THE UPPER MANTLE WORKSHOP

Summary of Proceedings

Camsell Hall, Ottawa — February 24, 25, 26, 1965

Sponsors: The Associate Committee on Geodesy and Geophysics of the National Research Council

The Department of Mines and Technical Surveys

Workshop Committee:

L. W. Morley - Chairman

A. S. MacLaren

C. H. Smith

K. Whitham

Arctic Section	-	Chairman	E. F. Roots
	-	Rapporteur	L. K. Law
Western Section	-	Chairman	F. K. North
	-	Rapporteur	R. W. Yole
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	-	Rapporteur	W. C. Brisbin
Appalachian Section	-	Chairman	W. H. Poole
	-	Rapporteur	B. D. Loncarevic

CONTENTS

1. Origin and Purpose

At a meeting of the Scientific Committee for the Upper Mantle in the fall of 1964, it was considered that the original interdisciplinary aspect of the Project had been lost as far as Canada was concerned. The money for projects had been granted and the scientists concerned had fallen comfortably back within the narrow confines of their own disciplines. Something was needed to restore the spirit of the original concept.

The idea was hit upon to divide the area of Canada and its continental shelves into 4 zones and hold four simultaneous informed sessions for each zone lasting two days and bringing together within each zone scientists from universities and government scientists representing the several disciplines of geology and geophysics concerned with the Upper Mantle Project. The Upper Mantle Workshop was the result.

2. Program

Opening Plenary Session February 24th 9:00 a.m. - 12:00 Noon

Opening Remarks	Dr. W. E. van Steenburgh
Canadian Upper Mantle Project Accomplishments to date	Professor R. J. Uffen
The Integration of Geological and Geophysical Data	Professor H.D.B. Wilson
Tectonic Map, Precambrian Shield	Dr. C. H. Stockwell
Gravity Map of Canada	Dr. M. J. S. Innes
Aeromagnetic Atlas of Canada	Dr. L. W. Morley
Magnetic Field Variations and Upper Mantle	Dr. K. Whitham
Palaeomagnetism and the Upper Mantle	Mr. E. R. Irving

PROGRAM

Arctic Section - Meetings held in the Board Room, Room 332
Administration Building, 588 Booth Street

Chairman - E. F. Roots Rapporteur - L. K. Law

Note: The keynote of the workshop is to be one of round-table discussions, and participation by all those attending, rather than of certain speakers delivering an address to an audience. Participants who have particular results or papers to present will be welcome and will be encouraged to do so; but it is hoped that such papers will give rise to discussions which may be as extended as required or lead in any direction that is profitable. The agenda below therefore lists general subjects for discussion and not specific titles of papers, and indicates participants who have indicated a willingness to speak, informally or formally, on that subject or some aspect of it; but it is expected that the discussion will not be limited to those listed, and that the participants whose names appear will contribute also to discussions on other subjects.

Date	General Subjects	Principal Contributors
Wed. Feb.24	Structural and crustal characteristics of Arctic regions:	
	Geological framework of northern North America	Christie
	Tectonic featues of northern North America	McNair
	Some inter-relationships between geophysical parameters in the Arctic Archipelago	Whitham
	Theories and evidence on the evolution of the Arctic Ocean Basin	Roots
	Soviet ideas on Arctic tectonics and geology	
	Some guidelines for hypotheses of continental movement	Presunka

Date	General Subjects	Principal Contributors
Thurs. Feb. 25	Geological and geophysical evidence relating to the nature of the crust and mantle under Arctic Canada:	
	Elements of Precambrian arctic geology	Blackadar
	Development and nature of arctic geosynclines	Tozer
	Geomagnetic anomalies in disturbed z zones of arctic Canada	DeLaurier
	Geothermal measurements in arctic Canada	Law
	Seismic crustal investigations	Overton
	The crustal structure of arctic North America from seismic evidence	Sander
	Resonances in seismic noise in the Arctic Ocean and archipelago	Milne
	Gravity interpretations in the Queen Elizabeth Islands	Sobczak
	Structural implications of the gravity surveys over the Arctic Coastal Plain and continental shelf	Weber
	Vertical crustal movements in the Arctic Archipelago and Hudson Bay	Pelletier, Fyles
	Continuation of above discussion, with emphasis on areas of particular interest, such as:	(as appropriate)
	Nares Strait, northern Ellesmer Island and northwestern Greenland	
	The diapir belt	
	The Ringnes diabases	
	The outer edge of the continental shelf	
	Parry Channel	
	Baffin Bay	
	Other areas	
	Discussion and preparation of a summary of conclusions on major problems within the area and topics under discussion, and recommendations for future work.	(as appropriate)

Western Section - Topographical Survey Board Room (Room 501), 615 Booth Street, Ottawa

Chairman - F. K. North Rapporteur - R. W. Yole

1. 2:00 p.m. 24 February

   Covered shield of the Prairie Provinces, and ranges east of the Rocky Mountain Trench.

2. 9:00 a.m. 25 February

   Southern Interior Ranges

3. 2:00 p.m. 25 February

   (a) Northern Interior Ranges

   (b) Coastal Ranges and offshore region

The following participated in the various items of the program.

1. R. A. Burwash, G. D. Garland, G. L. Cumming, R. M. Ellis, D. Rankin, R. A. Price, G. B. Leech, H. Baadsgaard

2. J. O. Wheeler, J. V. Ross, D. C. Findlay, J. E. Reesor, G. L. Cumming, Trevor Lewis.

3(a). H. Gabrielse, D. K. Norris.

3(b). A. Sutherland-Brown, H. White, R. M. Ellis, R. W. Yole.

Central Section

Chairman - W. F. Fahrig Rapporteur - W. C. Brisbin

February 24

The Nelson River High, N.E. Manitoba

Western Ontario and Southeast Manitoba
(emphasis on volcanism, geochemistry, geophysics)

The Kapuskasing Gravity High - Ontario

February 25

The Lake Superior Basin

Hudson Bay

The Slave and Bear Provinces
(emphasis on the Coppermine Basaltic Area)

The Eastern Shield
(emphasis on the Grenville)

General Problems of the Central Zone
(heatflow, basaltic dykes, craters, etc.)

Summation

Appalachian Section - Room 237, Admin. Bldg., 588 Booth Street

Chairman - W. H. Poole Rapporteur - B. D. Loncarevic

A. Appalachian region in general:

1.	Structural units, tectonics	- W. H. Poole
2.	Metallogeny	- W. D. McCartney
3.	Seismicity	- W. E. T. Smith

B. Eastern Townships, Gaspe, bordering Shield and covered Shield (Anticosti Is.) and related parts of Gulf of St. Lawrence (G.S.L.)

