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BULLETIN D'INFORMATION

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VIème REUNION de la COMMISSION GRAVIMETRIQUE INTERNATIONALE

Paris, 7 - 11 Septembre 1970

La Commission Gravimétrique Internationale s'est réunie pour la 6ème fois, du 7 au 11 Septembre 1970, à Paris, dans les locaux de l'Institut d'Astrophysique (98bis, Boulevard Arago) ; ces locaux ayant été mis aimablement à la disposition des délégués par le Directeur de l'Institut : M. LALLEMAND.

La dernière réunion avait eu lieu en 1965.

Les participants composant l'Assemblée étaient d'une part, les délégués principaux représentant officiellement leur pays et d'autre part, les délégués de grands services géodésiques et géophysiques ainsi que des techniciens confirmés, spécialistes de questions particulières. Les participants au nombre de 100 provenaient de 29 nations différentes.

Certains pays n'ayant pu envoyer de délégués ont exprimé leurs regrets de ne pouvoir participer aux discussions de la C.G.I. On signalera en particulier les pays suivants : Bulgarie, Grèce, Liban, Portugal, Rhodésie, Tunisie, Turquie et Yougoslavie.

La plupart des pays représentés (ainsi que la Rhodésie) ont envoyé des Rapports Nationaux :

Allemagne Démocratique ..	(C. ELSTNER & B. SCHULER)
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Argentine	(Comité National de l'U.G.G.I.)
"	(Instituto Geografico Militar)
"	(E. BAGLIETTO & E. CERRATO)
Australie	(B.C. BARLOW)
Danemark	(O.B. ANDERSEN)
Etats-Unis	(D.A. RICE)
Finlande	(T. HONKASALO)
Inde	(Survey of India)
Japon	(National Committee)
Norvège	(S. BAKKELID)
Pologne	(Polish National Committee of Geodesy & Geophys.)
Rhodésie	(M.F. PODMORE)
Suède	(Geographical Survey Office of Sweden)
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PROGRAMME

Les questions scientifiques traitées au cours des réunions de la C.G.I. sont réparties dans les rubriques suivantes :

- I - Mesures absolues de la pesanteur.
Formule internationale de la pesanteur. (Sp. St. Gr. n°4-18).
- II - Mesures de pesanteur en mer. (Sp. St. Gr. n°4-20).
- III - Techniques spéciales des mesures de pesanteur. (Sp. St. Gr. n°4-21).
- IV - Nouveaux instruments gravimétriques.
- V - Réseau gravimétrique mondial de 1er ordre. (Sp. St. Gr. n°4-05).
- VI - Quelques problèmes de Géodésie physique.
- VII - Mesures de pesanteur en avion.
- VIII - Gradient vertical de la pesanteur.
- IX - Variation séculaire de la pesanteur.
- X - Divers.

Les résumés de nombreuses communications ont déjà paru dans le Bulletin d'Information n°23, p.I-10 à I-16.

ORDRE DU JOUR

Lundi 7 Septembre 1970

- 10 - 12 h
- 14 - 15 h : Inscription des délégués et distribution des documents.
- 15 - 16 h : Séance d'ouverture -
 - Prof. J. COULOMB, Président de l'U.G.G.I.
 - Prof. Y. BOULANGER, Vice-Président de l'A.I.G.
 - Prof. P. TARDI, Directeur du B.G.I.
 - Prof. C. MORELLI, Président de la C.G.I. et de la Section 4 de l'A.I.G.
- 16h30-17h : Rapport du B.G.I. (P. TARDI - S. CORON)
- 17 - 18 h : "On storage and retrieval of gravity data". (J.G. TANNER).

Mardi 8 Septembre

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|-----------------------------|--|----------------|
| 9h15-10h45 }
11h15-12h } | Mesures absolues de la pesanteur. | (J. TERRIEN). |
| 12-12h30 }
14h30-17 h } | Mesures de pesanteur en mer. | (J.L. WORZEL). |
| 17-18 h } | Choix des stations de mesures absolues.
Formule de pesanteur. | (C. MORELLI). |

Mercredi 9 Septembre

- 9h15-10h45 : Techniques spéciales des mesures de pesanteur. (L. PETTERSSON).
- 11h15-12h30 : Nouveaux instruments de pesanteur. (B. SZABO).
- 14h30-17h15 : Quelques problèmes de Géodésie physique. (C. MORELLI).
- 18 - 20 h : Réception par le Comité National Français de Géodésie et Géophysique.

Jeudi 10 Septembre

- 9h15-10h45 : Mesures de pesanteur en avion. (C. WILLIAMS).
- 11h15-12h30 : Gradient vertical de la pesanteur. (L. CONSTANTINESCU).
- Après-midi : Visite du Château de Versailles et dîner.

Vendredi 11 Septembre

- 9h15-10h45 : Réseau mondial de 1er ordre. (C. MORELLI).
- 11h15-12h30 : Variation séculaire de la pesanteur. (G. BARTA).
- 14h30-16h30 : Réseau mondial de 1er ordre. (C. MORELLI).
Résolutions.
- 16h30 : Champagne "Farewell".

SEANCE D'OUVERTURE

Le Prof. J. COULOMB, Président de l'Union Géodésique et Géophysique Internationale, ouvre la séance en souhaitant la bienvenue aux délégués :

" Mes Chers Collègues,

I apologize for giving in french the present speech. It shall be very short, just a wellcome, but my english would be too idiomatic.

Je remercie d'abord mon confrère le Prof. TARDI, qui m'a demandé de présider cette séance d'ouverture. Je suis heureux de vous accueillir, d'une part au nom des scientifiques français, d'autre part au nom de l'Union Géodésique et Géophysique Internationale qui patronne avec plaisir, quoique d'assez loin, l'activité de la Commission Gravimétrique Internationale. Les représentants de l'Association Internationale de Géodésie vous diront tout à l'heure de façon plus précise, les conseils qu'ils attendent de vous pour les guider dans la gestion du Bureau Gravimétrique International.

J'ai cependant regardé avec l'attention qu'elle méritait la circulaire qui vous indiquait, d'une part les sujets de vos débats, d'autre part les interventions annoncées (la correspondance entre les deux classifications restant à vrai dire un peu difficile à établir). Un point soulèvera, je suppose, des discussions passionnées : c'est la proposition du Dr. MATTHEWS de ne pas adopter la nouvelle formule internationale de pesanteur. (It is written : to adopt the new international gravity formula, but I suppose we should read not to adopt the formula). Les géophysiciens sont peut-être allés un peu vite en adoptant d'enthousiasme les données fondamentales des astronomes, mais il me semblerait personnellement difficile de s'arrêter au milieu du chemin. Une autre fois nous pourrions être plus conservateurs, comme les métrologistes qui attendent d'avoir deux chiffres significatifs supplémentaires avant de changer la définition de leurs unités.

Un autre sujet important, que vous traiterez en principe vendredi après-midi, sera l'extrapolation des anomalies de gravité aux régions sans observations. Aucune intervention n'est annoncée sur ce point qui devrait, me semble-t-il, être traité en liaison étroite avec les collègues s'occupant de la Géodésie dynamique par satellites, autrement dit avec les hommes du potentiel extérieur.

Certains d'entre vous sont venus de très loin pour assister à cette réunion, je les remercie de tout coeur. J'espère qu'elle ne les décevra pas et qu'ils seront récompensés de leur attachement par de très fructueux échanges de vues.

Je laisse au Prof. Tardi le soin de remercier tous les organisateurs, à commencer par Melle S. CORON, et de remercier aussi tous ceux dont l'aide nous a permis d'être ici ; je donne donc, sans plus tarder, la parole à notre éminent collègue le Prof. BOULANGER, Vice-Président de l'Association Internationale de Géodésie*.

Le Prof. Y. BOULANGER s'adresse à son tour aux délégués :

" Mr. President, Ladies and Gentlemen,

After a five years interval we again have the pleasure to meet in hospitable Paris for discussion of important problems in the field of gravimetry.

The role of the International Gravimetrical Commission in the development of gravimetric studies is great. The Commission encouraged the development of international cooperation aimed at solution of vital problems of gravimetry. Without this cooperation it would be impossible to establish the world gravimetric network of the first order, to elaborate the formula for the determination of the normal value of gravity, to determine the correction to the Potsdam system, to systematise and collect gravimetrical data in one Center ; and it is impossible to compile the gravimetric map of the World without all this.

The International Gravimetrical Commission stimulated the development of works on the aquatories of the World Ocean, which are so important for the determination of the Earth's figure and the study of the structure of the Earth's crust.

The amazing progress achieved in the last years in the field of elaboration of new instruments for gravity determinations on land, on ships and airborne, the accomplishment of astonishing precision in gravity measurements allow to project new scientific problems in gravimetry of fundamental importance to science. I would name some of these problems :

- The study of slow, secular and spontaneous changes of gravity. The data of these measurements will yield new information about physical processes taking place in the Earth's interior. The solution of this problem will need the application of all our resources in high-precision measurements of gravity.

- Increased technical possibilities allow to pose the problem of measuring the vertical gradient of gravity, the lack of which causes considerable difficulties in recalculation of gravity downwards and upwards. Perhaps the time is not far off when we shall be able to use maps of the vertical gradient of gravity as freely as we use now the maps of gravity anomalies.

- The rate with which gravimetrical measurements both on land and on sea are progressing suggest the task of compilation of gravimetric maps for individual continents and maps covering large parts of the aquatories of oceans. The compilation of such maps will need close international cooperation of interested countries.

There are many problems, similar to those mentioned above, which could be found in gravimetry, but I would not wish to take up time by enumerating them to such highly qualified gathering. They are well known to all those present here.

Since the field of gravity acceleration, which we study, is a global phenomenon, the efforts in gravimetry need continuous international cooperation. In this connection I would wish to hope that this cooperation will develop still further, yielding more and more results to a complex of sciences where these results are applied. We must, however, be fully aware that we, scientists, as yet encounter, and much more often than we would have wished, the preventing and prohibiting signs on the path of our cooperation, which drastically reduce the progress of scientific research. Our task, the task of scientists, is to overcome these difficulties and as far as possible clear the way of the signs inhibiting the development of world science.

In conclusion allow me to express the hope that this meeting of the International Gravimetric Commission shall be as interesting and as productive as the preceding sessions.

I would further wish to express in the name of the International Association of Geodesy and personally deep gratitude to you, Mr. President, and to Dr. Coron for your kind invitation to the meeting and for the opportunity offered to all of us to take part in the discussion of the important scientific problems in the field of gravimetry — Thank you. "

Le Prof. P. TARDI, Directeur du B.G.I., rappelle les réunions antérieures et évoque la mémoire des principaux gravimétristes et géodésiens décédés depuis 1965 :

" Chers Collègues, chers amis,

La Commission Gravimétrique Internationale se réunit ces jours-ci pour la 6ème fois. Le Bureau Gravimétrique International avait été créé en 1951 à l'Assemblée Générale de Bruxelles de l'U.G.G.I. et les réunions successives de la Commission ont eu lieu en 1953 - 1956 - 1959 - 1962 et 1965, c'est-à-dire, à une exception près, chaque fois l'année qui précède une Assemblée Générale de l'Association de Géodésie. En l'occurrence il s'agissait des Assemblées Générales de Rome, Toronto, Helsinki, Berkeley et Lucerne. — Le but de ces réunions consiste à préparer les discussions et surtout les décisions à prendre par l'Assemblée Générale de l'année qui suit, Assemblée Générale qui, seule, a un pouvoir de décision. Il en est de même pour tous les régimes parlementaires. C'est dans cet état d'esprit que nous avons préparé l'ordre du jour ("l'agenda" pour parler anglais) de notre réunion.

Mais avant de voir avec vous le détail de cet ordre du jour, je voudrais que nous rendions un hommage à la mémoire des Collègues qui avaient assisté à notre dernière réunion en 1965 et qui ont disparu depuis. Je ne vous citerai que les principaux d'entre eux, ceux qui ont été vraiment des "gravimétristes". Si j'ai oublié quelques noms qui vous paraissent dignes d'être évoqués, je vous demanderais de me les indiquer afin qu'ils puissent figurer dans le texte de mon discours.

J'évoquerai ces noms en rappelant le pays dont ils sont la fierté :

Etats-Unis

Le Prof. W.D. LAMBERT, ancien Président de l'Association de Géodésie, Directeur de la section de gravimétrie et astronome du Coast and Geodetic Survey à Washington, après y avoir été Mathematician Senior, décédé en 1969 à Washington.

France

Le Prof. J. VIGNAL, décédé à Paris le 20 Février 1969, qui s'était particulièrement intéressé aux influences des variations de la pesanteur sur les nivellements de précision.

Grande-Bretagne

- B.C. BROWNE, ancien Président de la Section IV de l'A.I.G. et de la Commission Gravimétrique Internationale, décédé à Cambridge en 1968.

