System. The UM-260 airborne proton magnetometer also came under further development in the form of a stand-alone magnetometer unit. This magnetometer was originally developed as a front end to the UDAS-100 Integrated Survey System.

In addition, a software program was developed for automatic positioning and flight path recovery techniques using the new generation dopplers.

In 1981 Urtec spent close to $200,000 in further development of existing UDAS based instruments.

17. McPhar Geophysics, Toronto

R&D expenditures during 1981 totalled $487,000, involving six engineers, six technicians and two geophysicists.

A significant portion of the budget was directed to continued development of new tools for the computerized RD-600 logging system and a new, one-man operation, multi-parameter logging system called Portalog III which is coming on stream in early 1982.

A result of 1981 development work will be the introduction this year of the Rock Stress Monitor for underground mining operations. This is an all electronic system which measures signals emanating from rock under severe stress which normally procedes a roof fall or wall burst.

Work continued on an initially NRC sponsored program to produce an atlas of EM multi-layer response master curves of ellipse parameters. Also, the inverse program is currently under development.

Research work was initiated to investigate ways and means of transferring large scale digital signal processing from the "computer room" to the "field unit". The initial investigations relate to microprocessor techniques for real time processing of signals buried in noise.

Airborne system development continued in the form of miniaturization of on-board instrumentation and data acquisition systems.

GOVERNMENT

18. Resource Geophysics and Geochemistry Division, Geological Survey of Canada (A.V. Dyck, Q. Bristow, P.G. Killeen, R.L. Grasty, G.R. Bernius, K.L. Ford, B.W. Charbonneau, A.K. Sinha, P.B. Holman)

Work by this Division in Geomagnetism and Engineering Geophysics has been reported on in their respective chapters of the Bulletin.

The following summary covers activities in radiometric, seismic and electrical methods:

Borehole electromagnetic modelling studies were carried out and the results were published as a University of Toronto monograph (see list of publications).

A borehole x-ray fluorescence logging system developed at Karlsruhe Nuclear Research Institute, Germany, for direct determination of uranium was tested and evaluated in G.S.C. calibration models and test boreholes.

International intercalibration experiments were conducted with G.S.C. logging equipment, at Grand Junction, Colorado, and Adelaide, Australia. This work, done in collaboration with the South Australian Geological Survey confirmed discrepancies among the Canadian, U.S., and Australian calibration facilities.

The problem is basically related to calibration of laboratory gamma ray spectrometers. New primary standards have been developed for the laboratory in an effort to correct the discrepancies.

Three drill holes 120 m deep, and one hole 300 m deep, separated by distances of 10 m to 100 m, were drilled at the G.S.C. calibration facility in Bells Corners, to provide for testing of hole-to-hole logging techniques.

Field investigations of the possible application of borehole gamma ray spectrometry to gold exploration, based on redistribution of potassium and thorium, were carried out at Larder Lake. Several auriferous syenitic bodies were studied on the surface in an investigation of correlations between trace elements (Au, As, Sn, W) and the radioelements.

Under the Canada-Nova Scotia Mineral Development Agreement, airborne gamma ray spectrometer surveys were flown, with 1 km line spacing, over granitic areas to the northeast, and to the west of Halifax. Ground investigations of several Maritime granites showed interesting trends in uranium and thorium variations, and correlations with trace elements, particularly tin. A study of disequilibrium in the uranium decay series, based on crystalline rocks from five different areas of Canada, showed that individual samples may have significant excess or deficiency of uranium relative to its daughter products, but the average values of uranium and bismuth-214 are close to the equilibrium ratio.

In cooperation with Saskatchewan Mining Development Corp. and Canadian Occidental Petroleum Ltd., two deep sounding EM systems, Geonics EM-37 and Maxiprobe, were tested in the Athabasca basin for the detection of conductors associated with uranium mineralization. With the cooperation of Gulf Minerals Canada Ltd., a waterborne resistivity and induced polarization survey was conducted by Hardy Associates (1978) Ltd., on Wollaston Lake to test the method for mapping electrical and structural properties of the contact between the Athabasca formation and the underlying basement.