1.	Structural, tectonics	- W. B. Skidmore
2.	Aeromagnetics	- A. S. MacLaren
3.	Seismic	- G. D. Hobson(GSL) - M. J. Keen and G. N. Ewing(GSL)
4.	Gravity	- A. K. Goodacre (Gaspe and GSL) - M. Fitzpatrick (E. Townships)

C. New Brunswick, PEI, Cape Breton and Gulf of St. Lawrence

1.	Structural, tectonic	- W. H. Poole and D. G. Kelley
2.	Seismic	- G. D. Hobson(GSL)
3.	Seismic, Gravity, Magnetics	- M. J. Keen - C. F. Tsong and G. N. Ewing(GSL)

D. Bay of Fundy, Southern Nova Scotia and Scotia Shelf

1.	Structural, tectonics	- D. G. Kelley and H. L. Cameron
2.	Aeromagnetics	- H. L. Cameron
3.	Seismic and magnetics	- J. E. Blanchard and C. E. Keen
4.	Gravity	- B. D. Loncarevic

E. West Newfoundland, Gulf of St. Lawrence, and adjacent Shield

1.	Structural, tectonics	- H. Lilly
2.	Palaeomagnetics	- R. F. Black
3.	Seismic	- G. D. Hobson and A. M. Dainty
4.	Gravity	- D. F. Weaver

F. Northeastern Newfoundland and adjacent Shelf

1.	Structural, tectonics	- H. Williams
2.	Magnetic, seismic, gravity	- G. D. Hobson - M. J. Keen - A. M. Dainty

G. Avalon Peninsula, Grand Banks to Flemish Cap

1.	Structural, tectonics	- W. D. McCartney - H. Williams
2.	Seismic, gravity	- B. D. Loncarevic - J. E. Blanchard

UPPER MANTLE WORKSHOP

Opening address by Dr. W. E. van Steenburgh

Gentlemen, it gives me much pleasure to welcome you to the "Workshop" on the Upper Mantle Project, or to give it's more comprehensive name "The Upper Mantle and its influence on the Development of the Earth's Crust".

This whole program, which was planned to begin January 1962 and extend to December 1964, was the brain child of Academician V. V. Beloussov of the USSR who proposed it to the International Union of Geodesy and Geophysics at the Union Meeting in Helsinki, Finland in 1960. The suggestion received the support of the Assembly of the Union and the member countries were requested to cooperate in the program.

Discussions were held in Canada soon afterwards and under the initiation of the Department of Mines and Technical Surveys, the National Research Council and universities were consulted and a formal submission was prepared for Cabinet.

This memorandum was forwarded to the Government in May 1961. To provide a proper assessment by those responsible for authorizing major projects of this nature a booklet outlining suggested research, costs, and staff required, accompanied the submission. Some time later the Cabinet approved the project and indicated that $3,000,000 would be available for the 3-year project. Positions requested were to be subject to annual review by Treasury Board.

Unfortunately, a government austerity program announced in June 1962 radically restricted both the flow of finance and the acquisition of positions. Much of the proposed program, with certain important additions, has however been absorbed into the normal budgets of Mines and Technical Surveys and National Research Council. The program has now extended beyond the period originally chosen. I am confident it will have no deliberate end.

As the research was originally planned, it was to be an integrated cooperative program between the Branches of the Department and the universities, with the National Research Council providing financing for research undertaken in the universities. Two committees were established early: a Scientific Committee to coordinate the research program with Professor R. J. Uffen as Chairman, and an Executive Committee, of which I acted as Chairman. My job appeared to be to help persuade the Government to provide the necessary funds. I hope, however, that I have helped to provide a suitable atmosphere for the research. This is all explained in The Canadian Progress Report of December 1963.

The Canadian participation was enthusiastic and vigorous. This was exemplified by the suggestion of a Symposium held at the National Research Council in October 1961. At these meetings a fairly complete study and assessment was made of the proposed Canadian effort. Much of the future program was planned at that time.

The Canadian effort provided, I believe, a guide and pattern for many other Nations. Our original pamphlet "International Upper Mantle Project" was requested and used by the scientists of many countries in planning their individual research. The lead initially secured has been maintained as shown by the Canadian Progress Report 1963, which was issued at the IUGG Meeting in Berkeley, California, in that year. A second report, indicating Canadian progress was issued in 1964. Material from these reports have provided considerable information for the IUGG report which was recently circulated.

In the field of the Upper Mantle research, Canadians can feel justly proud of their effort. We are not drilling any "Mohole", but the basic information being provided by our many projects is impressive and will greatly enhance our knowledge of this planet.

I am particularly pleased about the cooperation which has developed between the scientists at the universities and those in the Department. I can assure you that in the future, as in the past, I shall do everything I can to promote this healthy situation.

This type of informal interdisciplinary meeting you are having should be intensely interesting but I warn you, it will not be without its tense moments. When pure scientists from two such proud disciplines as geology and geophysics contend with each other in small groups over the same ground, something is bound to happen. My hope is that, on the average, what happens will be good.

The Upper Mantle Project, as far as this department is concerned and probably as far as the Science of the Solid Earth generally in Canada is concerned, has marked a permanent turning point towards increased emphasis on the third dimension. This change is not so noticeable as far as the work of the Observatories Branch is concerned, since it has always been concerned with the inner earth, but is more noticeable in the case of the Geological Survey which is completing its reconnaissance surface mapping at a scale of 4 miles to the inch and is now looking with increased emphasis towards geophysical methods and to drilling for information from depth.

We are indebted to the Associate Committee on Geodesy and Geophysics of the National Research Council for their contribution in the co-sponsoring of this conference.

Report of the Arctic Session

Chairman: E. F. Roots Rapporteur: L. K. Law

A most interesting aspect of the discussions of the Arctic group was an appreciation of the magnitude of presently occurring earth movements in an area which many of us had previously considered to be relatively stable. Increase in sensitivity and the location of certain seismic stations enable us now to record earthquakes that previously were unknown; seismic evidence in 1962 indicates sixty earthquakes, grouped primarily along the continental margin and in Baffin Bay. In addition, bathymetric and physiographic measurements suggest an uplift approaching 1,000 feet in the last 10,000 years, and dating of the rates of marine emergence reveal that the rate of uplift has been as large as 20 feet per century. Many tempting hypotheses, such as high temperature convection cells, were postulated and means of testing for these were discussed.

Regional mapping of the emerged landmasses is proceeding at a reasonable rate in the arctic and sub-arctic and there is now considerable coverage in geology, gravity and aeromagnetics. While it is necessary to continue the mapping programs, it is felt that certain specific problems should now be investigated in order to understand and remove some of the weaknesses of the existing data. At present most of the data applies to surface or near-surface features and it is hoped that future experiments will concentrate on deeper structures in three main areas: the transition region between the continental block and the Arctic Ocean, the Franklinian geosyncline, and the Baffin Bay-Nares Strait region.

The present program of investigation of possible motion along Robeson Channel and known faults should be continued; this program includes measurement of horizontal and vertical movement, tilting, gravity, conductivity, heatflow, seismic character, and geological continuity. Another critical area for these studies is Baffin Bay, which has properties characteristic of both continental

and oceanic structures and has been compared to the Mediterranean Sea. Geophysical studies, particularly seismic, are necessary in this area, and it is desirable that in the near future investigation along the lines of the present Hudson Bay project be carried out in Baffin Bay.