- De GRAFF HUNTER, ancien Président de l'Association de Géodésie, décédé en Australie où il s'était retiré le 23 Février 1967, à l'âge de 85 ans.

- M. HOTINE, décédé le 12 Novembre 1968, à l'âge de 70 ans, après un séjour de plusieurs années aux U.S.A. et qui a été un des cerveaux les plus puissants de notre génération (nous étions du même âge). Il a laissé un ouvrage posthume d'un exceptionnel intérêt : "Mathematical Geodesy" publié par l'E.S.S.A. à Washington.

Italie

- P. DORE qui avait succédé à G. Cassinis (décédé lui-même en Janvier 1964) comme Président de la Commission Géodésique Italienne, décédé le 6 Mai 1969.

- S. BALLARIN, décédé le 11 Mars 1969 et qui avait contribué au calcul des premières tables de la gravité normale.

Pays-Bas

F.A. VENING MEINESZ, ancien Président de l'Association de Géodésie, de 1933 à 1945 et de l'U.G.G.I. (1948-1951) qui fut un très grand gravimétriste (pas seulement par sa très haute taille) aussi bien dans le domaine expérimental que dans le domaine théorique, décédé à Amersfoort le 10 Août 1965 à l'âge de 79 ans.

U.R.S.S.

Le Prof. MEŠCHERIKOV qui a été un des plus importants théoriciens de la gravimétrie.

Je sais Messieurs que ma liste est incomplète, mais je n'ai voulu citer que les plus représentatifs de nos morts.

Pour honorer leur mémoire, je vous demande de vous lever et de garder quelques instants de silence.

.....

Peut-être parce que j'ai atteint un certain âge (je dirais plutôt un âge certain), je suis toujours un peu ému par de telles commémorations et un tel hommage, et je ne puis m'empêcher de penser : hodie ei, cras mihi. Je traduis en anglais : "to day for them, tomorrow for me".

Mais le meilleur moyen d'honorer la mémoire de nos morts est de continuer l'oeuvre que nous avons entrepris avec eux et c'est ce à quoi nous allons nous employer aujourd'hui et les jours suivants.

.....

Le Prof. Tardi signale que l'ordre du jour a été déjà indiqué dans le Bull. Inf. n°23 et que les différentes questions abordées au cours de ces réunions ont été groupées dans un document qui vient d'être distribué à tous les délégués.

Il se borne donc à préciser quelques points de l'ordre du jour en particulier, donne des détails sur les "manifestations" amicales et culturelles ; et en concluant :

"J'émetts le voeu pour terminer que cet emploi du temps vous conviendra et je concluerai en citant cette devise qui, paraît-il, était fréquente dans le Far West :

Don't shot on the pianist, he did at his best".

Le Prof. C. MORELLI, Président de la Section IV de l'A.I.G. et de la C.G.I. fait un exposé général sur les problèmes actuels de la Gravimétrie, insiste sur l'établissement du réseau gravimétrique mondial homogène (F.O.W.G.N.), oeuvre de longue haleine qui viendra bientôt à terme ; il signale que le groupe de travail "Bedford Group" s'est réuni pendant 3 jours, à Gif, dans les environs de Paris, afin de pouvoir discuter des divers résultats de calculs et les présenter à la Commission.

Après le "coffee break" le Prof. Tardi passe la parole au Dr. S. CORON pour présenter le Rapport d'Activité du Bureau Gravimétrique International. (voir page suivante).

Ensuite, le Dr. FALLER fait un exposé sur "Storage and retrieval of gravity data" at Earth Physics Branch, Ottawa. (p.25).

BUREAU GRAVIMETRIQUE INTERNATIONAL

Paris

The main activities of the B.G.I. set up in 1951, can be summarized as follows :

- A - Collection of gravity data
- B - Information
- C - Distribution

A - COLLECTION OF GRAVITY DATA

- The library, properly so called, contains 4.500 articles dealing with geodesy and geophysics branches. Papers are classified by author and discipline under a classical card form.

It will be considered, later, to proceed to the recording of the papers on punched cards with key words.

- The maps holding, includes : gravity maps of isanomales and,
: maps of mean values
which are classified according to the type of anomalies : free-air, Bouguer or isostatic. About 1.000 maps are now indexed.

- The sketches library, gathered sketches of gravity sites, extracted from publications or obtained directly from scientists themselves. Sketches are collected following to the B.G.I. classification : by square of $10^{\circ} \times 10^{\circ}$ and by degree of latitude and longitude. (See code p. 32 in Bull. Inf. n°5).

For the time being we have about 5.500 sketches.

- Punched cards , (see Bull. Inf. n°5 and 11).

As suggested in 1962 and 1963 at the International Gravity Commission, the B.G.I. carries on to collect gravity data on punched cards, according to the adopted format.

Now, the distribution of punched cards is approximately the following :

	<u>Index Card</u>	<u>Complementary Card</u>
Sea measurements	45.000	20.000
Continental measurements :		
- Europe	72.000	64.000
- Asie	8.000	8.000
- Afrique	60.000	25.000
- Amerique	20.000	20.000
- Australasie	19.000	2.540
- Antarctique	2.500	

These data are spreading over 45 countries.

Since 1969 a great number of data have been recorded on magnetic tapes to make easier computation.

B - INFORMATION

1°) The B.G.I. supplies any person with individual gravity information when required.

This information concerns particularly :

- the sites of gravity stations,
- the gravity anomalies maps for special studies, for instance : studies of grabens, continental platforms,
- the mean values of gravity anomalies.

2°) The B.G.I. goes on with the publication of the Bulletin d'Information. Since the meeting of the A.I.G. (Luzern 1967) 7 Bulletins have been published. (See annexe p.24.).

Usually in **each** Bulletin, the second part is reserved for the list of publications received at the B.G.I. In the first part various subjects are reported.

So, in the Bull. Inf. n°22 we compiled information concerning gravity at sea with maps of tracks.

In the Bull. Inf. n°23 we listed the new sketches or descriptions of gravity sites received at the B.G.I. (Additif to the Bull. Inf. n°15 and 16), and we described the special stations indexed on the punched cards.

In the Bull. Inf. n°21, statistical problems have been presented.

3°) The following maps of gravity anomalies have been prepared, in the format previously adopted :

- Maps of 1/1.000.000°
Sheets of Rabat and Laghouat (1969-1970).
- Map of about 1/10.000.000°
"Carte des anomalies de Bouguer, Europe - Afrique",
3rd edition (1970-1971).

This map is covering a big part of Africa (between 0° and 38°N and until 40° E.G.). Some geologists and geophysicians would like to see the establishment of a Bouguer anomalies map printed on a geological support, for the whole Africa. The I.G.B. which has already in preparation such a map is willing to collaborate with the National Services to complete and publish it in accordance with the I.G.C.

Remarks concerning the map of Africa

"Several research groups from the United Kingdom have undertaken gravity measurements at various places in Africa during the past few years ; notably from the University of Newcastle (R.W. GIRDLER & W.H.C. SOWERBUTTS), the University of Leicester (Dr. M.A. KHAN) and the Institute of Geological Sciences (D. MASSON SMITH, R.B. EVANS, E.M. ANDREW & A.J. BURLEY). Countries visited have included Kenya, Tanzania, Malawi, Swaziland and Lesotho. The University of Newcastle (W.H.C. SOWERBUTTS) has compiled a punched-card index of stations in and around the Eastern Rift and the I.G.S. has some maps in preparation.

At the present stage it would probably be worth-while to commence compilation of a gravity map of Africa, possibly at the 1/5.000.000° scale or even 1/1.000.000° for some regions. In compiling an overall map it would be necessary to decide in advance whether to compile Bouguer or isostatic anomalies. There is good evidence of isostatic compensation over several major regions".

(Dr. W. BULLERWELL)

"By the end of the year, the first gravity map (Great Dyke Survey and Bouguer anomaly map of the Central trip of Rhodesia will be available. In the future it is hoped to extend the present survey to cover the Western and Eastern parts of Rhodesia and connect with gravity surveys in adjacent countries..."

(Nat. Rep., F. PODMORE)

Prof. Y. BOULANGER indicates that the U.S.S.R. establishes world gravity anomalies maps (1/5.000.000°) and presents six maps concerning North and Central Americas and Oceans. He plans to extend these maps to the African continent.

- 4°) The computation of mean gravity values is in preparation at the I.G.B. (See Bull. Inf. n°17, p. 9). Particularly, we are planning to bring up to date the free-air mean values by 5° x 5°.
- 5°) In the last months, the I.G.B. prepared a world map showing the tracks of gravity at sea. The chosen support was the one of Lamont-Doherty Geological Observatory, as Dr. Talwani suggested.

This world map is composed of 12 sheets on which we distinguished cruises of each country.

Three of these sheets have already been published in the Bull. Inf. n°22 (reduced scale). The others will be published later, probably in the Bulletin d'Information.

C - DISTRIBUTION

The Bulletin d'Information published by the I.G.B. is sent, free of charge, to about 220 geodesists or geophysicists.

Two or three issues are published each year according to the financial resources of the I.G.B.

The general maps of anomalies of great interest to the geophysicists are at their disposal at the I.G.B., on request.

The listing of gravity data on punched cards (or copies of punched cards) are sent to the Offices which inquire to the I.G.B., however, the data not yet published cannot be reproduced without the agreement of the Office concerned.

We tried to make maps as complete as possible, this can be realized only with the collaboration of everyone.

In particular, the preparation of general maps of gravity tracks at sea necessitated a great exchange of mail between the different Services and we would like to point out the kind assistance we received from all participants.

On the other hand, the I.G.B. is ready to plan any work that the International Gravity Commission will think useful or interesting for the future. Every suggestion on this matter will be much appreciated.

Prof. P. TARDI

Dr. S. CORON

BULLETINS D'INFORMATION

N°17, Décembre 1967

- Compte-rendu of the Section IV (Gravimetry) of I.A.G., Luzern, Sept.25 - Oct.7, 1967.
 - Absolute gravity measurements.
 - First order world gravity net, standardization problem.
 - Gravity measurements at sea.
 - Airborne gravity measurements.
 - Resolutions.

N°18, Mars 1968

- Gravity measurements at sea.
- Gravimetrical test-work.
- Bibliographie : Oct. 1966 - Sept. 1967.

N°19, Décembre 1968

- Gravity measurements at sea
- Détails sur le géoïde (Europe Occidentale).
- Bibliographie : Oct. 1967 - Sept. 1968.

N°20, Mars 1969

- Recherches gravimétriques et magnétiques de la structure des Océans : A.G. GAINANOV.
- Mesures de pesanteur en mer : Etats-Unis, France, Japon.
- Travaux en Argentine.
- A superconducting gravimeter : W/A/ PROTHERO, Jr & J.M. GOODKIND.
- Bibliographie : Oct. 1968 - Mai 1969.

N°21, Novembre 1969

- Estimation des anomalies inconnues à l'aide d'un modèle stochastique : M. ALBUISSON.
- Quelques fonctions aléatoires utilisées en gravimétrie et leurs propriétés : J.M. MONGET.
- Bibliographie : Juin 1969 - Oct. 1969.

N°22, Mars 1970

- Mesures absolues de la pesanteur.
- Mesures en mer.
- Bibliographie : Oct. à Déc. 1969 - Jan. à Fév. 1970.

N°23, Juin 1970

- International Gravity Commission, 7 - 12 Sept., Paris.
- Stations gravimétriques :
 - Nouvelle station gravimétrique (Rome).
 - Répertoire des stations gravimétriques (Schémathèque B.G.I.)
 - Stations de référence et de contrôle utilisées par chaque pays pour ses campagnes et codifiées au B.G.I.

STORAGE AND RETRIEVAL OF GRAVITY DATA

R.J. BUCK, J.G. TANNER and R.K. McCONNELL

Earth Physics Branch, Ottawa, Canada

The existence of computer systems capable of processing large volumes of data for a variety of applications has led to the development of computer techniques to store and retrieve information. Storage and retrieval systems are of added interest to gravimetrists because of their value as a means of establishing and maintaining uniform gravity standards over large areas of the Earth. In Canada the Earth Physics Branch at Ottawa operates a storage and retrieval system which serves as a reference for all gravity work in Canada. This data and program library is used extensively by the mineral and petroleum exploration industry and by geophysical agencies to obtain basic information in a form suitable for application to their program.

Experience at the Earth Physics Branch with storage and retrieval systems has shown that the largest computers usually make for the most economic operation. For this reason the data library is maintained on an IBM 360, model 85 computer. Again for economic reasons, magnetic disk is used as the storage medium for the gravity data.