It is estimated by A.G. Darnley, Director of the Division, that the above activities involved 15 scientist years and 9 technician years, for a total expenditure of $575,000.

19. Geology/Geochemistry Section, Ontario Geological Survey, Ministry of Natural Resources

Multi-frequency horizontal loop and time domain EM equipment was used to investigate the physical characteristics of a test range established by the Section in the Timmins area.

A gravity interpretation program was initiated on existing survey data in the Cobalt Embayment-Grenville Front area, comprising 33,000 sq. km and a total of 10,879 gravity stations. Interpretation procedures consist of pattern recognition studies and computer modelling, using the results of 3,400 rock density measurements from the area.

Two airborne geophysical surveys were carried out totalling 13,691 line km of combined magnetic and EM data in the Sioux Lookout and Swayze areas. Four catalogues of theoretical responses and phasor diagrams were prepared to aid users of the geophysical data.

Section staff, together with Aerospace Engineering and Research Consultants Limited (AERCOL) carried out tests on two aircraft structurally modified to carry two vertically displaced high resolution magnetometer sensing heads. These systems were designed under a joint Ministry of Natural Resources/DREE program to develop a commercial airborne magnetic gradiometer system. Complete vibrational spectra of three separate sets of accelerometers in each aircraft were calculated and compared. Subsequently, a contract was awarded to Kenting Earth Sciences Limited, Ottawa, for the development of a magnetic gradiometer system.

UNIVERSITIES

20. Department of Earth Sciences, University of Manitoba

W. Moon developed a new potential field modelling method for calculating gravitational anomalies of simple 1-D, 2-D and 3-D models with continuously varying densities. P. Lui extended the technique to include magnetic models.

Derbew Messfin and W. Moon worked on the development of a seismic technique for Precambrian terrain. Seismic velocity data for typical Precambrian lithological units are being compiled and velocity measurements are being made on new samples. The study is aimed at improving techniques for exploration problems (both shallow and deep) under the prevailing conditions of very low impedance contrasts.

D.H. Hall, Head of the Department, estimates that there are 6 staff members doing work in mining geophysics, on an annual budget of not more than $10,000.

21. IREM-MERI/Ecole Polytechnique, Montreal

IREM-MERI reports continued activities in 2-channel MT/AMT, AFMAG and EMAS (dirigible-supported EM). The MT/AMT program consists of instrument development, field testing and computer simulation of 2-D and 3-D models. A portable, 2-channel hybrid computer receiver (MTCH) will measure in real time the amplitude ratio, phase shift, and coherence between two signals at audio and sub-audio frequencies. Design, development and testing was carried out by M. St-Amant. Financial support was provided by Energy, Mines and Resources, Canada. Logistic support was provided by URANERZ.

On a research contract with DSS, a drill hole AFMAG was developed and tested. The instrument measures the ratio, phase shift and coherence between the vertical and horizontal magnetic components at a frequency of 220 Hz. This work was also directed by M. St-Amant.

G. Arbour carried out preliminary studies and design of a system of EM surveying by dirigible or aerostat (EMAS).

Ecole Polytechnique reported field work by M. Chouteau with an earlier-designed MT Instrument.

Gravity interpretation was carried out in the Abitibi region under an NSERC grant by L. Laverdure.

There are now three professors and one research associate in the Applied Geophysics Group of Ecole Polytechnique. IREM-MERI reported a staff of more than 12 and a budget of about $1 million, of which some $112,000 was provided in grants to Ecole Polytechnique and McGill University. This budget includes geological and geostatistical work, in addition to geophysics.

22. Department of Geology and Geophysics, University of Calgary

K. Duckworth commenced development of an EM scale modelling system to simulate behaviour of continuous wave and transient methods over conductive environments. Digital acquisition and processing methods are employed, to a maximum frequency of 400 khz.