Data obtained recently over the continental margins is extremely interesting. For example there is a 100 milligal amplitude gravity high, 350 kilometers long and 90 kilometers wide, parallel to and on the edge of the continental shelf. A seismic profile across this anomaly would be valuable but unfortunately an opportunity to obtain this was missed; although an existing seismic line provides useful information, the line misses the anomaly. Other, similar anomalies are expected along the shelf and it is suggested that gravity and seismic coverage should be extended over the continental slope and also include the junctions where the Lomonosov Ridge and the Alpha Rise join the continental margin.

In the third area - the Franklinian geosyncline - a great deal of surface information is available but we lack knowledge of the lateral extent and actual depth measurements. It would be interesting to trace any continuity of this feature with the Greenland and Cordilleran orogenic belts and also to determine the relationship of the northern margin to the continental structure. Estimates of the volume of sediments should be made, and their sources determined. Study of a few highly anomalous areas may be rewarding; a notable one, of course, is at Mould Bay, where anomalous conductivity and seismic measurements have been obtained. It is suggested that scientific drilling be carried out on the north flank of the Franklinian geosyncline to determine its edge under the overlying formation.

Two general recommendations of the Arctic group are: cooperation with and participation of university groups should be increased; and an interdisciplinary committee should be set up to encourage and coordinate study of presently occurring earth movements.

Report of the Western Session

Chairman: F. K. North Rapporteur: R. W. Yole

I'm afraid, due to the complexity and uncertainties involved in such an area as the Western section, we were not able to summarize as briefly and succinctly as we would like the information gained in two days of a rather intensive study of the problems involved. We hope in the mimeographed information to be sent to the participants to give at least the highlights of individual contributions from many very interesting and informative speakers. Rather than go through the individual list of speakers as we had planned, which might take more time than we should take, I will just briefly mention some of the main topics that were looked at.

The first session was devoted to the geological and geophysical information available on the area east of the main deformed belt, covering such topics as: the dating of basic dykes and sills in the Prairie Provinces; the gravity data available; the theory of magneto-telluric currents and the present program and progress in that field to date; the refraction work done by the University of Alberta, Department of Physics, a profile from the southern Alberta Plains, extending into Saskatchewan; seismic reflection data also by the University of Alberta, extending a profile across the southern deformed belt too; and heatflow studies being carried on by workers at the University of Western Ontario and compilation from these data of maps of isogeotherms and isogradients.

The sessions today were involved with the regional tectonics of the northern and southern Cordilleran belt, and of the Rocky Mountain Trench, and the geology and geophysical information available on the western coast. As you would suspect, many more uncertainties are available than solid facts in this region. Certain discrepancies have shown up in the information. For instance, the suggestion from geophysical work of a thinning of crustal rocks westward, whereas other data suggest isostatic

equilibrium in the uplifted belt of the mobile region. The extension of the crystalline shield beneath the deformed belt, and its western limit, is still a problematical thing. The information available at present gives no firm indication where the western margin of this shield type crystalline basin lies.

I think the remainder of the time available I will devote to the various proposals which have been made for further work to resolve some of the problems which remain. One of the things which has come out of the discussions has been the apparent need for the coordination geophysical and geological information on a much closer basis than has been perhaps apparent in many cases in the past. Out of this sort of feeling has come a suggestion that comprehensive geophysical profiles, including all the types of surveys which can be made - magnetic, gravity, seismic reflection and refraction and magneto-telluric studies - should be made on profiles where the structural and tectonic information gained from surface mapping is best. One of the areas suggested where this sort of thing could be done is in the profile across the southern Cordillera now being undertaken by the Geological Survey of Canada and their associates from the University of British Columbia. Several other cross sections where accessibility permits in the central and northern parts of the western Cordilleran region were suggested as other sites at which such comprehensive geological-geophysical surveys could be carried on.

A second major proposal, which came out of the discussion this afternoon, is that the success of the Lake Superior type of seismic program, where large charges detonated in a body of water were analysed from recorders long distances away from the explosion, providing much valuable data, suggests that this type of work should be attempted in western Canada if reasonable sites for the explosions can be found either in the off-coast waters of British Columbia or in some suitable body of water lying on the margin of the shield.

There also became apparent a very great need for further geophysical work in the off-shore areas of British Columbia to study the nature of the present day continental edge. Seaborne gravity work of a reconnaissance type perhaps is a prime need. Geophysical work along the west coast of the Queen Charlotte Islands appears to be a very urgent need, in that here a steep continental slope, apparently broken by a major fault paralleling the coast, and uncomplicated by various topographic or bathymetric effects, might yield some very useful information on a near continental edge area.

Electromagnetic studies are in a preliminary stage as far as interpretation is concerned and much more work is needed in this direction, in both the field and the laboratory, with a view to improving the present interpretive methods and gaining much valuable information on the deeper levels.

Isotopic studies are a prime need and especially those obtained through the rubidium strontium method and the lead and uranium methods.

A suggestion was made, in regard to the lack of geophysical information, that many data of this type lie dormant in company files. It is strongly recommended that efforts be made to gain, particularly from oil companies, the release of much of this information which could fill many of the critical gaps in the data now available.

It is also suggested that, in regard to the geological aspects of the western region, there are several important areas that are relatively poorly mapped or unmapped. Strong efforts should be made to complete these, and investigate specific areas of interest following along the lines already started by workers from the University of British Columbia in the southern Cordillera and various other workers in the north.

One other recommendation, perhaps not of direct interest to the scientific or data gathering process, but very important from the point of view of encouraging people to work in the field, is a suggestion put forward that some effort be made to reimburse

the student help involved on any project of this type at a rate which would enable them to participate without any serious financial disadvantage compared to taking work in other fields, particularly for the summers.

That summarizes the recommendations made by the Western Group. As a last remark, I would wish to make note of the very great strides which have been made in both the geophysical and geological approaches in this wide and complex region. The compilations of tectonic data on a regional scale done by workers in the Geological Survey of Canada formed a very prominent adjunct to our discussions today. Thank you.

Chairman: Prof. F.K. North

Session A: Wednesday, February 24, 1965, p.m.

Western Plains

R.A. Burwash - Radiometric dating of basic dykes and sills

Earlier work, mainly on mineral separates, has been supplemented with whole-rock analyses. Profiles across single dykes have resulted in markedly different apparent ages from wall-rock, chilled margins and central parts of the bodies. Further investigations of such variations are necessary. In general, results to date indicate the presence of three separate sets of dykes, with different trends and average ages (approximately 1,000 m.y.; 1,500 m.y.; and 2,500 m.y.).

R.J. Buck - Gravity observations in the Prairie provinces by the Dominion Observatory

A regional gravity compilation map, constructed from data obtained by oil companies and independent university workers as well as Observatory data, was presented. Anomalies pointed out included a small positive feature in southern Manitoba, a linear positive trend across central Manitoba and southeastern Saskatchewan (believed to be related to an extension of the Nelson River high), and negative anomaly trends from northwestern Saskatchewan to east-central Alberta and east-west across southern Alberta. Geostatic studies, analyses to remove the cover-rock effects, and model studies are to be carried out on these features.