The main files of the data library are two output files called the Control Station File and the Principal Facts File respectively. The first of these consists of about 6,000 base stations throughout Canada and elsewhere and is used to provide the national datum and scale for gravity measurements. The Principal Facts File consists of about 150,000 gravity observations reduced to Bouguer and free air anomalies. This latter file is the one used most frequently because of its importance in providing data for geophysical, geodetic and geological purposes.

Important aspects of this data library are the accuracy or reliability factors associated with all the measured parameters. In some cases, such as the co-ordinates giving the location of the station, where it is not always possible to specify the accuracy of the particular parameter, the source of that parameter is given. Experience with data storage and retrieval has clearly indicated that the value of data libraries is greatly reduced if a comprehensive system to specify the source and accuracy of observed data is not maintained.

The program library basically consists of a set of subroutine and standard programs which are used to perform specific operations on the data. These routines can be called upon by other programs of linked through the job control language to carry out a particular operation on the data. The development of this program library has proceeded to the point where the programming needed to store, update and retrieve the data has been completed. Documentation for this programming is in the process of being completed.

In the future it is proposed to expand the program library to provide for improved analysis of the data and thereby improve upon the present system of assigning reliability factors.

The most common form of output from the system is graphical display. The medium for graphical display is a flat-bed plotter which is operated from magnetic tapes prepared on the computer. Although both line and point plots with printed values can be obtained on the plotter, about 70 % of the plotter output consists of stations plots showing the value of the gravity anomaly or some related parameter.

RESOLUTIONS ADOPTED BY THE
INTERNATIONAL GRAVITY COMMISSION
PARIS, SEPTEMBER 1970

(Provisional text)

Resolution n°1

The International Gravity Commission

recommends that absolute values of gravity with the presently possible accuracy (few μ gals) be adopted as a reference datum in geodetic and geophysical problems connected with variations of the Earth's physical conditions (secular variation of gravity, sea level, crustal deformations, etc...).

La Commission Gravimétrique Internationale

recommande que les valeurs absolues de la pesanteur, avec la meilleure précision actuellement possible (quelques μ gals), soient adoptées comme base de référence pour les problèmes géodésiques et géophysiques relatifs aux variations des conditions physiques de la Terre (variation séculaire de la pesanteur, niveau de la mer, déformations de la croûte...).

Resolution n°2

The International Gravity Commission

recommends with regard to the presentation of gravity anomalies, that all necessary information dealing with measurements and reductions, whatever their form of publication, be clearly expressed and that the (international) reference gravity formula be mentioned.

La Commission Gravimétrique Internationale

recommande que dans la présentation des anomalies de la pesanteur, toutes les informations utiles sur les mesures et les réductions, publiées sous n'importe quelle forme, soient clairement exprimées, et que la formule de référence (internationale) soit indiquée.

Resolution n°3

The International Gravity Commission

considering the recommendation of the 1967 I.U.G.G. Assembly dealing with the use of instruments of different characteristics and of equal accuracy for the measurements of the calibration lines,

wishes that absolute gravity measurements should be carried out with the Dr. FALLER's transportable apparatus along the Argentinian calibration line at the Tucuman, Bahia-Blanca and Ushuaia stations.

	φ	(g)
Tucuman	- 27°	978.910
Bahia-Blanca	- 35°	980.070
Ushuaia	- 55°	981.610

La Commission Gravimétrique Internationale

considérant la recommandation de l'Assemblée de l'U.G.G.I. (1967), relative à l'utilisation d'instruments de caractéristiques différentes et d'égale précision pour les mesures des bases d'étalonnage,

souhaite que des mesures absolues de pesanteur soient faites avec l'appareil transportable du Dr. FALLER sur la ligne d'étalonnage de l'Argentine, aux stations de Tucuman, Bahia-Blanca et Ushuaia.

	φ	(g)
Tucuman	- 27°	978.910
Bahia -Blanca	- 35°	980.070
Ushuaia	- 55°	981.610

Resolution n°4

The International Gravity Commission

approves the important role of the I.G.B. with regard to the collecting, the analysis and the distribution of gravity data for all contributor's benefit and particularly to the clarifying and maintaining of all details of F.O.W.G.N. and,

wishes that the I.G.B. should actively maintain its information role by means of the Bulletin d'Information and more especially by keeping up to date the track maps of gravity measurements at sea and the state of the various maps of mean gravity anomalies.

La Commission Gravimétrique Internationale

reconnait le rôle important du B.G.I. dans la collecte, l'analyse et la distribution des données de pesanteur, pour le bénéfice de tous les organismes participants, en particulier, dans la clarification et la conservation de tous les détails du F.O.W.G.N.

et souhaite que le B.G.I. continue activement son rôle d'informateur par le canal du Bulletin d'Information particulièrement, en tenant à jour les cartes des croisières gravimétriques en mer et l'état des différentes cartes d'anomalies moyennes de la pesanteur.

Resolution n°5

The International Gravity Commission

recognizes the importance of mean gravity anomalies in worldwide studies and advantages of having a uniform system of block sizes which are most suitable for these studies,

recommends that a special working group be formed under the I.G.C. to study suitable block sizes for recommendation to be presented, if possible, in Moscow meeting of 1971.

La Commission Gravimétrique Internationale

reconnait l'importance des anomalies moyennes de pesanteur pour des études mondiales et l'avantage d'avoir un système uniforme de "blocs" dont les dimensions seraient les plus appropriées pour ces études,

recommande qu'un groupe spécial de travail soit formé, dans le cadre de la C.G.I. pour étudier les meilleures dimensions à donner à ces "blocs" en vue de présenter une proposition, si possible, à l'Assemblée de Moscou en 1971.

" " " " : Bull. Inf. n°17, p.12
(As. Gén., A.I.G., Lucerne, 1967).

TABLE A

Summary of measurements with the HAMMOND-FALLER apparatus

<u>Site</u>	<u>Location</u>	<u>Value (mgal)</u>
National Bureau of Standards Gaithersburg, Md.	Rm. 01, Bldg. 202 (NBS-3)	980 102,40 $\pm$ 0.06
National Physical Laboratory Teddington, England	Rm. B-17, Bushy House (BH)	981 181.935 $\pm$ 0.05
Bureau International des Poids et Mesures, Sèvres, France	Salle 1, BIPM Laboratory (Sèvres A)	980 925.965 $\pm$ 0.05
Air Force Cambridge Research Laboratories, Bedford, Mass.	Pier 1, Seismic Facility (2 measurements)	980 378.68 $\pm$ 0.05 980 378.69 $\pm$ 0.05
Geophysical Institute, Univer- sity of Alaska, Fairbanks, Alaska	Rm. 1 1, Patty Bldg.	982 234.96 $\pm$ 0.05
Universidad Nacional de Colombia, Bogota, Colombia	Quarto 111, Edificio Matematica y Fisica	977 390.00 $\pm$ 0.10
University of Denver, Denver, Colorado	Rm. 8, Science Hall	979 597.72 $\pm$ 0.05
Scott Laboratory of Physics Wesleyan University Middletown, Connecticut	Rm. 7B, Scott Lab. (Middletown A)	980 305.31 $\pm$ 0.05

Then, J.E. FALLER compares the laser interferometer results with other recent absolute measurements. A tentative correction to the Potsdam system is made (table B).

TABLE B

Summary of recent measurements of the acceleration due to gravity				
Year of publication	Location and Author	Value implied at site indicated (a) (mgal)	Difference from Potsdam system (mgal)	Method
1969	NBS-3, Hammond-Faller	CB: 980 104.24 $\pm$.08	13.76 $\pm$ 0.08	TPFF, moving interferometer reflector
1966	NBS-2, Tate	CB: 980 104.77 $\pm$ 0.45	13.23 $\pm$ 0.45	TPFF, photoelectric detection, falling enclosure
1963	Princeton, N.J., Faller	CB: 980 103.8 $\pm$ 0.7	14.2 $\pm$ 0.7	TPFF, moving interferometer reflector
1969	NPL, Hammond-Faller	BFS: 981 181.865 $\pm$ 0.06	13.60 $\pm$ 0.08	TPFF, moving interferometer reflector
1967	NPL, Cook revised 1969 (b)	BFS: 981 181.81 $\pm$ 0.13	13.66 $\pm$ 0.14	SFM, photoelectric detection
1969	BIPM, Hammont-Faller	A : 980 925.965 $\pm$ 0.05	13.795 $\pm$ 0.09	TPFF, moving interferometer reflector
1969	BIPM, Sakuma (c)	A : 980 925.965 $\pm$ 0.006	13.795 $\pm$ 0.070	SFM, moving interferometer reflector

(a) CB : Commerce Base - BFS : British Fundamental Station - A : Sèvres, point A

(b) A.H. COOK & J.A. HAMMOND, Metrologia, V.5, n°4, Oct. 1969, p.141-142.

(c) This latest result was communicated to J. FALLER by A. SAKUMA in October, 1969.

M. TERRIEN insiste sur le fait que c'est la première fois que des résultats de valeurs absolues peuvent être utilement comparés en un aussi grand nombre de régions du globe.

Il présente ensuite les travaux de A. SAKUMA (momentanément au Japon) réalisés au Bureau International des Poids et Mesures, Sèvres, France :

Méthode utilisée avec l'appareil de mesure absolue du B.I.P.M. et résultats sur trois ans d'observations. (Doc. I-2).

"Une première station permanente de gravimétrie absolue vient d'être constituée au B.I.P.M. Cet appareil a été mis en oeuvre après 10 ans d'études, dont les trois dernières années ont été consacrées à la recherche des causes éventuelles d'erreurs systématiques et à l'amélioration de la précision de la mesure de g.

Ce gravimètre absolu possède à l'heure actuelle une sensibilité et une exactitude de mesure supérieures à $3 \mu\text{gal}$ ($< 3 \times 10^{-9} \text{ g}$) et en conséquence la perturbation de g due à l'effet luni-solaire peut être nettement déterminée.

.....

Valeurs de g d'Août 1967 à Août 1970

Les valeurs de g au point de mesure Sèvres A₂ ont été révisées en deux fois selon l'état d'avancement des études sur l'élimination des erreurs systématiques. Ces corrections, de l'ordre de $- 10 \mu\text{gal}$, sont dues uniquement aux erreurs systématiques apparues dans la détermination de la longueur de l'étalon.

Les valeurs moyennes les plus probables, après les corrections théoriques de la marée gravimétrique et les écarts types sur une mesure, sur les trois dernières années, sont donc :

g _{A2}	= (980 925 662 ± 13)	μgal	Août- Sept.	1967
"	= (55 ± 25)	"	Avril	1968
"	= (51 ± 19)	"	Août-Sept.	1968
"	= (50,5 ± 08,2)	"	Juin-Juill.	1969
"	= (49,0 ± 05,4)	"	Août-Sept.	1969
"	= (54,1 ± 10,6)	"	Oct.- Nov.	1969
"	= (58,7 ± 5,8)	"	Décembre	1969
"	= (60,3 ± 9,0)	"	Janvier	1970
"	= (50,0 ± 9,1)	"	Février	1970
"	= (57,9 ± 2,8)	"	Août	1970

Ces résultats ne permettent pas de mettre en évidence la variation séculaire ni la variation saisonnière de la pesanteur. Néanmoins nous pouvons tirer une limite supérieure concernant ces phénomènes géophysiques importants : la valeur de g a été constante à $2 \times 10^{-8} \text{ g}$ pendant la durée des trois années considérées.

Problèmes dans le futur

Les corrections théoriques de la marée gravimétrique atteignent souvent plus de 100 μ gal. De plus ces corrections varient quelquefois de plus de 0,7 μ gal par minute. Ainsi est-il très important d'établir les vraies corrections locales de la marée gravimétrique pour la gravimétrie absolue de haute sensibilité. Nous avons comparé jusqu'à présent les trois tableaux de corrections de marée gravimétrique calculés par 3 organisations spécialisées dans ce domaine et il s'est avéré que le tableau établi par l'Institut de Physique du Globe à Strasbourg (grâce à la collaboration du Prof. LECOLAZET) sur 378 ondes en tenant compte des déphasages locaux de la marée, est le plus cohérent avec les mesures absolues effectuées à l'aide de notre gravimètre. Un autre problème est la perturbation de la valeur moyenne de g par les variations de l'attraction des masses atmosphériques et par les déformations du globe qu'entraînent ces masses et conduisant à l'affaissement du sol.

Notre prototype atteignant aujourd'hui une sensibilité de l'ordre de 1 μ gal, de tels problèmes géophysiques pourront être étudiés dans l'avenir avec cet appareil.

Une autre station permanente de gravimétrie absolue, analogue à celle du B.I.P.M., sera réalisée dans un proche avenir à : l'International Latitude Observatory, Mizusawa (Japon), en vue de l'étude de la variation séculaire du géopotential".

G.A. BELL speaks about :

The absolute determination of the gravitational acceleration at Sydney, Australia.