A laboratory study of the IP characteristics of lead-zinc ore at permafrost temperatures was completed. Significant increases of dimensionless chargability and of time constant were seen as temperature was lowered.

K. Duckworth is the only staff member active in mining geophysics; the annual budget is approximately $22,000.

23. Department of Geological Sciences, University of Saskatchewan

D. Gendzwill carried out research into the cause and nature of earthquakes at the Cory Potash Mine, west of Saskatoon. This involved a study of micro-earthquake activity, vertical seismic reflection studies, and laboratory tests on rock samples from a deep drill hole. Changes in stress distribution and static elastic moduli are being compared with ongoing mining activities.

Magnetometer, MT and magnetic rock property studies are being carried out with the help of a Varian cesium vapour magnetometer donated by Eldorado Nuclear.

Peter Kosteniuk, Z. Hajnal and K. Paulson designed, constructed and field-tested an 8-channel MT system incorporating a 16 bit mini-computer and 9 track magnetic tape recorder. The system was used on surveys near Cluff Lake and Bengough. Work is continuing on the development of additional software, including hard copy plot programs and filtering routines.

24. Department of Geophysics and Astronomy, University of British Columbia

W.F. Slawson, T. Watanabe and D.C. McCollor carried out an investigation into the possible use of power harmonic radiations as an EM prospecting source. Cooperation was provided by BC Hydro. Coherent signals were recorded up to 660 Hz. Signals were recorded up to 10 km from a 500 kv power line.

25. Department of Geophysics, University of Western Ontario

W.R. Ravenhurst and L. Mansinha studied borehole transient EM methods with emphasis on determining the limitations of and improving existing interpretation techniques.

S.M. MacRitchie and L. Mansinha studied results of Maxiprobe EMR 16 multifrequency EM surveys in order to determine resolution limits for various 3-layer earth models.

C.J. Mwenifumbo and L. Mansinha continued research on mise-a-la-masse responses for vein type bodies using scale modelling and field experiments.

C.M. Carmichael and D.L. Marcotte interpreted ground magnetometer survey data at the Granduc Mine, British Columbia.

G.S. Surveyer and H.C. Palmer interpreted INPUT survey data from Bateman Township, Ontario.

D.A. Wilkinson and L. Mansinha carried out interpretation studies on gravity data near New Liskeard, Ontario, under an OGRF grant from the Ontario Ministry of Natural Resources. Various filtering and modelling procedures were used to derive a geological interpretation.

26. Geophysics Laboratory, Department of Physics, University of Toronto

(a) Electrical Exploration - G.F. West and associates

A. Dyck has completed his Ph.D. thesis on the interpretation of down-hole electromagnetic data.

J. Macnae, currently an NSERC industrial fellow, continues his studies on EM interpretation methods in association with Lamontagne Geophysics.

S. Holladay, Ph.D. candidate, has examined the effect of steel well casings on surface electrical surveys over known petroleum deposits. A new, microprocessor-controlled EM system is being developed for sedimentary basin exploration (NSERC strategic).

P. Walker has completed his M.Sc. thesis on modelling plate like structures in layered media. He is presently developing the corresponding inverse problem (NSERC).

M. Bloore, research assistant in computer science, continues to improve the software library. Programmes PLATE and SPHERE are now available for general release (OGS & NSERC).

D. Boerner, M.Sc. student, is studying the IP response associated with hydrocarbon deposits from the viewpoint of a physical chemist (NSERC).

(b) Electrical Exploration - R.N. Edwards & Associates

D. Nobes and P. Wolfgram, Ph.D. candidates, are developing an electrical method, based on the MMR technique, for deep sea exploration (NSERC, Imperial Oil, DEMR, NSERC equipment).

E. Gomez-Trevino, post doctoral fellow, has conducted a number of geothermal surveys using the wide-band PRBS electromagnetic system (DEMR, NSERC). He has completed his Ph.D. thesis describing a major survey of the sedimentary basin of Southern Ontario with the same system (Imperial Oil, NSERC strategic).