E.R. Niblett - Magnetotelluric investigations by the Dominion Observatory

Analysis and interpretation of magnetotelluric data were discussed. Interpretations depend on the devising of suitable models. Simple and sophisticated layered models analysed to date have indicated a sharp increase in electrical conductivity at about 80 km. depth, perhaps related to the low-velocity seismic layer. Studies of vertical magnetic variations are being undertaken in an effort to determine structure of the extraterrestrial sources of magnetotelluric phenomena. In western Canada, long-period pulsations are being studied to gain information on deep crustal horizons.

R.M. Ellis - Results of magnetotelluric investigations by University of Alberta

Data from stations in Alberta and Saskatchewan, plotted as apparent resistivity vs. period, were presented, along with theoretical curves calculated from appropriate models. The major deep break in conductivity apparently occurs at different depths at different stations (approximately 80 km. at Beiseker, 30 km. at Vulcan). In the Montreal Lake area of Saskatchewan, separation of the Hx-Ey and Hy-Ex curves suggests the effect of some crustal structure. A fault separating materials of strongly differing resistivity is one possible solution.

D. Rankin of the University of Alberta outlines the future program for these studies in western Canada. A 2000' drill hole is proposed at a base station intended to make continuous recordings of magnetotelluric data. A portable unit taking readings across the plains from shield to mountains is to operate in conjunction with the permanent base operation. Investigations of the sources of magnetotelluric currents will form part of the program.

G.L. Cumming - Refraction seismograph data from western Canada by the University of Alberta

Profiles in southern Saskatchewan and Alberta indicate a westerly slope on the Mohorovicic discontinuity from Swift Current to Suffield (depths of 45 km. to 50 km., respectively). From Suffield to the Rocky Mountain Trench, a change in slope is indicated, leading to the inference of a thinner crust under the mountains than beneath the plains to the east.

From data recorded from the Lake Superior project of 1964, the low velocity layer in the mantle appears to be about 50 km. thick, and occurs 80 km. below the Mohorovicic discontinuity.

E.R. Kanasewich - Reflection seismograph data from western Canada by the University of Alberta

The current program is designed to obtain near-vertical incidence reflections from deep crustal horizons in order to assess the nature of the discontinuities, to measure vertical velocities, and to determine whether any structure exists on the discontinuities. Results to date have

identified the Conrad discontinuity as a sharp, rather than diffuse, zone at a depth of 33 km. This depth is close to that determined for the same discontinuity (35 km.) by refraction studies in Alberta.

A.E. Beck - Heat flow studies in western Canada

Studies by the University of Western Ontario on temperature data from bore holes in western Canada have resulted in preliminary maps showing isogeotherms and isogradients. An eastward bulge in isogeotherms in western Alberta, roughly coinciding with a change in basement lithology but not reflected in isogradients, suggests an anomaly of conductivity rather than heat flow.

Discussion:

Discussions during and after the presentations brought out the problems of interpreting the various types of geophysical data, and the acute need of more extensive observations. Several speakers brought up the problem of the discrimination of basement province boundaries in the region masked by cover rocks and in the western Cordilleran region. It was noted that earthquake epicentres appear to be aligned along some of the province boundaries, and further study may reveal other similar relationships.

Session B: Thursday, February 25, a.m.

Southern Cordilleran region

J.O. Wheeler - Tectonic framework of western Cordillera

The regional setting of this complex province was described by means of discussion of a regional tectonic map. The history of crustal behaviour in the region was described in terms of tectonic elements, sedimentary sequences and orogenic phases.

R.A. Price - Tectonic style in the southern Canadian Rockies and its effect on crustal thicknesses

The imbricate thrust plates of this area, with up to three miles of sedimentary section in one of them (the Lewis plate), in effect thicken the crust. The radial pattern of surficial translatory motion suggested

by the three arcuate salients of the deformed belt suggest a tectonic focus in the ancient Purcell geanticline, which may represent the pre-Laramide continental margin.

J.V. Ross - Structural studies in southern British Columbia and cover-basement relationships

The presence in certain western Cordilleran areas of basal crystalline complexes (San Juan Islands, northwest Washington), of northeast trending folds with crystalline cores (Chilliwack-Hope), of northeast trending pre-Early Mesozoic dislocations (Revelstoke) and of mantled gneiss domes (Shuswap) is evidence of an old "basement" in the region. Whether this is the same "basement" as exists east of the Cordillera is not known. However, the northeast-trending lineaments are suggestive of shield trends to the east.

J.E. Reesor - Mantled gneiss domes and silicic plutons of the southeastern Cordillera

Problems associated with the interpretation of the mantled domes were illustrated by data on the Thor-Odin dome. Evidence is not conclusive as to whether the gneissic cores of the domes are metamorphosed sediments of the Windermere or other Proterozoic sediments, or remobilized basement. K/Ar datings of the metamorphic rocks have yielded mid-Cretaceous ages. Attempts to date them on the basis of Rb/Sr ratios, and thus determine whether any older, "relic" minerals remained, have to date been unsuccessful.

It has been proposed, on the basis of Sr^{87}/Sr^{86} ratios (Fairbairn et al), that some of the plutons (Coryell type) are more closely related to differentiates of subcrustal basaltic material than to reconstituted sediments. Geological Survey determinations of these ratios indicate that significant variations occur, depending on whether the samples are obtained from peripheral regions of plutons or central localities. Specimens from the latter localities have ratios similar to those of sediments, while peripheral specimens have ratios similar to those determined by Fairbairn's group.

D.C. Findlay - Basic and ultrabasic rocks of the Cordilleras

Two types of ultrabasic intrusions occur in the region. "Alpine type" intrusions lie mainly in a central Cordilleran belt. (Cassiar, Prince George, Shulaps, etc.) "Zoned intrusions" are found in the Alaska panhandle and in the Tulameen-Kamloops area. These are characteristically undersaturated bodies; they contain no orthopyroxene; and they display a "bullseye" pattern of concentric shells of dunite, pyroxenite and peripheral gabbro. The zoned type of ultrabasic body is unknown in the remainder of North America. Its occurrence in the western and southern Canadian Cordillera may be explained by either a different composition of mantle source material here or by different depth of derivation than that of the other types of ultrabasic bodies. Ages determined for the zoned intrusions are 100 m.y. (Alaskan) and 186 m.y. (Tulameen).

T. Lewis - Heat flow program of the Dominion Observatory

From the few Cordilleran stations measured, continental average values have been obtained. An accelerated measuring program, including the drilling of three holes in the Stikine Plateau area, was outlined.

R.M. Ellis - Preliminary results of a variometer profile from Crowsnest to Vancouver by the University of British Columbia

An anomaly in the diurnal component of the magnetic field has been discovered at Crowsnest Pass. Trends of conductivity changes differ along the eastern part of the profile (e.g. NNE at Crowsnest; WNW at Kootenay Lake). The results also differ from those obtained in California. Further investigations, with closer spacing of stations, are planned.