This determination has been made at the National Standards Laboratory, Chippendale, N.S., W. Australia, using the ballistic method in which a corner reflector is projected vertically in a vacuum and its passage timed between horizontal planes at a known vertical separation :

The beam splitter of a Michelson type interferometer divides the collimated beam of white light from a zirconium arc. A hollow cube corner reflector is projected vertically up and reflects the vertical beam of light through 180° on to the horizontal reference mirror whence it is reflected back through the cube corner to the beam splitter and focussed on to the detector.

The rays which leave the beam splitter horizontally are turned through 90° and part is reflected at the top surface of a length bar and part at a mirror optically contacted to the lower end of the bar.

When the optical path of the rays reflected from either end of the length standard is equal to the optical path through the corner reflector, the recombined rays form an interference pattern which is detected by the photo diode and displayed on the CRO screen. Thus, the distance travelled between signals from the upper and lower stations is determined precisely in terms of the length standard.

...

The determination of the length of the standard at 20°C is estimated to be in error by not more than 1 in 10^7 .

The intervals between consecutive passages of the corner reflector through each measuring plane must be measured to 10^{-8} second ; this is achieved by timing the occurrence of the central fringe in each light interference pattern...

The corner reflector comprises 3 fused silica aluminised mirrors adjustably mounted in an aluminium alloy body. They are flat to $0.025 \mu\text{m}$ and are adjusted to be mutually perpendicular to 0.2 sec. using a Michelson interferometer and a laser source.

Results :

To the middle of June 1970, a large number of throws had been made with the catapult and the whole apparatus adjusted to its optimum condition. In the last week of June, 51 determinations were made over a period of 3 days which gave the result :

$$g = 979\,671,34 \text{ mgal}$$

with a standard deviation of : 0,19 mgal

This value is referred at a point 12 m. above the floor in room B. 37 of the Nat. Stand. Lab. The corresponding value at floor level at the B.M.R. gravity station is : 979 671,7 mgal.

The difference between this value and the value obtained in "Potsdam" system (979 685,7) is - 14.0 mgal, in good agreement with results derived from other recent absolute measurements.

R. SCHULER presents the paper :

Absolute gravity experiments at Potsdam and in Berlin. (Doc.I-4).

In the Geodetic Institute, Potsdam, the method of reversible pendulum is applied (2 pendulums swinging on the same support).

A first apparatus has two 25 cm. pendulums of brass furnished with interchangeable knife-edges.

An another apparatus has stable knife-edges on which 3 pairs of quartz pendulums of the length 37,5 - 50 and 75 cm. are swinging.

...

In 1968 and 1969 six sets of measurements with 25 cm. pendulums have been achieved using steel and agate for knife-edges and bearings.

...

Measurements by using quartz pendulums had been performed in 1969. In this time four sets of measurements have been achieved. Previous investigations had indicated that attention must be paid to the manner of fixing knife-edges. To avoid electrostatic charges the pendulums were coated with aluminium.

The variation of every length was very little. Therefore every set of measurements enclosed the timing of swings only and investigations for the determination of corrections. Length measurements could be executed independently. The following arrangement shows the corrections for Δg_B , dilatation Δg_D , deformation of the plane bearing Δg_E , atmospheric pressure relative to the end standard Δg_K .

Pend.	37,5 cm.	50 cm.	75 cm.	25 cm.
g_B	-0,09 mgal	-0,24 mgal	0,40 mgal	-0,41 mgal
g_D	0,20	0,27	0,39	-
g_E	0,64	0,49	0,33	-0,96 -1,03
g_K	1,7	1,28	0,96	0,80

The measurements with the 25 cm. brass pendulums and quartz pendulums yielded gravity values that allowed the formation of a final result using the weighted mean values of both instruments. As the quartz pendulum measurements have shown a higher accuracy the weights are different. The final result of all experiments at Potsdam is

$$g_{\text{Potsdam}} = (981,2601 \pm 0,0003) \text{ cm s}^{-2}$$

referred to the reference level of the Potsdam system (pillar SO, 87 m). This value shows a deviation of -13,9 mgal to the former value of Potsdam.

In Berlin, at the Deutsches Amt für Messwesen und Warenprüfung (DAMW), the method of the free fall is applied. The apparatus is operating according to a variation of the three-position experiments.

The fall-distances were founded by the theory of error. Provided that the total fall-distance is 1 m, the uncertainty of the measured value of gravity is a minimum, if the distance between the upper and the middle measuring point amounts to 180 mm and the distance between the middle and the under measuring point amounts to 770 mm. The distance between the release-point and the upper measuring point is 50 mm.

The experiments are achieved in an evacuated tube of steel of a length of 1.400 mm and an inside diameter of 117 mm. The pressure within the tube amounts to 10^{-5} Torr.

The three measuring points are realized by light-beams.

...

The mutual distance of the light-beams is measured by a vertically hanging invar rule, which is permanently inside the tube. The marks having the distance of the light-beams consist of glass-lamina covered by metal foil and are engraved as a slit of a width of $1,5 \mu\text{m}$. By adjusting of the microscopes, the slit-images of the light-beams are superposed photoelectrically with the marks of the rule. By this means, the distance of the rule are transposed to the light-beams and the vertical fall-line of the falling body is determined.

The falling body is a brass cylinder of a length of 100 mm and a diameter of 15 mm. In the center of gravity a mark is placed of the same condition as the marks of the rule.

The light-pulses, being produced if the falling body is passing the light-beams, have a bell shape. Their half-value period is from $1,5 \mu\text{s}$ to $0,3 \mu\text{s}$ in dependence of falling speed. The light-pulses are picked up by photomultipliers and forwarded to the timing-installation, equipped with two 10 MHz-counters. Those permit to measure the times of fall with an uncertainty of $0,1 \mu\text{s}$.

In the beginning of 1970, the measurements were finished.

The result for the observation station in Berlin - Friedrichshagen is :

$$g = 981\,266,31 \text{ mgal} \pm 0,50 \text{ (m.s.e.)}.$$

At this station, the value of g in the Potsdam reference system is :

$g = 981\,279,69 \text{ mgal}$; therefore, the correction to the system of Potsdam is $-13,65 \text{ mgal}$.

It is noted that the following corrections were considered in the results of observations :

- extension of the rule by weight,
- " " " " " vacuum
- temperature of rule
- differences of pulse timing, caused by different half-value periods of light pulses,
- gradient of gravity,
- microseisms.

C. ELSTNER speaks :

On the variations of amplitudes and phase differences of two pendulums swinging on the same support. (Doc. I-5).

"Disturbances are investigated which are introduced by the sway effect into the time-functions of amplitudes and phases of 2 pendulums swinging on the same support. Rate and period of the disturbances are represented as functions of the initial conditions and the quotient (q) formed by the parameter of elastic coupling and the differences of the periods of the 2 pendulums. Hence it follows that the perturbations of the amplitudes and phase differences are biggest if $|q| = 1$. With increasing $|q|$ the influence of the initial conditions is growing up.

The results of absolute and relative pendulum measurements confirm the theoretical statements. In the course of the Potsdam absolute gravity measurements with the 25-cm reversible pendulum apparatus some observations were made during several hours. The sway effect for this apparatus is very big caused by the special large distance between the knife-edges and the centres of gravity of the reversible pendulums, the coupling effect amounts :

$$\gamma = 1.2 \cdot 10^{-5} \text{ s}.$$

$$\gamma = 0.6 \cdot 10^{-5} \text{ s is valid, for the small distances.}$$

The observed and calculated time-functions of amplitudes and phase difference are shown. The observations are reduced with respect to the damping. The small deviations between observed and calculated values are mainly generated by the observation errors of the initial values. May be that also weak seismic pulses during the measurements affected the observations.

Furthermore, a special experiment with a relative apparatus was accomplished to control the behaviour of the phase difference for different values of q . The synchronism of the used invar pendulums was distributed up to $3 \cdot 10^{-5} \text{ s}$ by the aid of the magnetic field of a coil. The results of different measurements confirmed the features of the calculated variations of the phase difference".

S. GERMAN reports on the measurements at the Physikalisch-Technische Bundesanstalt, Braunschweig. (Doc. I-6).

Method : Free falling bar of quartz (length ca. 2 m
diameter 75 mm
weight 5 kg)

coated with a photosensitive layer (Kodak-MR).

Sparks : Half-width of duration (in the ultraviolet)
ca. 10^{-7} s 130 sparks /s

Vacuum : $2 \cdot 10^{-5}$ Torr.

Movement of the apparatus due to start and microseism : $< 2 \cdot 10^{-7}$ m.

Results : Provisional value for the reference-point of the apparatus.

$$g = 9\,812\,523 \text{ m s}^{-2}$$

with a standard deviation $s = 2 \cdot 10^{-5} \text{ m s}^{-2}$.

The Potsdam System value of this point is :

$$g = 9\,812\,536 \text{ m s}^{-2}.$$

Therefore the experiments lead to a correction of :
 $(-13 \pm 2) \cdot 10^{-5} \text{ m s}^{-2}$.

The big amount of the standard deviation results from the uncertainties of the length-measurement (unquality of the different lines). Possible improvements would be very expensive in time and money and would not reduce the standard deviation for a considerable amount. So the provisional value has the character of a final value. The significance of having finished this measurement with its somewhat out of date method is seen in the confirmation of the expected value with an absolutely independent method in spite of the somewhat big amount of the standard deviation, compared with that of the results of modern methods".

A la 2ème séance de la matinée (11h15), M. LACOMBAT décrit rapidement : le gravimètre transportable de type absolu , en cours d'étude au Centre de Recherche THOMSON-CSF.

"Nous cherchons à mettre au point un appareil de précision qui puisse être utilisé pour des relevés rapides en différentes stations, c'est-à-dire dont l'une des caractéristiques intéressantes soit d'être transportable.

Dans un précédent exposé, M. FALLER a parfaitement défini le principe de mesure de g par interférométrie laser, principe qui se trouve appliqué également pour notre dispositif. Pour un appareil transportable, c'est-à-dire de poids limité, nous n'avons pu adopter le principe de mesure par mouvement symétrique de M. VOLET et nous déterminons la valeur de g par la mesure simultanée de deux intervalles de longueur et de temps d'origine commune. Cette origine est distincte de la position départ qui ne peut être utilisée par suite des forces et frottements parasites présents au moment de lâcher.

Afin d'obtenir des relevés rapides et répétitifs qui permettent de définir une bonne valeur moyenne de g , toutes les mesures sont digitalisées. c'est-à-dire que les intervalles de longueur correspondent à des nombres entiers de franges, de même que les temps correspondent à des nombres entiers de périodes d'une horloge. On évite ainsi les mesures d'excédents fractionnaires et les valeurs alphanumériques ainsi obtenues peuvent être utilisées sur un petit calculateur qui affiche directement la valeur de g .

Les intervalles définis précédemment correspondent exactement, quelle que soit la mesure, à 500.000 et 1.500.000 franges, ce qui donne une hauteur de chute de 0,50 m environ.

Cette méthode permet de définir chaque point de mesure avec une précision de 5 centièmes de franges.

Sur le montage actuel, les temps T sont mesurés avec une résolution de 10 nanosecondes.

Les premières expériences en laboratoire ont donné les résultats suivants :

- exactitude : 0,2 mgal,
- écart type de la dispersion : 0,35 mgal.

A partir de ces essais, nous avons défini un prototype qui est actuellement en cours d'élaboration et qui doit aboutir prochainement à un appareil transportable de type industriel. La précision recherchée est de 0,1 milligal".

S. BAKKELID, en l'absence du Prof. T. HONKASALO, donne lecture du papier de B. HYTONEN :

Absolute gravity measurement with long wire pendulum in Helsinki. (Doc. I-7).

"Final observations to determine the absolute gravity by the aid of a long wire pendulum are going on. The measurements will be carried out by using the two different lengths, 8 and 4 m, of one and the same pendulum. A swinging body weighing 8 kg has been made of copper. The absolute lengths of the pendulums are difficult to determine, but they are needed to know with an accuracy of only 0.1 mm. The accuracy of the final result is depending on the accuracy of the difference between the lengths of the pendulums and here the systematic errors are more easy to eliminate. As this method differs essentially from the other methods used at present for the absolute gravity measurements, the systematic errors there must be different from those others, and therefore the comparison of the result to be obtained may be of some value. The error caused by the suspending point is the smaller the longer the pendulums are. The difference in length of pendulums is measured by means of Väisälä light-interference comparator.

This length difference is determined with an accuracy of 1-2 μ m. The counter records the total time of 500 oscillations. The accuracy of one swinging period is 1-2 μ s.

The variations in length of the wire and the moving of the fixing device, caused by change of temperature, are measured by the aid of microscopes.

Another body, made of gold weighing 18 kg has been used in order to find out the swaying of the support. This body is exactly of the same size and shape as one made of copper.