D. Nobes and E. Gomez-Trevino carried out MMR ground surveys at the Meager Mountain geothermal resource (DEMR) and at Atikokan, Ontario under the AECL waste management programme (DEMR/AECL).

D. Pai has joined the group as a research associate. He is developing algorithms for the modelling of 2 1/2 dimensional electromagnetic problems (NSERC strategic).

D. Lo, M.Sc. candidate, is developing a down-hole MMR technique. Preliminary results have been obtained in conjunction with Newmont Exploration Ltd., Tucson (NSERC).

(c) Electrical Exploration - D.W. Strangway and associates

D. How and J.D. Redman continue their AMT field work. Surveys were completed for AECL at Chalk River, Pinawa and Atikokan (NSERC, AECL, Woodward-Clyde, DOE, DEMR).

J.D. Redman continued to develop a tensor AMT system with micro-processor control (NSERC).

(d) Airborne Geophysics

W.E.S. Urquhart, Brandfield Fellow (Noranda) and Ph.D. candidate, is applying advanced digital processing techniques to aeromagnetic data from the Mattagami area recently released by the Quebec Government.

F. Mayer and R. Bailey have completed a detailed study of the limitations of multichannel airborne radiometric data, using field data supplied by the GSC (DEMR).

27. McGill University - Applied Geophysics Laboratory (O.G. Jensen, E. Baranyi, P.T. LaFleche)

Geophysical Application of VHF-EM (very-high frequency electromagnetic) Waves and Fields

Ms. Baranyi and Dr. O.G. Jensen are currently evaluating a broad variety of appropriate physical models describing the essential electrical and magnetic parameters of geophysical materials. Theoretical descriptions of the derived geophysical measures of local EM wave impedance, apparent conductivity, rate of wave attenuation and induction losses, field decay, and backscattering are being determined for half-space structures comprising realistic conditions of electrical conductivity and permittivity, magnetic permeability and the electrochemically related induced polarizability.

For comparison with the theoretical material models, a substantial catalog of data obtained by numerous researchers about real geological materials is being compiled with a view to recognizing and separating the complex parameters of the material models which are important to geophysical measurements of electromagnetic fields and waves at very high frequencies. This background research is necessary to a logical extension of geophysical instrumentation and measurement of localized physical and structural properties of soils and rock masses.

Mr. Paul T. LaFleche and Dr. O.G. Jensen are exploring the feasibility of developing a geophysical VHF-EM instrument system which would employ a continuously-swept band of frequencies in the 1MHz - 1GHz range. A phased transmitter array is to be used to steer a narrow beam throughout the subsurface geology, while a single, portable phase-linked receiver will be used to detect and measure the complex amplitude of the reflected EM field at distance over the surface.

Processing methods analogous to those employed in vibroseis seismology and holography should then allow for the reconstruction of a geophysical model having a conductivity/permittivity structure representative of the sub-surface geology. It is expected that these methods will find application in mineral exploration in high resistivity, low permittivity-loss environments such as the Abitibi volcanic belt and in glaciology and hydrological surveying.

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XI ENGINEERING GEOPHYSICS

Compiled by: J. Hunter

1. Introduction

In recent years engineering geophysics has played an increasingly important role in geotechnical surveying on land and in the marine environment. Canadian companies offering such services are, in general, working to capacity. Major projects such as the A.E.C.L. RADWASTE program and offshore hydrocarbon development in the Arctic and elsewhere require specialized techniques which have stimulated research in the industry, government and university sectors. Several Canadian universities are now offering courses oriented towards engineering geophysics in their undergraduate programs.

2. Geo-Physi-Con Ltd.

Research into the application of the time-domain electromagnetic method is underway utilizing the Geonics EM-37 unit. The work is directed towards mapping structure of thick permafrost for static corrections of seismic records and for well site surveying. A recent survey conducted on the Alaskan north slope successfully mapped permafrost structure. Other applications include exploration for coal and mapping of structures in the oilsands.