Discussion:

During discussion, the discrepancy suggested by apparent gravity compensation in the Cordilleran belt, and thinning of the crust indicated by seismic data was brought out. It was suggested that compensation could be in part subcrustal, and the seismic observations were not necessarily measuring the same phenomena as the gravity method.

If "basement" rocks had been involved in "remobilization" and flowage into fold cores, as suggested by some field work, old "basement" lineaments would have beendestroyed or at least deformed. Hence apparent orientations of early lineaments in the Cordillera, similar to those of shield features to the east, are not necessarily indicative of the continuation of shield structures beneath the Cordillera.

The western belt of ultrabasic intrusions appears to be parallel and close to the western edge of the batholithic complex of the Coast Ranges. Similar relationships appear elsewhere (e.g. Sierra Nevada). The occurrences of the zoned type of ultrabasic intrusions in two distinctly differing geological environments (i.e. Alaska panhandle and interior B.C.) suggest some fundamental, deepseated control.

Closer liaison between geologists and geophysicists as to the most desirable locations for planned bore holes for heat flow studies should result in information being gained from the most critical localities for both geophysical and geological purposes. The use of such holes for other studies, in addition to heat flow, should be taken into account.

Session C: Thursday, February 25, p.m.

Northern Cordillera

H. Gabrielse - Tectonic framework of northern Cordillera

The tectonic history of the region was explained with the aid of a compilation map. Sedimentary sequences, facies patterns, and orogenic and plutonic phases were outlined.

The dating of granitic intrusions and sedimentary evidence of rapid uplift and unroofing of these bodies during the Mesozoic are indicative of relatively high mobility of the subcrustal material.

The major lineament of the region, the Tintina trench, may be interpreted as a right lateral fault. Evidence from Alaska and the Yukon suggests that a displacement in the order of 250 miles is possible. The almost colinear feature to the south, the Rocky Mountain trench, shows no evidence of such great horizontal displacement.

D.K. Norris - Paleomagnetic data bearing on the nature of the curvature of the northwestern Cordillera

The marked changes in the trend of the eastern mountain chains (MacKenzies-Ogilvies-Richardsons) have been investigated from the paleomagnetic point of view. The horizontal components of remanent magnetism for specimens of Cambrian and Precambrian rocks from the northwestern Cordillera were determined. Results indicate consistent directions in the mountains along the sinuous front of the deformed belt; in the interior ranges and plateaus, directions are highly variable. The implication is that the "bending" is not a result of rotation about a vertical axis, as would be required by Carey's orocline theory.

A. Sutherland Brown - Geology and tectonic history of the Coastal belt of the Cordillera

The major sedimentary, volcanic, intrusive and tectonic events of the region, and in particular of the Queen Charlotte Islands, were described and illustrated with maps and cross sections. One of the most important features of the region is the Queen Charlotte fault, marked by a series of linear depressions along the continental slope off the west coast of Queen Charlotte Islands. This lineament is the locus of shallow earthquake epicentres. Detailed bathymetric, geophysical and geological studies of this phenomenon are needed.

W.R.H. White - Seismic data from the west coast by the Dominion Observatory

Seismic data from the Ripple Rock explosion and other observations by the Dominion Observatory suggest the presence of a thick crust (50 km.) beneath Vancouver Island. Thicknesses of the crust of 30 km. under the Rockies and 50 km. under the plains are indicated. No observations from the Coast Ranges are as yet available.

G.B. Leech - Structure of the southern portion of the Rocky Mountain trench

Northeast trending lineaments (e.g. Bull River and associated faults) cross the trench without apparent offset, and have apparently effected sedimentation since early Paleozoic time. Hence it is inferred

that no major strike slip movements parallel to the trench have occurred since the early Paleozoic.

Discussion:

The reliability of palaeomagnetic data from relatively weakly magnetized sediments was questioned.

Discussion of "geofractures" brought out the need for more information on regional patterns, and more detailed studies of known examples. Certain continental edge downwarps (e.g. South Atlantic, Western Australia) are apparently not directly related to major faults.

Persistently positive and intruded parts of geosynclinal belts should be investigated moreintensively, with such studies as heat flow, to determine fundamental causes of such activity.

The integration of data from the Ripple Rock and Suffield explosions seems to present a promising avenue for advancing geophysical knowledge of the Cordilleran region.

UPPER MANTLE PROJECT WORKSHOP (WESTERN SECTION)

PROPOSALS FOR

FUTURE WORK

1. A great accelerated program of geophysical work in the Cordilleran region, and especially west of the Rocky Mountain trench (an area described by one speaker as a "geophysical desert").

   Specific proposals:

   a) The conducting of a Lake Superior type of Seismic experiment, involving explosion of a 2 to 5 ton charge and detector stations 1500 to 2500 km. from the explosion site, in western Canada.

   b) Extending the deep crustal reflection seismic studies on the plains and then westward.

   c) Comprehensive geophysical studies along three or more profiles crossing the Cordillera in areas where best structural control is available.

d) Aeromagnetic survey of Cordilleran region with flight line spacings of 3 to 4 m.

e) Coordination of the seismic data from the Ripple Rock explosion and the Suffield explosion.

f) Seaborne geophysical studies of the west coast region, and particularly of the Queen Charlottes area, combined with bathymetric studies and marine sampling programs.

g) Heat flow studies to be conducted in many more localities especially crystalline belts and major fault zones.

h) The acquisition of more paleomagnetic data.

i) Electromagnetic studies to be extended, both in the field and laboratory, to gain more basic data, analyse more sophisticated models, and investigate presently indicated anomalies and structures.

j) Stepped-up efforts to obtain oil-company and other privately-obtained data.

2. Promote the obtaining of more isotopic data, particularly Rb/Sr and lead-uranium.

3. Investigate possibilities of deep-drilling to provide maximum geological and geophysical data in critical areas.

4. Accelerate efforts to complete regional mapping of the Cordillera.

5. Study gabbroic complexes of region to ascertain whether any other zoned ultrabasic complexes are present.

6. Attempt to have all compilation maps for the project drawn on the same type of base.

7. A strong plea to ensure that student assistants involved in the project and related studies are reimbursed (e.g. from grant money) at a rate sufficient to meet the current competition from other potential employers.

8. Make every effort to maintain close liaison between geologists and geophysicists on all phases of the project. A particular case in point is the locating of bore-holes for heat flow studies; these could be placed in positions providing much useful information in other aspects of Cordilleran problems, in addition to the heat flow characteristics of the sites.

Report of the Central Session

Chairman: W. Fahrig Rapporteur: W.C. Brisbin

The discussions of the scientists attending the Central Zone section of the Upper Mantle Workshop have covered a large spectrum of geological and geophysical studies which are presently being done in a widespread number of localities in the Precambrian Shield of Canada. The diverse nature of the investigations, which for the most part are still continuing, and the large area involved, create a situation which is likened to that of a jig-saw puzzle in which most of the pieces are missing and the ones with which we are now working are continually changing their shape. Nevertheless it was obvious to those who attended this session that each individual study was making a valuable contribution, either directly or indirectly, to the knowledge of the Upper Mantle and its effect upon the crust.