The fastening of the wire is performed firstly by clamping the wire in grooves between two steel blocks. According to extensive tests a groove 10 m smaller than the diameter of wire was found to be the most suitable. Secondly the length of wire was set by letting the wire go over a horizontal steel cylinder. The cylinders of diameter 2 and 6 mm are used.

The final measurements are carried out by the aid of three different ways of suspending mentioned before, clamping blocks and two different cylinders. The observations are ready this autumn. The accuracy is estimated to be about 1 mgal".

B. SZABO reports on :

The development of a charged particle absolute gravimeter.

A new concept for the measurement of the acceleration of gravity is the employment of the charged particle technology. In this concept a 100 micron aluminium coated hollow glass particle is used in a symmetrical rise and fall trajectory of about 15cm amplitude. Photomultipliers detect the passage of the particle as it passes upper and lower marks on a bar and start a nanosecond counter. The length reference is measured under most favorable laboratory conditions with an accuracy between $\pm 0,01$ and $0,02$ micron. A digital data processor computer receives the data and performs the required calculations to produce the adjusted average and its variance from a large number of measurements.

The completely assembled system is under performance analysis to increase its accuracy from the present ± 1.0 mgal to the desired goal of ± 0.1 mgal. The system is transportable with a total weight of 300 kg including electronics and computer.

A complementary session was held on Tuesday afternoon (5 to 6 p.m.) to discuss on the : choice of absolute gravity stations in the world and the recent changes of the Reference Geodetic System (Lucerne, 1967).

J.J. LEVALLOIS présente la note distribuée aux délégués (texte français et anglais) :

Quelques conséquences géophysiques des nouvelles méthodes de haute précision de mesures absolues de g. (Doc. I-10).

..."Si nous considérons qu'une variation de g de l'ordre de 10^{-5} gal (centième de milligal) correspond à une variation de l'ordre de 3 centimètres dans la distance station-centre des masses de la terre et qu'une telle variation ne peut provenir que de deux causes , puisque la masse reste constante :

- précisément une variation de cause physique du rayon.
- ou une dérive de la constante de gravitation G.

Il semble que l'on dispose dorénavant d'une méthode correcte et précise pour mesurer "la respiration de la terre".

On pourrait envisager un réseau mondial d'une vingtaine ou d'une trentaine de stations continentales permanentes de mesures absolues de pesanteur, pouvant mesurer g à 10^{-9} , régulièrement espacées, situées en des points où la sismicité soit très faible ; ces points pourraient servir :

- 1°) de stations fondamentales pour un réseau gravimétrique mondial,
- 2°) de stations de référence de mesures de g pour l'étude des variations de position du centre des masses, ou inversement des mouvements de la croûte terrestre par rapport à ce centre des masses, qui est à priori le point origine du développement du potentiel.
- 3°) Ces stations seraient reliées par un nivellement de très haute précision à un groupe de marégraphes, suffisamment voisin pour que la jonction soit précise, et suffisamment éloignés pour que les micro-séismes engendrés par l'agitation des flots (marées, tempêtes...) soit imperceptible de la station.

Il est clair qu'un tel réseau permettrait de suivre :

- les variations à courte période de g (s'il y en a), et de les rattacher à la période annuelle ou à la période de Chandler ou à des effets saisonniers étudiés par ailleurs (cf. Temps Universel),
- les déformations à longue période de la croûte dues aux mouvements actuels, en réitérant les mesures dans le temps, ce qui permettrait de poser les premières assises d'une solution de l'important problèmes sur les mouvements actuels de la croûte terrestre.
- la variation de la constante G de la gravitation pourrait également être décelée de cette manière par la mise en évidence d'une dilatation progressive dans les résidus de l'ensemble des rayons des stations, nonobstant tout déplacement relatif du centre des masses.

$$\frac{dg}{g} = \frac{dG}{G} - \frac{2}{r} \frac{dr}{r} \quad \frac{dM}{M} = 0$$

$$\frac{dr}{dG} = f(G)$$

- les variations réelles du niveau moyen de la mer par rapport au centre des masses par l'intermédiaire des liaisons par nivellement".

D.H. MATTHEWS gives his personal views on the changes of the reference ellipsoid, already mentioned in the Bull. Inf. n°23 :

(1)
 "I very much hope that the Commission will decide not to adopt the new international gravity formula since to do so will involve a great deal of confusion as to whether surveys have or have not been corrected to the new formula. For almost all purposes the old formula was entirely adequate and a new one, being an expression of the best known values, is bound to be subject to change again. There are two classes of users : those who wish to use gravity anomalies for prospecting at sea and on land those who are concerned with the best possible geodetic values. The latter group are bound to improve their formulae whenever better data become available. An exactly similar situation arose in the protracted negotiations which finally arrived at the International Geomagnetic Reference Field in Washington in October 1969. The interests of the two groups, one for stability, one for accuracy, cannot and should not be reconciled".

J.J. LEVALLOIS donne lecture des 2 vœux adoptés à Lucerne (1967) par l'U.G.G.I. et l'A.I.G., relatifs à cette question :

Vœu n° 1

L'Union Internationale de Géodésie et Géophysique, constatant que l'Ellipsoïde International adopté à Madrid en 1924 et la formule internationale de gravité adoptée à Stockholm en 1930 ne représentent plus les dimensions, la forme, et le champ de gravité de la Terre avec une précision suffisante, bien qu'ils puissent encore servir de référence pour des travaux courants dans lesquels un changement serait désavantageux et,

considérant

a) que des valeurs plus appropriées sont nécessaires et actuellement disponibles pour les besoins scientifiques,

b) que l'Union Astronomique Internationale après consultation de l'U.G.G.I. a adopté au cours de son Assemblée Générale en 1964, comme partie d'un nouvel ensemble de constantes astronomiques, des valeurs beaucoup plus proches de celles couramment considérées comme les meilleures et,

c) que l'U.A.I. et l'U.G.G.I. ont adopté en 1967 une nouvelle Origine Internationale Conventionnelle pour le mouvement du pôle, et que le B.I.H. adopte les longitudes conventionnelles pour la détermination de TU 1, (et TU 2).

(1) not was unfortunately omitted in the Bull. Inf. n°23.

recommande

a) que l'ensemble suivant de constantes conventionnelles définisse le Système de Référence géodésique 1967 :

- rayon équatorial de la Terre : $a_e = 6\,378\,160\text{ m}$
- constante géocentrique de gravitation : $GM = 398\,603 \times 10^9 \text{ m}^3 \text{ s}^{-2}$ terrestre, y compris l'atmosphère
- facteur d'ellipticité géopotentielle : $J_2 = 10\,827 \times 10^{-7}$

b) que le petit axe de l'ellipsoïde équipotentiel de référence dans le système décrit ci-dessus soit parallèle à la direction définie par l'origine internationale conventionnelle pour le mouvement du pôle, et que le méridien origine soit parallèle au méridien zéro des longitudes adoptées par le B.I.H.

Voeu n° 2

L'Association Internationale de Géodésie,

décide que les paramètres de l'ellipsoïde équipotentiel (Ellipsoïde de Référence 1967) qui correspondent au système de référence géodésique 1967, ainsi que l'expression en série et sous forme finie de la formule de pesanteur correspondante (formule de pesanteur 1967), et les méthodes de calculs utilisées soient publiées dans le Bulletin Géodésique.

Puis, J.J. LEVALLOIS, en tant que Secrétaire Général de l'A.I.G. signale que, conformément à ces décisions, le Bureau Central de l'A.I.G. a entrepris le calcul de nouvelles tables de l'ellipsoïde de référence, en utilisant les 3 paramètres géométriques adoptés ci-dessus (voeu n°1) et pour 4ème paramètre, la vitesse angulaire de rotation terrestre ω définie par l'astronomie avec une excellente précision ($\omega = 0.000\,072\,921\,151\,467$ radians/seconde).

Ces tables ont été calculées indépendamment par 4 Instituts, avec des méthodes et des formules différentes (KOVALEVSKY, LEVALLOIS, MILBERT, MORITZ) et sont en parfait accord.

Elles font l'objet d'une publication spéciale du Bulletin Géodésique : "Geodetic Reference System 1967".

En terminant, C. MORELLI pense (comme MM. LEVALLOIS & SZABO) qu'il est nécessaire aux géodésiens de connaître les meilleurs paramètres de l'ellipsoïde afin de pouvoir faire la jonction entre les résultats géodésiques et ceux des satellites. Il ajoute toutefois, que chaque géodésien et géophysicien peut faire les calculs dans le système qui lui plait, suivant le but poursuivi, pourvu que ce système de réductions soit clairement exprimé. C'est précisément le sens que l'Union Géodésique et Géophysique Internationale a voulu attacher à son vœu n°1 à Lucerne (voir texte souligné), et c'est également le sens du vœu n°2 adopté par la C.G.I., (voir page I-27).

J.J. LEVALLOIS signale encore que la table de conversion jointe aux tables précédentes permet de passer rapidement du Système de Référence 1967 à l'ancien Système de Référence de l'Ellipsoïde de Hayford (1930).

Papers presented or distributed at the Meeting

- I-1) J.E. FALLER & J.A. HAMMOND - "A laser-interferometer system for the absolute determination of the acceleration of gravity".
Final report. AFCRL-70-0163, Bedford, 139 p. (not distributed)
- I-2) A. SAKUMA - "Observations expérimentales de la constante de la pesanteur au Bureau International des Poids et Mesures, Sèvres, France". Typewritten text, 4 p. + 3 fig.
- I-3) D.L.H. GIBBINGS, J.B. PATTERSON & G.A. BELL - "The absolute determination of the gravitational acceleration at Sydney, Australia".
Nat. Stand. Lab., Typewritten text, 8 p. + 5 fig. (not distributed)
- I-4) R. SCHULER, G. HARNISCH, H. FISCHER & R. FREY. - "Absolute gravity experiments at Potsdam and in Berlin".
Geod. Inst. Potsdam & DAMW, Berlin, Typewritten text, 5 p.

- I-5) C. ELSTNER - "Zur Einwirkung der Stativelastizität auf Amplituden und Phasen von Schwerependeln".
Deutsche Akad. Wissensch. Berlin, Veröff. Zent. Physik der Erde
n°3, 17 S + 8 Abb.
"On the variations of amplitudes and phase difference of two pendulums swinging on the same support". Typewritten text, 4 p.
- I-6) S. GERMAN - "g" measurement in Physikalisch-Technische Bundesanstalt". Braunschweig. Typewritten text, 1 p.
- I-7) E. HYTONEN - "Absolute gravity measurement with long wire pendulum in Helsinki : report on progress of the measurements".
Geod. Laitos, Helsinki, Typewritten text, 2 p.
- I-8) B. SZABO - "The development of a charged particle absolute gravimeter".
(not distributed)
- I-9) D.H. MATTHEWS - "Modification of gravity anomalies due to recent changes of the reference ellipsoid and equatorial value of g".
University of Cambridge.
(Abstract in Bull. Inf. n°23, p.I-11).
- I-10) J.J. LEVALLOIS - "Quelques conséquences géophysiques des nouvelles méthodes de haute précision de mesures absolues de g".
I.G.N., Paris. Typewritten text, 2 p.
"Some geophysical consequences of the new high precision methods of absolute measurements of gravity". Typewritten text, 2 p.
- I-11) M. LACOMBAT - "Etude d'un gravimètre transportable de type absolu". TH-CSF, Paris. Typewritten text, 3 p. + 4 fig.

III - SPECIAL TECHNIQUES OF GRAVITY MEASUREMENTS

Sp. St. Gr. n°4-21.

One meeting was held on Wednesday 9th September (9.15-10.45 a.m.)

Chairman : Dr. PETTERSSON presides over this meeting instead of Dr. HONKASALO, unfortunately transported to the Hospital*.

He presents the Report prepared by T. HONKASALO ; this report (see annexe p.I-52) deals with studies made in 9 countries : Canada, Finland, France, German Democratic Republic, German Federal Republic, Hungary, Japan, Sweden, U.S.S.R.

Dr. Pettersson invites each delegate to speak himself about studies and experiments made in his own country.

It is to be added work made in Poland and Czechoslovakia mentioned in the papers (III-2 and III-3) indicated hereafter (p.I-51) : Results are given concerning the dependance of the calibration coefficient of gravimeter relating to temperature, atmospheric pressure and time. The study of the non-linearity of the reading scale is also related - it exceeds the error of the observations executed with the gravimeters. (Sharpe gravimeters n°228 G and 184).

Then, some delegates give new information and details on the accuracy of gravity meters and on the possible changes of gravity :

B.C. BARLOW

"Erratic results obtained with quartz-type gravity meters strongly suggest that ground vibration can cause errors of up to several tenths of a milligal in observations made with those instruments. A change of reading point of 0.8 milligal due to vibration induced by a helicopter idling at a particular speed has been observed on a gravity meter some meters from the helicopter. During some thousands of calibration runs using quartz-type meters two well-documented, sudden apparent changes in calibration factor have occurred. It is suggested that each is due to a change (within 20 minutes) of the nature and/or intensity of natural micro seismic activity at one of the two calibration stations, this change producing a change in the gravity meter reading of about 0.07 milligal.