3. Huntec ('70) Ltd.

(a) Huntec has commenced work on the Seabed 2 Project, a joint research and development effort involving several Federal Canadian government agencies, with Huntec as prime contractor. Dr. J.M. Ross joined Huntec during 1981 under the Executive Exchange Program, as Seabed 2 Project Manager.

The objectives of Seabed 2 are to continue the development of quantitative acoustic remote sensing technology, which began with the 1974-1981 Seabed Project. Seabed 2 will involve the development of new digital hardware and software for quantitative high-resolution sub-bottom profiling and side-scan-sonar mapping. This new equipment will be deployed in a towed body at towing depths to 2000 metres.

(b) Research is continuing at Huntec's Dartmouth facility, into computer processing of data collected by the Huntec Deep Towed Seismic (DTS) profiler system. Principal investigators D.J. Dodds and D.R. Parrott aim to develop new methods to extract quantitative information about seabed characteristics, from seismic signals received by the DTS.

Among the techniques presently being investigated are sonogram analysis and calculations of acoustic reflectivities. The success of the former in extracting attenuation, volume internal scattering, and surface scattering through model-fitting, is the subject of a paper to be presented at the 1982 Oceanology International Conference in Brighton, England.

(c) Huntec-Lapp Systems Limited has just completed a non-linear acoustics project funded by the Canadian Hydrographic Service. Most of this research was done by Huntec in cooperation with the University of Bath, England. The project's objective was to develop a confined parametric source suitable for through-the-ice bathymetric sounding. Tests conducted in acoustic tanks at Bath and Huntec, and in a cold room at the Canadian Centre for Inland Waters in Burlington, indicate that the technique has promise for high-resolution ice probing.

The number of full-time research staff at Huntec during 1981 was fourteen (14).

4. Nova Scotia Research Foundation Corporation

(a) The deep-tow high resolution seismic profiler has recently been in use in the Beaufort Sea and the East Coast as well as in European and South American waters. The deep-tow profiler operates on the principle of displaying the travel time of vertical incidence reflections and can be used with a variety of sparker acoustic sources so that the best compromise can be made between penetration and resolution for any particular survey site. With the present 600 metre cable, the profiler can be deployed within 40 metres of the seabed in water depths of up to 300 metres. In greater water depths, decoupling of sensors from ship motion and their remoteness from noise still give some advantage over ship-mounted or surface-tow devices to the extent that useful information has been obtained in water 1000 metres deep.

(b) The construction of a 12-channel array with tightly clustered hydrophone groups was carried out under contract for the Terrain Sciences division of the Geological Survey. This array was used in conjunction with both airgun and sparker sources to record multi-channel information on a Nimbus seismograph for subsequent analysis by both the refraction and the wide angle reflection techniques. This data processing and the interpretation of the resulting acoustic velocities in terms of ice-bonding in the seabed sediments is being carried out by the Geological Survey.

5. Paterson, Grant & Watson Ltd.

Research has been conducted into the application of high resolution seismic reflection methods to geological waste disposal problems (A.E.C.L. RADWASTE Program). The company acted as prime contractor on MINI-SOSIE surveys in 1980, followed by conventional high resolution surveys in 1981. The results of the MINI-SOSIE surveys were very marginal. The main limitation was the inability to operate the continuous sources under the prevailing field conditions, thereby requiring explosives which the MINI-SOSIE system is simply not suited for. Lack of dynamic range and limited recording options were the main problems. In 1981 an extremely careful field program was conducted using both buried charges and buried geophones and a highly structured field surveying program. The initial results seem to have justified the extra trouble and cost.

6. Piteau & Associates

Research is being initiated into the measurement of dielectric constants and radar attenuation in earth materials. This work will be oriented towards assessing the application of ground-looking radar in geotechnical investigations.

Research is also being initiated into the detection of underground cavities/workings with the electrical resistivity technique. The surveys will utilize the modified Bristow technique.