The only direct information bearing on the position and the properties of the Upper Mantle came from seismic studies which are being conducted in several locations in the Precambrian Shield. Attempts have been made to add to and to extend this information by gravity techniques and by new magnetic interpretation methods. As well, heat flow measurements, although sparse, are providing interesting data. The results and interpretation of these geophysical studies have indicated the necessity of improving our knowledge of the architecture of the crust and its development. In many cases the masking effects of the crust have created ambiguities in the interpretations. In this respect the present research being done in field and experimental geology, age dating, geochemistry, etc., in the Central Zone, is providing excellent data to help overcome this problem.

Two lines of research are of particular note in that they may provide information about recent movements within the mantle. One of these, in the field of rock mechanics, involves strain release measurements in crustal rocks which may be used to calculate the state of stress in the crust. The other has to do with recent and present movements of the crust as determined by the distribution of Pleistocene marine deposits and by long-term geodetic surveys in critical areas.

Recommendations:

The following recommendations have arisen from the considerable discussion of the Central Zone section of the Upper Mantle Workshop:

Seismic Studies

(a) Seismic crustal determinations should be increased to accelerate the production of regional maps of the M. and C. discontinuities. This will require continued support from existing groups and the creation of full-time crews. The determinations may be widely spaced at first and used as control points for regional gravity, magnetic and electrical methods which will fill in between. It is suggested that the Seismic Subcommittee of N.R.C. be asked to report on the feasibility of such project. (Hall).

(b) A major effort, similar to the Lake Superior or Hudson Bay seismic project should begin to make full use of the calibration of the Yellowknife array. This calibration will probably take place within a year or two and the participation of groups other than the Seismology Division of the Dominion Observatory will ensure good crustal and upper mantle seismic coverage over a wide area of the Northwestern Territories. (Manchee).

(c) Existing seismic groups should attempt to improve their methods of recording and identifying converted waves in order to make the most of their interpretation. (Brisbin).

Gravity

Continuation of regional gravity studies is recommended with more detail in areas in which other geophysical tools are being used to study the crust and Upper Mantle. Gravity interpretation should take into account all of the available geophysical information in any particular area, and as well, make use of the results of other geophysical studies.

Heat Flow

(a) Twelve heat flow holes are proposed to determine regional heat flow stress between Edmonton and Norman Wells along a great circle lying between the two points. (Beck).

(b) Twelve holes are proposed to determine heat flow differences between shield and covered shield areas along the line of latitude between Moosonee and the Rocky Mountain foothills. (Beck).

(c) Ten holes along the 65°N. latitude line between Hudson Bay and the Alaska border are proposed to determine heat flow differences in the various geophysical provinces of the shield. (Beck).

(d) A line of seven heat flow holes, 200 miles apart, is proposed across the Nelson River gravity anomaly where major crustal displacement has been identified. (Jessop).

Age Dating

Progress in our study of the Precambrian history of the Canadian Shield is hindered by our meagre knowledge of the extent of old supercrustal rocks that have been affected by more than one orogeny and of rocks formed during early orogenies that have been affected by later orogenies. As a rule the potassium-argon dating method gives only the age of the youngest event. However, there is every hope that the whole rock rubidium-strontium method and zircon (Pb-U) will date older orogenies or will "see through" younger metamorphic events.

Three such problems come immediately to mind. (1) In the Superior Province pre-Kenoran orogenic activity is known or suspected. (2) In the Churchill Province at least three problems exist. In the Flin Flon-Lynn Lake, Nonacho - Rankin Inlet, and Labrador trough regions supercrustal rocks of Archaean age that have been affected to varying extents by Kenoran orogeny and intruded by Kenoran and pre-Kenoran granitic rocks are suspected to occur. (3) In the Grenville Province the Grenville orogeny has probably masked the presence of granitic rocks related to Kenoran, Hudsonian, and Elsonian orogenies.

In order to properly study this problem a large number of (as many as 50) rubidium-strontium whole rock isochrons will be needed over a period of a few years. It is urged that Rb/Sr dating in the Canadian Shield be given top priority by the Geological Survey of Canada and that the radioisotope laboratory of the Geological Survey be expanded (particularly in terms of additional scientific staff on the Ph.D. level). (McGlynn, Wanless, Stockwell, Fahrig).

Crustal Movements

It is recommended that support be given to studies dealing with recent and present crustal movements. These may take the form of investigations of the distribution of Pleistocene marine deposits with respect to Pleistocene and present sea-level and long-term geodetic levelling and triangulation investigations in critical areas. (Uffen).

Crustal Stress Measurements

A program of measurement of stress in the Earth's crust is proposed either by stress release methods or by absolute stress measurements in situ. Such a program would involve research in measurement techniques and instrumentation. To study methods of isostatic compensation in the shield, stress measurement should be made in areas where isostatic compensation exists as well as in regions where isostatic gravity anomalies occur (e.g. the Grenville low). A stress measurement program within and at the edge of the Cordilleran region would be of value. (Nyland and Brisbin).

Deep Drilling

Crustal seismic studies have now identified the Conrad discontinuity in two locations to be within 8 kilometers of the surface. We should now be considering the possibility of drilling a hole to this discontinuity which appears to bear a fundamental relationship to shield geology (H. D. B. Wilson).

Combined Geophysical and Geological Studies

Several geologists have proposed integrated seismic, gravity and magnetic studies to provide the third dimensional picture of the rock masses with which they are working (for example anorthosite masses). There is no question of the value of integrated studies and it is recommended that wherever possible organizations should promote this practice. (Emslie, Gaucher, Bell).

Future Workshops

At the close of this workshop there was a unanimous feeling that these meetings were highly successful and are far better designed

for the exchange of information and discussion than are the formal type of scientific meetings. It is, therefore, recommended that an annual workshop be implemented as part of the Canadian Upper Mantle Project.

Report of Appalachian Session

Chairman: W. H. Poole Rapporteur: B.D. Loncarevic

I would like to start right away with the first recommendation which has been made and which I think is the most important. I hope it will be endorsed by everybody present. It reads: Considering the demonstrated usefulness of workshop-type meetings and appreciating the importance of keeping the established lines of communication open, it is recommended that another meeting be organized for next year. I think our group in particular achieved the true workshop atmosphere. We were particularly fortunate that no one attempted to deliver a formal paper. I don't think anybody could have read a paper because we fired too many questions at our contributors and too many people jumped in with both feet every time a seemingly dogmatic statement was made. We operated as a small group in a very small room with about 30 of us present at any one time. About 54 signed the attendance list.