We would at all times beware of the fact that ground vibrations, both natural and man-made, may produce similar errors in observations with other types of gravity equipment.

* Dr. HONKASALO is now very well.

Analysis of measurements made in Australia by the United States Air Force, Dominion Observatory of Canada and the Australian Bureau of Mineral Resources using LaCoste & Romberg gravity meters suggests that it is optimistic to seek an accuracy of several hundred thousands of a milligal from the existing gravity ties. Discrepancies of up to 0.2 mgal occur between the results of the various LaCoste meters".

D.A. RICE

"There have been two special gravity measurement projects by the U.S. Coast & Geodetic Survey in connection with the study of earthquake mechanism. In 1962 the San Joaquin Valley area of California, a region of high earthquake activity, was covered by survey lines involving spirit level elevation measurements at 840 stations and also precise gravity measurements at these same stations. In 1969 this combined elevation and gravity survey was repeated for the purpose of detecting any changes in elevation or gravity anomaly during the 7-year period. Both elevation and gravity should be observed in repeat surveys in order to discriminate between simple changes in elevation of the marks and possible changes of gravity anomaly which may prove to be useful as indicators of crustal strain build-up and associated violent seismic re-adjustment. In these special gravity measurements the Coast Survey obtained accuracies of about ± 0.02 mgal. While this accuracy is considerably lower than some of the accuracies reported in this meeting, it is much easier to obtain high accuracy (namely a few microgals) under special conditions in the laboratory or at fixed locations than it is in a gravity survey conducted over an extensive region such as our 1962-1969 survey. We believe that the accuracy of ± 0.02 mgal will prove useful in our current studies of earthquake mechanisms and that it would be quite difficult to increase the accuracy very much in this type of operation.

As part of the damage surveys following the Alaskan earthquake of March 1964 the Coast and Geodetic Survey made special gravity observations in the summer of 1964 in Prince William Sound near the epicenter area, and along new level lines on the Kenai Peninsula west of Prince William Sound. The observations were repeated in 1965. In conducting these surveys, special care was taken to measure accurate elevations above sea level at each station at the time gravity observations were made. Gravity measurement accuracies were about ± 0.04 mgal in most cases. A study of the gravity differences observed in the year following the earthquake indicated that changes due to geophysical causes, if they occurred, did not exceed a few hundredths of a milligal in the investigated areas. The repeat survey in Prince William Sound showed no measureable changes of gravity anomaly. Slight changes of both elevation and gravity were detected on the Kenai Peninsula but anomaly changes could not be identified as such. One important finding of the investigation was an upheaval on Middleton Island, located about 150 km south of Prince William Sound.

According to these measurements, the Middleton Island location uplifted about 0.6 meter with respect to the Anchorage gravity base during the first year following the earthquake. This was an especially important finding because due to its isolated location and the lack of a 1964 tidal datum station; the gravity measurements provided the only evidence of the Middleton Island uplift".

W. BULLERWELL

"Experience in the U.K. confirms the experience reported by B.C. BARLOW and D.A. RICE, and suggests that, with available geodetic gravity meters, it is extremely difficult to establish differences between stations to better than 0.02 mgal. A recent re-observation, by the Ordnance Survey and the I.G.S., of the primary base network in the U.K. shows differences of up to 0.04 mgal which appear to represent only instrumental uncertainties.

In special applications to determine very small gravity differences or changes in gravity, site selection becomes very important. Many meters are sensitive to vibration, some are even microphonic and will respond to aircraft noise. Urban traffic noise can therefore cause difficulty especially where the conurbation extends over spreads of river terrace or alluvium. Changes in water-table are perhaps more common and larger than is generally appreciated. Some of the U.K. network connexions may be affected by both these conditions and in some cases it is possible to distinguish "bad sites" from lack of consistency in the network closures".

M. BONATZ

"Deflections of the beam positions of the gravimeter to vibrations coming from big diesel motors in the vicinity of the meter were observed with a Worden and some Askania meters at Bonn".

T. MURPHY

"When a Worden gravimeter is used in heavy traffic high drifts of short duration are encountered. This has been attributed to the warming of the springs which are known to resonate under these conditions".

R. LECOLAZET donne quelques indications sur la précision obtenue dans l'enregistrement des variations luni-solaires de la pesanteur :

"Nous avons réalisé à Strasbourg un enregistrement des variations luni-solaires de la pesanteur, avec un gravimètre North American muni d'un système photographique, pendant 3 ans (1964-67). L'analyse des données n'est pas encore terminée, mais nous avons pu extraire l'onde lunaire de quinzaine, d'amplitude voisine de $6\mu\text{gals}$, d'une année d'enregistrement.

Une nouvelle série d'observations va commencer incessamment avec un gravimètre LaCoste & Romberg muni d'un dispositif d'asservissement électrostatique (méthode de zéro) et d'un enregistrement digital. Les essais font espérer un accroissement substantiel de la précision".

Papers presented or distributed at the Meeting

- III-1) T. HONKASALO - Preliminary report of the Special Study Group n°4-21, of the International Association of Geodesy.
Special techniques of gravity measurements.
Typewritten text, 7 p.
 - III-2) M. MAJEWSKA & R.B. RUKAWISHNIKOV - Examination of the changeability of the unit in Sharpe gravimeters n°228 G and 184 relating to temperature, atmospheric pressure and time, as well as of the non-linearity of their reading scales, applying the laboratory calibration by means of tilting method. Inst. Geod. & Cart. Warszawa, Typewritten text, 11 p.
 - III-3) S. OLEJNÍK & L. TRÄGER - Calibration of the CG-2 gravimeter Sharpen°174-G by the tilt method. Inst. Geod., Prague.
Typewritten text, 8 p.
-

ANNEXE III-1) - Preliminary report of the Special Study Group n°4-21 of the International Association of Geodesy.

SPECIAL TECHNIQUES OF GRAVITY MEASUREMENTS

by T. HONKASALO, President of the SSG.

For study of secular variation of gravity and some other purposes gravity measurements of high precision are necessary. To collect experiences and initiate new methods a new special study group was established at the General Assembly of the I.A.G. in Lucerne in 1967.

In April 1970 a circular was sent to 25 scientists presumed to be interested in the tasks of this study group. Studies made in several countries are reported here on the basis of 13 answers received.

Canada (J.G. TANNER)

There is a calibration line over a range of 500 mgal in Western Canada, with an accuracy of ± 0.02 mgal. The line lies just to the east of an area where considerable vertical movement occurs. Plans have been made to establish a network across the region of post glacial uplift in Central Canada. The testing of instruments and techniques are also planned.

Finland (A. KIVINIEMI)

To study the variation of gravity caused by the Fennoscandian land uplift a line of gravity stations was built in 1966. This comprises three stations. Each station has one principal observation point and two reserve points. Each observation point consists of a plane of 50 x 50 cm cut in bedrock and a bench mark of precise levelling fastened into bedrock. The gravity difference between all these points does not exceed 1.3 mgal. Since the difference in land uplift between the first and the third station is 5 mm/year a change in gravity between these stations of the order of μ gal must occur. A very high accuracy is needed to observe these changes within a reasonable period of time.

The U.S. Army Topographic Command placed four LaCoste-Romberg gravimeters and one observer for this purpose at the disposal of the Finnish Geodetic Institute in 1966.

Four back and forth measurements with four LaCoste-Romberg gravimeters gave a standard error of $\pm 3 \mu$ gal for one measured gravity differences. The tidal corrections were computed using the value 1.14 for the gravimetric factor δ , which is derived from the Finnish observations. The Finnish stations were remeasured in connection with the continuation of this line to the Atlantic in 1967.

INVESTIGATED INSTRUMENTAL ERRORS OF LACOSTE-ROMBERG GRAVIMETERS

	G-24		G-55		G-69		G-115	
- Change of reading caused by 10°C increase								
. in outer t° (μgal)	+5.8±4.0		+4.8±1.9		-16.0±3.7		-4.0±1.1	
. in outer t° influence on daily drift (μgal)	+0.4±0.9		-4.8±1.0		+3.6±1.6		-6.5±1.2	
- Change of scale constant caused by 24° increase in outer t° (10 ⁻³)	+0.1±0.9		-1.8±0.4		+0.4±0.5		-2.9±0.3	
- Change of reading caused by 100 Torr increase in the air pressure (μgal)	+2.8±0.8		-3.6±2.8		+1.6±0.7		+2.5±0.8	
	A	x ₀	A	x ₀	A	x ₀	A	x ₀
- Periodical errors A sin(x-x ₀) (μgal)								
Periods								
1 ^R			2.9±0.7 : 154°±13°					
3.94							1.9±1.3 : 265°±20°	
7.38							0.8±0.25 : 83°±18°	
35.47	11.8±3.7	309°±9°	6.5±1.8	266°±8°	7.6±1.3	33°±7°	2.7±0.3	92°±3°
70.94	19.8±3.7	45°±11°	10.2±1.8	287°±11°	11.0±1.3	357±5°	1.7±0.3	276°±12°
503							3.8±2.4	11°±18°
1206							2.5±4.8	165°±20°

July 30. 1970

DRIFT OF GRAVIMETER CAUSED BY AIR TEMPERATURE CHANGES

Rising temperature

Falling temperature

+40°C +40 μ gal

+20° +20

0° 0

G-24

+40°C +40 μ gal

+20° +20

0° 0

-20 μ gal

G-55

+40°C +40 μ gal

+20° +20

0° 0

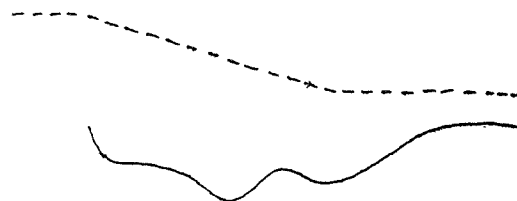
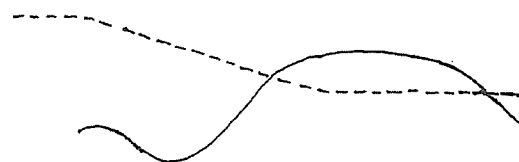
G-69

+40°C +40 μ gal

+20°C +20

0° 0

G-115



The high accuracy achieved in all these measurements provided an accurate determination of the characteristics of all the six gravimeters used. This study was made by the Finnish Geodetic Institute but not all the gravimeters have yet been at the Institute's disposal for this purpose. The results so far are given in the attached table.

The drifts of gravimeters at different temperatures were determined by letting the instruments stand several times in a thermostated room for longer periods in different temperatures.

The gravimeter readings after a change in air temperature showed a permanent but reversible change. The values in the table give the changes several hours after the temperature change. During the first hours the drift is irregular. Some examples are given in the graphics which present the means of three observation series. If we further consider that the curves depend on the speed of the temperature change, it does not seem possible to compute any correction for variation of temperature. For the high accuracy measurements the temperature constancy is very important.

The influence of air temperature on the scale of gravimeters was investigated in a tower. A 17 mgal gravity difference was measured at + 14°C inside and in - 10°C outside the doors. Considerably great differences were found.

The influence of air pressure variation was small. The correlation analysis between the air pressure and drift of the recording gravimeter gave a value of $0.70 \pm 0.13 \mu\text{gal/Torr}$, which is greater than the theoretical value of 0.57. Instrumental errors are not yet known in this case.

No effect of magnetism was found.

The periodic errors in gravimeter G-115 were analyzed from the observations by the manufacturer with 20 mgal overweight. According to the number of teeth on the cogwheels of the gearbox the periods 3.94, 7.88, 35.47, 70.94, 503 and 1206 revolutions were to be anticipated and were found from observations. Comparisons on the 74 mgal temporary calibration line gave values for the periodic errors of 35.47 and 70.94 for the other gravimeters. When gravimeter G-55 had a daily drift of 30 μgal it was possible to study one mgal period, too. The same gravity differences were observed on a stairway once a week. Four observation series gave a clear periodical error of 3 μgal amplitude.

The study of gravimeters will be continued.

France (A. SAKUMA)

In 1967-1970 the absolute gravity measurements at the Bureau International des Poids et Mesures have been so accurate that it has been difficult to determine tidal and air pressure corrections with sufficient accuracy.