A number of seismic investigations were conducted in Canada in 1981 for the determination of bedrock depth, rock quality and rippabilities.

7. University of Waterloo

(a) Geophysical mapping of contaminant plumes from waste disposal sites

During 1981 David Slaine and John Greenhouse used electromagnetic resistivity devices to survey 8 southwestern Ontario landfill and industrial disposal sites, situated on a variety of geological and physical environments. The work has been carried out in

cooperation with the Ontario Ministry of the Environment (Dr. E. Rodrigues) and will form a suite of case histories which should allow the usefulness of geophysics in hydrogeological site investigations to be evaluated fairly.

(b) Statistical correlations of borehole core properties with geophysical logs in permafrost and glacial till

Electrical, neutron, density, gamma and caliper logs, digitally recorded in shallow holes, are being correlated against the (quantified) properties of continuous cores at or beside the logged hole. The objective is to determine to what degree geophysical logs can be used to derive core properties in these two heterogenous environments. The permafrost work (Fransham and Greenhouse, 1981) was quite successful at predicting densities and ice content in ten holes near Inuvik. The correlation program in glacial overburden can not yet be properly evaluated.

(c) Shallow seismic reflections

There is interest in developing the single channel Bison 1575B as a tool for stratigraphic mapping within till sheets. Efforts to date have been concentrated on developing software for display and processing, and on identifying reflections near cored boreholes.

8. Université Laval

During the summer season of 1981, Maurice K.-Seguin, Department of Geology and Program of Engineering Physics, M. Allard and G. Tremblay, Department of Geography, and three graduate students, René Mauffette, Christine Lebrun and Marie-Claire Belzile investigated the three-dimensional distribution of permafrost in the Manitounuk Strait on the eastern shore of Hudson Bay. The study included electrical resistivity soundings and geothermal measurements in varying physical and climatological environments. This study, which is almost complete, extended over a two year period. A model of discontinuous permafrost taking into account factors such as topography, snow cover, rock type, wind exposition, etc... has been constructed. This model will be useful for prediction of permafrost distribution in other similar environments. Two papers on the subject are now in preparation. A similar preliminary study for the region of Nastapoka is now under way.

9. Geological Survey of Canada, Electrical Methods Group

(a) Dr. A.K. Sinha of the Electrical Methods Group of the Terrain Geophysics Section carried out VLF surveys using US Navy VLF stations and a portable local loop VLF transmitter at the Atikokan Research area of the AECL Nuclear Fuel Waste Management Program. The local loop VLF transmitter has been designed and built at GSC to generate VLF fields with any desired azimuth. In areas like Atikokan in Northwestern Ontario and Lac du Bonnet in Manitoba, the azimuths of all Navy VLF stations are very close to each other. Since for the detection of all fractures in an area one requires at least two sources with their primary magnetic fields at right angles to each other, a local loop source is a necessity in such areas. Similar studies were also carried out at Lac du Bonnet, Manitoba. In both areas new fracture zones were detected which were not previously mapped using Navy stations.

A multifrequency ground electromagnetic system called Maxi-Probe was also used for mapping fracture zones at depth at Atikokan. The Maxi-Probe system was also tested to delineate a buried river valley near Copetown, Ontario. The results generally agree with known information from previous seismic surveys and geological information.

(b) Studies in radar have been carried on by Department of Electrical Engineering, Lakehead University, through an unsolicited proposal agreement under the direction of L.S. Collett. The investigations have been focused on crack detection in mines for safety purposes. Prof. Denis Roddy, who is in charge of the project, is also investigating improvements in antenna design and other features for fracture detection and sounding in general.

(c) Agriculture Canada has adopted the Time Domain Reflectometry (TDR) method for moisture measurements in soils. During the year they have contracted with an Ottawa electronics company, Foundation Electronic Instruments Inc., to build and market the TDR unit. This instrumentation has been a spin-off of work done by the group while investigating radar for engineering purposes.