Perhaps the most useful and most interesting aspect of this meeting was the excellent summary and presentation of the regional and local geology provided by the geologist for the geophysicists. I found this personally fascinating and I think I learned more geology here in 24 hours than in the previous ten years. At least, it all fell together and I think it was probably the most useful aspect of the meeting as far as geophysicists were concerned.

The definition of Logan's Line was brought up several times and was perhaps the major single geological feature that was discussed. I think the geophysicists are rather unhappy with shoving Logan's Line under the water because nobody can see it there.

As far as reported geophysical work in the region is concerned, I think the most important large contribution to the Canadian Upper Mantle project is the crustal work of the Dalhousie group under Professors Blanchard and Keen. This was really the most

important direct investigation of the upper mantle - the composition of and the depth to the upper mantle. They have completed a considerable amount of work on the east coast. There are several profiles near the coast of Nova Scotia. One favourite profile runs between Cole Harbour and Port Hebert, parallel to the Nova Scotia coast. They must like it very much because they repeated it three times. There are very good reasons for doing this. The profile falls on a very important section of the crust which is very uniform and which lacks an intermediate layer. Consequently, many detailed investigations on the nature of the mantle might be possible with improved techniques both in recording and, even more so, in interpreting the results. Besides this favourite profile where the depth to the Moho is 35 km., another line in the same area lies off the continental shelf in deep water and was obtained by means of sonobuoys and a shooting ship - two ships altogether. This line has been interpreted using a shipborne gravimeter survey through the same area. An interesting and certainly questionable, but we hope significant result, was that the only way gravity and seismics could be reconciled in a mathematically acceptable model was to assume layering in the upper mantle. As far as we know, there is very little seismic evidence for this. The layers could not be detected on the seismic results. But after that work was completed, a paper in the last issue of the Geophysical Journal mentions very timidly that the Esktalemuir Array believes that a second arrival from upper mantle may have been detected.

Three other crustal lines completed by the Dalhousie group are one in the Gulf and two near Newfoundland. The Gulf line and the northeast Newfoundland line both indicated high mantle velocities of 8.5 and 8.6 km. per second respectively. These high velocities are extremely interesting and are extremely significant if they can be substantiated. Two members of the Dalhousie group discussed the veracity of their results, much to the amusement of everyone. But one indisputable result is the great depth of 45 km. to the Moho discontinuity in these two areas. The last line is on

the west coast of Newfoundland and indicates a depth of 35 km. to the Moho. It seems now that the western Newfoundland and the Nova Scotia line are on the two flanks of the Appalachian geosyncline with 35 km. to the Moho, while the Gulf line and the northeastern Newfoundland line are somewhere inside the Appalachian geosyncline with 45 km. to the Moho. Thus a depression of the mantle by 10 km. and a possible increase in the mantle velocity indicates the Appalachian geosyncline in the area.

Other seismic work in the area has been done by George Hobson of the Geological Survey. Fortunately the GSC and Dalhousie work well together but this fortunate situation is simply because the number of ships is limited and consequently they've got to work together. One of the interesting results of the detailed shallow refraction work of Hobson is a possible graben-like fault structure paralleling the western coast of Cape Breton Island. This of course is an interesting area because the proposed Cabot-Great Glen Fault should pass somewhere through there.

Following the seismic work, the next field of investigation worth mentioning is the gravity work by the Dominion Observatory using bottom gravimeters in the Gulf and by the Bedford Institute of Oceanography using shipborne gravimeters on the Nova Scotia continental shelf, the continental slope, and the ocean deep.

Perhaps, while mentioning my own organization, I might insert a commercial here and mention that we at Bedford Institute are fortunate in having most of the facilities necessary for carrying out marine geophysical investigations. We hope we will live up to the challenge. We have had the opportunity of doing some exciting work on the Nova Scotia continental shelf and also of originating work that is done in the Arctic. The second part of my commercial is that we have access to a large number of ships - DOT icebreakers going north and a number of Navy ships which are being retired and consequently are looking for alternative means of employment. I think that we can probably find enough ships to keep between 200 and 500 geophysicists busy for the next 25 years. If anybody would like to come to Bedford Institute we would gladly welcome them.

The magnetic coverage of the area consists primarily of the Geological Survey aeromagnetic surveys which have been published and a certain amount of shipborne magnetometer work which is either in preparation in the case of the GSC work (who are better organized than Bedford) or somewhere in our heads in the case of the Bedford Institute work. Commercial companies have carried out aeromagnetic surveys and many other geophysical surveys.

Although we, as a group, did not make a formal recommendation to the affect, I would certainly most strongly endorse the recommendation made by the Western session and that is to try to extract as much material as possible for scientific purposes from commercial companies. I don't know how the Treasury Board would administer this, but I think that if out of the 5 cents per acre per square mile of lease which they must pay, a certain fraction of a cent could be returned to them if they provided us with scientific results. In that way they could, in fact, save a lot of money and we need not repeat the work they are already doing. The Nova Scotia and Grand Banks continental shelves for a number of years now have been an area of active interest by commercial companies. Last summer they blew up two ships and this summer they are chartering six more. They are obviously going to continue this work. To take out a lease they have to pay a deposit which is not returned unless they do exploration work. It is cheaper for them to do exploration work. This work is going on now. It is extremely desirable to have some mechanism of ensuring that, within a reasonable time, we could extract the material from the commercial companies. This is perhaps most important because in our discussion both the volume and perhaps the quality of discussion decreased as we went farther east to the point where we spent only about five minutes on the Flemish Cap, perhaps the most eastern part of the continental Appalachian system. The complete discussion on the Flemish Cap consisted of asking whether the Flemish Cap is really Tertiary and answering that Peter Hood says the magnetism of the Flemish Cap

is reversed and so maybe it is Tertiary. And then somebody else announced that he really would prefer it not be Tertiary. And that was the end of the Flemish Cap discussion.

Following this very brief summary of the discussions which were most fruitful and certainly most serious and sincere, I would like to read to you our ten recommendations that we managed to formulate. This by the way is primarily because our Chairman managed somehow to squeeze in all the discussions before coffee time today so to provide time to frame the recommendations between coffee and 5 o'clock.

1. The first and most important recommendation - about the value of the meeting - I have already given you. There have been in the past discussions about the need and the timeliness of establishing a Canadian Geophysical Union. This meeting has proven to everybody that there is both the interest and potential material available to justify some form of organization. Perhaps we should not rush into forming an organization at this time but simply agree that we should meet again.

2. The second recommendation is our most ambitious and most complete. We recommend that an integrated study be undertaken on a ribbon section across the Appalachian orogen from the Grenville craton to the ocean basin. Particular emphasis should be placed upon geology, petrology, petrochemistry, shallow seismics (reflection and refraction to trace the unconformity at top of the Grenville and the younger unconformities). Other studies should include a concentrated network of gravimeter and 3-component magnetometer measurements, radar photography, deep seismics and the Sable Island and Magdalen Island drill-holes for scientific purposes. There was considerable discussion on the Sable Island drill-hole because an oil company, which has been active in the area

for a number of years, has reached the point where it must drill because it has exhausted other means of exploration. We decided to make the recommendation primarily because a hole drilled for scientific purposes would provide more data and more opportunity for scientific study than perhaps a hole drilled by the oil company and also because we feel that such a hole should be drilled now. Sable Island is a platform uniquely located at the edge of the continental shelf. There are few such favourably located platforms in the world. We need to know now what underlies Sable Island to help us with geophysical investigations.