The results :

1967	Aug.-Sept.	980 925.662 $\pm$ 0.013	mgal
1968	Aug.-Sept.	.651 $\pm$ 0.019	
1969	June-July	.650 $\pm$ 0.008	
1969	Aug.-Sept.	.649 $\pm$ 0.005	
1969	Oct.-Nov.	.654 $\pm$ 0.011	
1969	Dec.	.659 $\pm$ 0.006	
1970	Jan.	.660 $\pm$ 0.009	
1970	Feb.	.650 $\pm$ 0.009	

Mean 980 925.654 mgal

Standard error of one determination à posteriori $\pm$ 0.005 mgal.
No secular variation can be stated on the basis of these results.

German Democratic Republic (C. ELSTNER)

A 250 km line of gravity stations at 50 km intervals has been planned for measurement this year. The greatest gravity differences will be about 10 mgal and an accuracy of $\pm$ 0.005 mgal is expected.

German Federal Republic (R. BREIN & R. SIGL)

The suitability of a LaCoste-Romberg gravimeter for precise measurements has been tested in the Institut für Angewandte Geodäsie. The optical reading was replaced by a photoelectric system. The most important errors were found in the clamping device and in the dial adjustment. The clamping system causes elastic after-effects and jumps in some μ gal. Jumps of the same order were observed with the adjustment of the dial.

Special studies on the electric spring have been made (R. BREIN : Die elektrische Feder bei der Messung von Schweredifferenzen mit hoher Genauigkeit, Na. Ka. Verm. Reihe 1, Heft 27). A new instrument was constructed on the electric spring principle which is used for compensation of differences in gravity. Experiments with it are in progress.

The influence of air pressure has been studied. The value 0.5 μ gal/Torr was observed in Frankfurt. In this value, as well as in the value 0.12 $\pm$ 0.04 μ gal/Torr obtained in Strasbourg, the influence of instrumental errors was eliminated with a pressure chamber.

Prof. Sigl has found changes in reading of the order of 0.02 mgal after 20°C fast temperature changes. No air pressure effects have been noted in observations at 3000 m height differences. The laboratory tests have shown surprisingly large elastic aftereffects.

Hungary (G. BARTA)

G. Barta points out that in addition to the meteorological effect, which can be several μgal , it is important to take changes in ground water level into consideration, too. (1).

Japan (I. NAKAGAWA)

The Geodetic Society of Japan has organized a working group for gravity measurements and precise levelling in Japan, in which the Geophysical Institute of Kyoto University, International Latitude Observatory of Mizusawa, Earthquake Research Institute of the University of Tokyo, Geographical Survey Institute and Meteorological Institute are represented. One of the main tasks is to study the possibility of using gravity measurements for earthquake prediction.

Several gravimeters have been studied. A clear correlation between the air temperature and the drift of Worden gravimeters was noted. The delay of the drift change is also evident.

An accuracy of ± 0.005 mgal has been attained by careful measurement at quiet stations.

Sweden (L. PETERSSON)

The Fennoscandian land uplift line was measured in 1967 with three LaCoste-Romberg gravimeters from Finland via Sweden and Norway to the Atlantic coast near Ålesund. There are now :

3	stations in Finland
2	" " Sweden
3	" " Norway

The accuracy has been of the same order as in the Finnish measurements.

U.S.S.R. (Y. BOULANGER)

Gravity change lines have for many years been measured in the U.S.S.R. The gravity differences between different stations are several tens of mgal. The accuracy of one measured Δg is $\pm 0.006-0.007$ mgal.

A special method for calibrating the gravimeters by tilts has been developed. The scale coefficients of different types of gravimeters can be determined with an accuracy of $5 \cdot 10^{-5}$.

The secular variation of gravity has been studied. The measurements at present testify that if secular variations of gravity exist then they do not exceed 0.01 mgal/year.

Prof. Boulanger proposes a coordinated international program for studying the secular variations of gravity.

(1) R. LECOLAZET (France) points out that he studied influence of rises of the "Meuse" river on the deviation of the vertical.

VIII - GRADIENT VERTICAL DE LA PESANTEUR

Séance du Jeudi 10 Septembre 1970 (11h15 - 12h30).

La séance est ouverte par le Prof. L. CONSTANTINESCU qui, à titre d'introduction et pour servir de cadre aux communications à présenter, fait quelques considérations générales sur le gradient vertical de la pesanteur en tant que paramètre dont les valeurs "normales" sont nécessaires pour certaines réductions des valeurs observées de la gravité, afin de les rendre comparables, aussi bien qu'en son rôle d'instrument de recherche. Comme pour d'autres grandeurs physiques, l'efficacité du gradient vertical dans les applications et dans les recherches n'est assurée qu'à la double condition d'avoir :

- a) Un modèle théorique raisonnable conduisant à des valeurs normales qui puissent servir comme terme de comparaison et,
- b) Des valeurs observées sûres, destinées à mettre en évidence les anomalies de la distribution spatiale de cette grandeur.

En ce qui concerne le premier point, la question importante qui est à signaler est celle des conséquences entraînées pour la valeur normale du gradient vertical par le choix d'une nouvelle formule de la gravité normale, en accord avec les valeurs indiquées par les recherches récentes pour le rayon équatorial terrestre et pour l'applatissage de la Terre. Il semble qu'à la place de la valeur actuelle de 0,3086 mgal/m, on devrait prendre celle de 0,3083 mgal/m pour le gradient vertical normal.

Les anomalies du gradient vertical, bien appréciées par les géophysiciens prospecteurs pour leur haut pouvoir de résolution, continuent à faire l'objet de nombreuses mesures directes (à côté des déductions par le calcul entrepris sur la base des anomalies de la pesanteur).

Les deux communications présentées au cours de la séance concernent les essais effectués pour mesurer directement le gradient vertical.

- 1° - "Mesures du gradient vertical de la gravité", (Doc. VIII-1). par E. GROTEN de Munich, et
- 2° - "Une balance à fléau, astatisée à système de compensation hydraulique pour la mesure des petites différences de la pesanteur", par M. BONATZ de Bonn.

E. GROTEN (see Annexe p.I-62) shows with slides the apparatus used for measurements, pointing out that the most relevant tool of his equipment seems to be the gravity recording, so you get outputs during a certain time span and the earlier discussed error influences of discrete readings can be avoided or reduced.

Then, he mentions the different causes of errors :

- level error,
- sunshine and wind,
- hysteresis
- low sensitivity of thermostat,
- drift, microseismic effect,
- tidal correction
- calibration error.

J.E. FALLER questions if calibration procedure via using calculable water masses had been considered for determining absolute masses of particules (μ gal) to eliminate "calibration error", in gravity gradient measurement technique involving translation of gravimeter.

E. GROTEN answers that as far a calibration is concerned, the use of pregiven calibrational masses is straightforward ; however, if very high accuracy is the goal then calibration on calibration systems of very high accuracy could be relevant. This can only be achieved by very well known masses.

He reminds that during the Earth Tides Symposium at Strasbourg (Sept. 1969) he proposed a calibration apparatus using heavy steel or brass balls. In the discussion of this proposal arguments in favour and against the use of liquid masses as, e.g., mercury for calibration of the meter were stressed.

He says also that the use of an additional gravimeter, of course, improve the accuracy but, in his opinion, not essentially. (To M. TALWANI).

An accuracy of $m (\Delta g) = \pm 0.001$ mgal is easily feasible now, in the future an improvement by a factor 10 (or 100 under special conditions) will be obtainable. Already now ± 0.0001 mgal is feasible through repetitions. (To Y. BOULANGER).

B.C. BARLOW speaks on the calibration problem :

The problem of calibrating a gravimeter for accurate measurement of small gravity intervals for determination of vertical gravity gradients is very similar to the problem of calibrating a gravimeter for use in recording tidal variations of gravity.

In Australia such a calibration of a tidal recording meter was made by raising and lowering it about 40 cm, the gravity interval between the two levels being measured by two LaCoste geodetic gravimeters as 0.116 and 0.120 mgal. To obtain a more accurate calibration it is proposed to use the calculable effect of the mass of a body of lead or water. Water has the advantage that it is easily moved and the use of a diving pool about 5 meters deep is being given particular consideration.

A. SCHLEUSENER adds that local depression of the crust due to the weight of the lead or the water would be a problem as a depression of 0.03 mm corresponds to 0.01 μ gal which is the accuracy which should be sought.

B.C. BARLOW replies that it would certainly be necessary to monitor the height of the surroundings of the diving pool by precision levelling from a stable point a short distance from the pool.

M. PICK mentions that in Czechoslovakia they tested different methods of computation of the value of vertical gradient of gravity from the gravity anomalies. For this purpose, they measured the value dg/dh in the Coech test area in mountains. The mean distance of point is ~ 1 km, the accuracy ~ 50 E. The accuracy of computed values is about 100 E. The differences between computed and measured values are ~ 150 E. The first results will be presented next year in Moscow.

M. DONATZ presents a paper on :

An astatized lever arm balance with hydrostatic compensation system for measurements of small vertical differences of gravity. (1)

"The attempt was made to build the prototype of an instrument with which it should be possible to measure vertical differences of gravity up to about 0,3 mgal. The aspired accuracy was 1 %.

As measurement system, an astatized lever arm balance with one in altitude variable ($\Delta h = 70$ cm) and one fixed mass (system Jolly) was chosen. The lever with equal arms (10 cm) and the masses (1 kg) were suspended by thin steel tapes (20 μ m). The system was supplemented by a hydrostatic compensation system : the differences in weight of the movable mass due to vertical differences of gravity cause a deflection of

- (1) "Eine Astasierte Hebelwaage mit hydrostatischem Kompensationsystem zur Direkt-Messung kleinster vertikaler Schwere-Unterschiede".
D.G.K., Reihe C : Dissert., H.n°138, München, 1969.

the lever arm ; on the bottomside of the in altitude invariable mass a thin vertical wire (0,3 mm) is mounted which dips in a liquid ; by changing the dipdepth, that means the hydrostatic buoyancy, the deflection of the lever arm can be compensated and simultaneously the amount of the gravity-difference can be measured. The zeropoint of the lever arm is observed by a microscope. All the measurement system is suspended and mounted in a vacuum tight case, vacuum is possible down to 10^{-3} Torr.

A lot of tests have shown that the system on principle operates as expected. The main difficulty measuring vertical differences of gravity with the lever arm balance lies in the zerodrift of the lever arm position. Improvements seem to be possible. The meansquare error for one measured gravity difference is, depending on the driftcurve, between + 6 and + 14 μ gal. From 62 measurements along the vertical calibration basis in the gravimetric earth-tidestation of the university of Bonn for an altitude difference of 70 cm a gravity difference of $(185,7 + 1,2) \mu$ gal was measured, the corresponding amount of the calibration basis is $(187 + 2) \mu$ gal. The good conformity seems to show that bigger systematical errors in the lever arm system did not appear. An increase of accuracy of the balance prototype due to technical improvements can be expected.

The instrument was especially built for measuring vertical calibration bases in gravimetric earthtidestations".

En conclusion, L. CONSTANTINESCU souligne que le problème du gradient vertical présente non seulement l'intérêt de résultats déjà acquis mais aussi de très prometteuses perspectives pour son développement futur.

Annexe VIII-1) - MEASUREMENTS OF VERTICAL GRAVITY GRADIENT

by E. GROTEN

Institute of Astronomical and Physical
Geodesy, Technical University, Munich.

... Using two steel frames (2m and 3m high, respectively) with movable platforms an accuracy of the order of 10^{-3} becomes feasible. In our experiments a model G LaCoste and Romberg gravimeter was used which has a capacitance-read-out-system with a strip chart recorder. In order to increase the accuracy and to get information about nonlinearity of dg/dh gravity was recorded at elevations $h = 0$; $h = 0,5m$; $h = 1 m$; $h = 1,5 m$... $h = 3 m$ above the ground. The error which is due to the imperfect knowledge of the real tidal perturbations can be avoided and hysteresis effects are reduced by recording gravity at every elevation for about half an hour. It has been found that within this time elastic aftereffects and hysteresis had decreased so corresponding errors could be reduced. On this way we get from the record pieces of the tidal curve at the point of observation which are shifted by translation with respect to each other. Moreover, the microseismic effects are mostly averaged out by this procedure. In our case the deflection of the gravimeter beam was recorded. As the calibration factor depends on the position of the beam a careful calibration of the gravimeter with respect to different reading lines is necessary whenever ultimate accuracy is the goal. In (Groten, 1969) a corresponding calibration apparatus has been described where heavy balls are used in order to produce gravitational differences in a laboratory. However, by using it we found that the temperature control of our gravity meter did not work so properly as we anticipated. Therefore, the dependence of the calibration function from the beam position has not yet been reliably established. But this is no principal defect. Moreover, the mass was not large enough in order to ensure an accuracy of $\pm 10^{-4}$ which corresponds to $0.1 \mu gal$.

It is all but impossible to have a movable platform at a light portable frame which is exactly horizontal at any elevation above ground. In order to avoid effects from levelling errors a more precise level was attached to the gravimeter in order to avoid such errors. Elevation differences were measured with an accuracy of about $\pm 1 mm$.