10. Geological Survey of Canada, Rock Properties Group

In order to assess the concept of high level nuclear fuel waste disposal in deep igneous crystalline rock formations, information is required on the possible radionuclide transport paths through the rock mass and the effect that the vault performance will have on these paths. Pore structure of the crystalline rocks plays an important role in all aspects of radionuclide transport and the vault performance. In order to determine the pore structure of the crystalline rocks, various physical properties are being measured by Dr. T.J. Katsube, such as: hydraulic permeability, electrical resistivity, porosity, fracture flexibility and ion diffusivity.

11. Geological Survey of Canada, Bore Hole Methods Group

(a) Dr. A.V. Dyck has been investigating the application of the VLF EM technique in boreholes as part of the AECL RADWASTE Program. This technique, using a primary EM field from U.S. Navy transmitters, measures both electric and magnetic field components with a sensor coaxial with the drillhole. The downhole signal is compared to a surface reference both in amplitude and phase producing in-phase and quadrature responses displayed as a function of depth. So far, seven holes have been logged at the Chalk River test site and the technique has been shown to detect fracture zones intersected by the borehole. The technique appears capable of sorting fault zones by size and aspects of fault geometry.

(b) Standard geophysical logs were run in AECL holes at the WN and URL sites at Pinawa, Manitoba, under the direction of L.S. Collett. The standard logs run in the boreholes were SP, single point resistance, 16" and 32" normal resistivity, focused beam, natural gamma, gamma-gamma (density), neutron-neutron (porosity), caliper, acoustic and fluid conductivity. The work was carried out by Roke Oil Enterprises Ltd., Calgary, Alberta. Since the logs were recorded in analogue form, they were digitized which also included logs run prior to 1981. The scale of plotting the logs is 1:500 and can be displayed side by side for comparison between logs and interpretation.

12. Geological Survey of Canada, Seismic Methods Group

(a) Research on the properties of "tube-waves" generated in a borehole is being continued by C.F. Huang as part of the AECL RADWASTE Program. Tube waves are generated at the point of intersection of faults open to fluid flow with the borehole. The excitation energy is a compressional wave from a surface explosive source. The method appears to be an efficient way of rapidly identifying cracks with significant fracture permeability. The tube-wave amplitude and crack size relationships are currently under study.

(b) H.A. MacAulay is conducting a re-interpretation of the occurrence of sub-seabottom permafrost in the Beaufort Sea utilizing refraction seismic data. Oil industry seismic data is being computer processed to enhance first arrival refraction events. The completed reconnaissance map will be compiled from the interpretation of over 30,000 records. Funding for the project has been obtained from the National Energy Program.

(c) J.A. Hunter is conducting research on the application of the "optimum window" hammer seismic reflection technique. The technique utilizes a multichannel digital enhancement engineering seismograph and a low-cost microcomputer. Field tests have been successfully conducted in various regions of Canada to obtain high resolution reflection coverage of the bedrock surface in areas of thick unconsolidated overburden.

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GUIDELINES FOR THE EDITOR AND REPORTERS
CANADIAN GEOPHYSICAL BULLETIN

1. The Canadian Geophysical Bulletin is an annual report of geophysical research and development activities in industry, government and universities in Canada. Its main purpose is to inform geophysicists in Canada and abroad of current projects, developments and publications in their own and related areas. At the same time, it provides an overview for those outside the earth science disciplines of the extent and directions of scientific research activity in this subject in Canada.

2. The Bulletin shall be made up of a collection of chapters authored by reporters named by the editor, after consultation with the National Correspondents.

3. The Editor will review the Chapter titles on an annual basis to ensure that together they continue to cover the full range of geophysical activities in Canada. He will then set a maximum length for each chapter after consideration of the following:

   i. the total length of the Bulletin, cover to cover shall not exceed 200 pages;

   ii. the importance of the Chapter topic in both the national and international community;

   iii. the number and productivity of Canadian workers in the field.