3. Thirdly, we recommend that the present program of geophysical investigations in the Gulf of St. Lawrence be accelerated. The boundary between the Appalachian orogen and the Grenville craton should be investigated. Logan's Line should be defined a bit better. The Dominion Observatory should continue the bottom gravity measurements in the Gulf to complete that large empty space between Newfoundland and the mainland.

4. Fourthly, we recommend that the two zones of epicentres, the Lower St. Lawrence zone and the Gatineau-Lake Champlain zone, be studied, in particular by stress and geodetic measurements and the area between them by anisotropy studies. Perhaps we ventured beyond the specialities of the people present. But it seemed obvious that some attention should be paid to the two zones and intervening area and their significance in terms of continental structure.

5. We recommend an increase in the number of palaeomagnetic studies in Nova Scotia and Newfoundland to test the orocline hypothesis for the origin of the bend in the Appalachian belt. This by the way provided an amusing opportunity to discuss geological terminology. We wanted to know what is an orocline and we were told by the geologists that it is a bend. We

asked why you don't call it a bend? They replied an orocline sounds much better. This is not exactly what they said but at the end of about five minutes of circular discussion all we could discover about an orocline was that it was a bend, but it is much nicer to call it an orocline than a bend.

6. Recommendation No. 6 is that a site selection study be made to assess the feasibility of drilling the significant gravity anomaly near Black Lake, Eastern Townships.

7. We recommend palaeocurrent studies in the Precambrian of the Avalon Peninsula to determine the palaeo-location of the source area.

8. A large unknown area within the region considered underlies the Grand Banks of Newfoundland. We recommend that geological sampling, mapping, and geophysical investigations be carried out in this area.

9. We recommend the study of the extension of the Appalachian orogen seaward to the ocean basin. This is an obvious one. What happens to the Appalachian belt northeast of Newfoundland? It probably extends across the continental shelf and ends in some unknown manner at the continental ledge.

10. Our last recommendation is to continue the crustal study of the subcontinental and suboceanic mantle.

I am very glad that my report to you ends with the word mantle because that was the intended topic for discussion at these meetings.

Concluding Remarks

by

Dr. J. M. Harrison
Assistant Deputy Minister(Research)
Department of Mines and Technical Surveys

First, I would like to compliment all participants on the successful workshop regarding the upper mantle. My present job is concerned not so much with science, in fact much of my time seems to be involved in jurisdictional disputes. So it is a pleasure to see geologists and geophysicists getting together spontaneously. I imagine that the geologists are not quite so enthusiastic about the "numbers" that the geophysicists might wish to use, and I imagine the geophysicists are a little bit fed up with the geologists who are not concerned with three dimensional problems quite as much as they might like.

We are just now getting to the stage where we know enough about surface geology of a country as large as Canada so that geologist can question some of the things that they accepted more or less on faith for a great many years. Geophysicists, in the meantime, have been working without coming to grips with some of the geological problems, and I think now is a critical time for the geologists and geophysicists to work together in the way that they have done here. I might say that in my experience around and about, that Canada is setting an example for the world to follow in liaison between geophysicists and geologists. This room full of people is a good illustration.

A multidiscipline approach is obviously going to have to develop and one of the things I have been impressed with is the fact that every one of the recommendations that has come out of the workshop has been slanted toward the geophysical side. Obviously geologists realize a great deal more geophysical information is needed.

As Charlie Smith has pointed out from time to time the isopach, or three-dimensional concept has developed from the reconnaissance study. I was interested to note that the Geological Survey has for many years been saying that they probably will have most of the reconnaissance geology of Canada done except for postage stamp holes by 1972. Dr. Innes today said that he hoped he would have the reconnaissance gravity map of Canada completed by 1972 except for the western Cordilleran. Dr. Morley has decided that the aeromagnetic map of Canada except for the Cordillera is going to be completed by 1972. Now this reconnaissance mapping is allowing us to get into the third dimension and we are going to need to test these third dimensional forecasts by drilling.

It is only about three years ago that the idea of extensive drilling as a scientific tool was first proposed by the Geological Survey, although the Observatories Branch had already sponsored some. The Survey proposal was carried to the National Advisory Committee of Geological Research and was greeted with a whole lot less than enthusiasm. Bob Uffen was one of the strongest proponents for carrying out the drilling project and I think without his support it probably would not have been done. But it has been done, it has been highly successful and I am interested to note how much drilling has been recommended by you people today. Apparently scientific drilling is an accepted medium of carrying out earth science investigations.

It has been recommended that we have more similar symposia. Why not consider the idea of having a similar type of symposium during the same week as the meetings of the National Advisory Committee of Geological Research and Associate Committee on Geodesy and Geophysics? It has been suggested that we might have the National Advisory Committee early in the week, the Associate Committee would meet later in the same week, and there could be seminars of this nature for two or three days in between. Those people who were coming for one meeting or the other could carry

on through the seminar and those who were interested in both could devote a week to it. This sounds like a lot of time but many of the people are going to be attending one or the other of the committee meetings so it probably isn't as serious as all that.

I won't make any specific comments on the recommendations that were made - they stand by themselves - except to say that I am to meet with some Treasury Board representatives tomorrow and some of the recommendations that were made here will be brought to their attention because they strengthen my argument. I'd like to point out that a group of this nature, in making recommendations, can do a great deal of good. The fact that a group like this, which somebody remarked was the finest collection of earth science brains in the country, takes the trouble to meet and frame ideas for research goes a long way towards making these ideas become a reality. Even if some of you may feel that you haven't got out of this workshop quite what you wanted, I am sure that you started something that will pay off later.

Now this is a concluding remark about the International Geological Congress in New Delhi where a symposium on geological aspects of the upper mantle was held. Incidentally all that I have heard indicated it was probably the best organized, best presented discussion held at the International Geological Congress. Moreover, the group included more geophysicists than people who normally classify themselves as geologists, and they presented a good many of the papers on geological aspects of the upper mantle.

Recommendations were made there too and I extracted a couple of sentences out of the main recommendations. "We recommend especially that geologists seek ways to participate in the various international and interdisciplinary programs emphasized by the upper mantle committee. Of special interest will be the working group on deep drilling, volcanism and petrology, tectonics, submarine geology and the programs which study the

continental margins and island arcs and the world rift system". I think in one way or another the recommendations that have been put up today are those of the New Delhi session. It seems fairly obvious that we are now recognizing where work needs to be done and how we are going to have to do it.

Without taking any more of your time, I can conclude my remarks by saying again that you are all to be congratulated on the excellence of the sessions that were held here, and I hope that you can continue to have similar workshops on upper mantle and other topics as the need arises.