4. Each chapter shall begin with an index, include a 1-page summary written by the appropriate correspondent or rapporteur, followed by a succinct account of current activities and conclude with a list of reports and papers that have appeared in print during the previous calendar year. Material in press or preparation will <u>not</u> be listed. Scientific publications in a recognized government series and appearing in the year under review may be included in the list of references. Theses accepted as part of a recognized graduate degree program during the period covered by the year under review should also be included in the list of references.

5. The accounts of current activities are listed in each chapter under headings for each reporting research group. Each of these items should include a brief statement of current activities. Lengthy statements of results obtained will not be allowed. The latter should be abbreviated to not more than two or three typewritten lines.

6. Copy-ready material will be prepared by the Earth Physics Branch of Energy, Mines & Resources Canada from clearly presented text supplied by the Editor not later than mid-February of the year following that covered by that issue of the Bulletin; this copy-ready material will be proofread by the Editor.

7. The Bulletin will be published by the Earth Physics Branch of Energy, Mines & Resources Canada in early Spring of the year following that which the material covers.

DIRECTIVES POUR LE RÉDACTEUR EN CHEF ET LES RAPPORTEURS
BULLETIN CANADIEN DE GÉOPHYSIQUE

1. Le Bulletin canadien de géophysique est un rapport annuel des activités de recherche et de développement géophysiques de l'industrie, du gouvernement et des universités au Canada. Son but principal est d'informer les géophysiciens au Canada et à l'étranger des recherches, des développements et des publications en cours dans leur propre domaine ou dans des domaines connexes. De plus, il fournit à ceux oeuvrant en dehors des disciplines des Sciences de la Terre une vue d'ensemble sur l'étendue et les directions de la recherche scientifique dans ce domaine au Canada.

2. Le Bulletin consistera en un ensemble de chapitres rédigés par des rapporteurs nommés par le rédacteur en chef après consultation avec les correspondants nationaux.

3. Le rédacteur en chef révisera les titres des chapitres sur une base annuelle afin de s'assurer que ceux-ci couvrent bien la totalité des activités géophysiques au Canada. Il fixera ensuite une longueur maximale pour chaque chapitre en tenant compte des considérations suivantes.

   i. la longueur totale du Bulletin ne doit pas excéder 200 pages d'une couverture à l'autre.

   ii. l'importance du contenu du chapitre tant sur le plan national que sur le plan international.

   iii. le nombre et la productivité des travailleurs canadiens dans ce domaine.

4. Chaque chapitre commencera par un index, suivi d'un résumé d'une page écrit par le correspondant ou le rapporteur approprié; résumé suivi des comptes-rendus concis des activités en cours. Le chapitre se terminera par une liste des rapports et des articles qui ont été publiés l'année précédente. Les publications sous-presse ou en préparation ne devront pas être mentionnées. Les publications scientifiques apparaissant au cours de l'année considérée dans une série reconnue du gouvernement pourront être incluses dans la liste de références. Celles acceptées pendant la période considérée comme partie d'un programme de diplôme reconnu pourront également être incluses.

5. Les comptes-rendus des activités en cours pour chaque chapitre seront accompagnés de titres se référant aux groupes de recherches rapporteurs. Chacune de ces rubriques devra inclure un bref paragraphe sur les activités en cours. Les longs exposés des résultats obtenus ne seront pas autorisés. Ceux-ci devront être abrégés afin de ne pas excéder une ou deux lignes dactylographiées.

6. Le matériel prêt à être reproduit sera préparé par la Direction de la physique du globe d'Energie, Mines et Ressources Canada à partir du texte clairement présenté fourni par le rédacteur en chef au plus tard à la mi-février de l'année suivant celle couverte par le volume du Bulletin. Ce matériel prêt à être reproduit sera corrigé par le rédacteur en Chef.

7. Le Bulletin sera publié par la Direction de la physique du globe d'Energie, Mines et Ressources Canada au début du printemps de l'année suivant celle couverte par le Bulletin.

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