From our experiences we draw the conclusion that the accuracy depends mainly on the stability of the frame. The lighter the frame the bigger is the influence of microseismic perturbations and aftereffects

It could be excluded that the vibrations due to heavy traffic and similar strong perturbations might sensibly affect the instrumental drift of the gravimeter during the observations. However, such drift effects can be eliminated by repetitions. On the other hand, micro-seismic perturbations can directly affect the readings whenever cross-coupling effects are produced. But (1) the necessary conditions for the existence of cross-coupling error are seldom fulfilled over longer time intervals ; (2) checks are possible since microseisms can be recorded.

The influence of even small temperature changes (due to slight sunshine effect) became evident during the observations. This can be anticipated by taking into account the extremely small variations of beam position which correspond to 0.001 mgal ; such problems were stressed by Schulze (1965).

Even if calibration is done on a gravity base the precise determination of the (non-linear) calibration function with an accuracy of $\pm 10^{-4}$ and better is not without problems.

However, it seems that by recording gravity (1) all errors connected with defects of the measuring screw are avoided ; (2) a lot of deficiencies of present gravimeter system are averaged out.

Further details will be published in a forthcoming paper. (Groten, 1971).

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und Physikalische Geodäsie". D.G.K., München, 1971 (in press).
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Berlin, 1965.
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LISTE DES PUBLICATIONS

reçues au

BUREAU GRAVIMETRIQUE INTERNATIONAL

(Mars à Juin 1970)

CONCERNANT LES QUESTIONS DE PESANTEUR

LISTE DES PUBLICATIONS

- ‡ 43 - QURESHY M.N., N. KRISHNA BRAHMAM, P.S. ARAVAMADHU & S.M. NAQVI.
 "Role of granitic intrusions in reducing the density of the crust,
 and other related problems as illustrated from a gravity study of
 the Cuddapah Basin, India".
 Proc. Roy. Soc., A. 304, p.449-464, 1968.

"A gravity "low" with an amplitude of some 70 mgal over the east Cuddapah basin of Precambrian (Proterozoic) age has been mapped which extends for about 400 km paralleling the eastern boundary of the basin with an average width of 60 km. This near parallelism between the boundary of the basin and gravity anomaly contours suggests a strong correlation between gravity and geology of the Cuddapah basin. Direct calculations based on the techniques of Bott & Smith (1958) and Skeels (1963) suggest the anomaly source to be within the crust.

In view of these direct calculations and some known granitic intrusions in the northeastern part of the basin, it is suggested that the anomaly is caused by massive granitic intrusions into the heavy rocks of Cuddapah system on the west and Dharwar system on the east. Although granitic intrusions are known only at a few places in the northeast, the extension of the gravity anomaly suggests that the granitic activity may be widespread and may occur all along the eastern Cuddapah basin. An average thickness of 20 km with a density differential of 0.1 g/cm^3 is needed to account for the observed variations in the isostatic anomaly. It is suggested that the granites with which mineralization in the Cuddapah basin is presumed to be associated may be cupolas of this inferred granite mass.

For the inferred east Cuddapah basin crustal column to be in isostatic equilibrium, the presence of about 16.5 km material of 3.01 g/cm^3 density between the mantle and the inferred granite or crustal thinning of the order of 6.5 km is required. This leads to a suggestion that in anomalous regions due consideration should be given to the compensating effect of anomalous masses that may lie below the sea level in addition to the usually adopted method of considering only topographic masses in computing isostatic effects.

On the basis of the comparison of the east Cuddapah basin crustal column having 20 km of inferred granitic mass with a standard continental crustal column (e.g. that due to Worzel & Shurbet 1955), it is concluded that granitic intrusions have locally reduced the density of an originally heavier upper crust".

‡ Les numéros font suite à ceux indiqués dans le Bull. Inf. n°22, Mars 1970.

- 44 - QURESHY M.N., N. KRISHNA BRAHMAM, S.C. GARDE & B.K. MATHUR.
 "Gravity anomalies and the Godavari Rift, India".
 Geol. Soc. America, Bull. v.79, p.1221-1230, 1968.

"A Bouguer anomaly map of the Godavari valley region extending from the deltas of the Krishna and Godavari rivers has been prepared by using data of the Survey of India and National Geophysical Research Institute. A gravity "low" of the order of 50 milligal is associated with the Godavari valley. A comparison of this map with the geologic map of India and the paleogeographic maps of the Gondwana periods by Fox (1931) and Ahmad (1961) indicates the Godavari structure continues northwestward at least up to 23°N.

Godavari valley appears to be a rift, according to the definition of a rift valley given by Girdler (1963). Its average width is 50 km and its lateral extent, as indicated by gravity and paleogeographic data, may be of the order of 800 km. The valley floor may lie at depths ranging from 3 to 4 km. The gravimetric and geologic data do not indicate extension of the Godavari valley structure into the sea. However, it appears to have its counterpart in the basins on the western and northwestern coasts of Australia.

It is suggested that the Godavari rift developed along a zone of weakness inherited from the Archean orogenies. It appears that after the Eparchean interval, but prior to the deposition of the Cuddapahs, tensional forces must have developed that caused formation of the graben, according to a mechanism proposed by Vening-Meinesz and Heiskanen (1958)".

- 45 - DAVEY F.J. & R.G.B. RENNER. - "Bouguer anomaly map of Graham Land".
 Br. Antarc. Surv., Bull. n°22, p.77-81, 1969.

"Since 1959 gravity measurements have formed part of a geophysical survey of the Scotia Sea and Graham Land. The marine gravity survey has been operated from ships of the British Antarctic Survey and H.M.S. Protector, while field parties have completed land traverses on the peninsula and the Larsen Ice Shelf. Bouguer anomalies have been calculated and are presented as a contoured map".

- 46 - GIBB R.A. & R.K. McCONNELL. - "The gravity anomaly field in Northern Manitoba and Northeastern Saskatchewan with maps".

N°68 - Gods Lake	N°72 - Southern Indian Lake
N°69 - Upper Nelson River	N°73 - York Factory
N°70 - Flin Flon	N°74 - Churchill
N°71 - Reindeer Lake	N°75 - Seal River
N°76 - Woollaston Lake	

Gravity Map Ser., Dom. Obs., 28 p, Ottawa, 1969.

"About 4100 new gravity stations were established in 1965 in northern Manitoba and northeastern Saskatchewan by the Dominion Observatory. The survey results are presented as nine Bouguer anomaly maps at a scale of 1/500,000. The local Bouguer anomalies are adequately explained by near-surface Precambrian geological structures using density relations obtained from measurements of rock samples collected in the area. The Bouguer anomalies show a correlation with the degree of granitization ; minimum values occur where the granitic rocks appear to be intrusive. Sedimentary and volcanic sequences are characteristically defined by relatively positive anomalies. Areas of dense granulite facies rocks are also outlined by positive anomalies. Interpretation of the gravity data is concentrated on the anomalous area traversed by the boundary between the Churchill and Superior structural provinces of the Canadian Shield. In this region the Pikwitonei subprovince of the Superior Province, an Archaean craton of granulites underlies the Nelson River gravity high. The northwestern boundary of the craton forms the boundary between the Churchill and Superior Provinces and is marked by a steep gravity gradient. Abrupt changes in lithology, density, metamorphic facies and age occur along this boundary".

- 47 - WEBER J.R. & P. ANDRIEUX. - "Radar soundings on the Penny ice Cap, Baffin Island".
J. Glaciology, v.9, n°55, p.49-54, 1970.

"The first successful radar echo soundings through glacier ice in Canada were carried out by the Dominion Observatory in 1965 on an outlet glacier of the Penny Ice Cap in Baffin Island. An unmodified 440 MHz SCR-718 radar altimeter was used, of the type that is readily and inexpensively available on the surplus market. The radar soundings were generally in agreement, within the range of the reading accuracy of the oscilloscope (± 15 m), with depths obtained seismically, gravimetrically, and by the electrical resistivity method. The minimum and maximum recorded depths were 45 m and 550m, respectively. The pip positions on the standard oscilloscope were recorded visually. This recording method was not satisfactory, but for future use the instrument could easily be modified to incorporate a larger oscilloscope with continuous photographic recording. Use of the relatively high carrier frequency of 440 MHz (compared with the more customary frequency of about 35 MHz) allows the use of smaller antennas and results in better resolution of the bedrock surface".

- 4 - SOBEZAK L.W., J.R. WEBER & E.F. ROOTS. - "Rock densities in the Queen Elizabeth Islands, Northwest Territories".
Geol. Asso., Proc., Contr. n°302, v.21, p.5-14, Ottawa, 1970.

"Results of 1900 density measurements of crystalline, carbonate and clastic rocks from the Queen Elizabeth Islands are presented graphically and in tables. The data were compiled directly from sampling of surface rocks and rock material from drill-holes, and indirectly by relating densities to seismic velocities and from detailed gravity profiles across topographic features.

The weighted mean densities of the Precambrian crystalline rocks, and of the Paleozoic carbonate rocks of the Franklinian miogeosyncline and Arctic Lowlands are each 2.76 g/cm^3 . The Paleozoic evaporite rocks, sampled mainly in the Bathurst Island area but common throughout the Franklinian miogeosyncline, have a weighted mean density of 2.56 g/cm^3 . The Franklinian clastic rocks exhibit a range of density, in part apparently related to age and/or depth of burial ; the Silurian clastics have a weighted mean density of 2.62 g/cm^3 and the Devonian clastic rocks 2.51 g/cm^3 . In contrast, the Mesozoic clastic rocks of the Sverdrup basin have a weighted mean density of 2.32 g/cm^3 ."

- 50 - TANNER J.G. & R.K. McCONNELL. - "The gravity field in the Richmond Gulf, Fort Chimo Area, Quebec with maps".
N°7 - Port Harrison N°9 - Belcher - Lake Minto
N°8 - Payne Lake N°10 - Fort Chimo
N°48 - Fort the McKenzie.

Gravity map Ser., Earth Physics Branch, 9 p, Ottawa, 1970.

"During the years 1959, 1960, 1961 and 1965 the Dominion Observatory observed some 1500 stations in northern Quebec west of 68°W and between latitudes 56°N and 60°N . Analysis of these measurements, together with observations taken in adjacent regions of northern Quebec, suggests that the Bouguer anomalies have a relative accuracy of $\pm 2 \text{ mgal}$.

Comparison of the Bouguer anomaly field with geology suggests that :

- a) local and regional variations of Bouguer anomaly within the Superior Province can be correlated with occurrences of high-grade metamorphic rocks (granulites) and,
- b) the linear negative anomaly over the Labrador Trough is most likely caused by deepseated structure".

- 51 - HORNAL R.W., L.W. SOBCZAK, W.E.F. BURKE & L.E. STEPHENS. - "Preliminary results of gravity surveys over the Mackenzie Basin and Beaufort Sea with maps".

N° 117 - Wrigley-Providence

N° 118 - Arctic Red River, Norman Wells

N° 119 - Inuvik, Horton River

Gravity map Ser., Earth Physics Branch, 12 p, Ottawa, 1970.

"Three Bouguer anomaly maps at a scale of 1/1.000.000 and contoured at 5 mgal intervals have been prepared from 6.100 gravity observations made in the Interior Plains and on the Beaufort Sea from latitude 60°N to 72°N.

The major features of the gravity field are : a gravity low over the Mackenzie Mountains which is attributed to a thickened sedimentary sequence and a deeper crustmantle boundary ; a relatively positive anomaly of 50 mgal-striking north from Trout Lake to Great Bear Lake which reflects a ridge or trough of mafic rock within the Precambrian basement, a negative anomaly over the Mackenzie River delta of 55 mgal which results from the deposition of more than 21.000 feet of Cretaceous and Tertiary sediments ; and a circular positive anomaly of 130 mgal situated south of Darnley Bay which is explained by a cone-shaped basic intrusion. Smaller variations in the gravity field in the Interior Plains may be attributed to changes in the depth to the Precambrian basement and density variations within the sedimentary column".

- 52 - SOBCZAK L.W. - "Gravity surveys in the Alexandria area, Eastern Ontario".

Pub. Dom. Obs., v.XXXIX, n°6, p.155-173, Ottawa, 1970.

"The results of 1.700 gravity observations completed by the Dominion Observatory from 1945 to 1964 are presented in the form of a Bouguer anomaly map. Seven profiles are analyzed. The Bouguer anomalies are correlated with magnetic and geological information and the interpretation of the gravity data is based on rock density measurements. Two maps showing the computed first and second vertical derivatives of gravity are also presented.

Negative Bouguer anomalies are correlated with the Chatham-Grenville syenite stock and a similar intrusion at Mount Rigaud on the southern border of the Grenville-A subprovince. It is postulated that the negative anomaly near Plaisance indicates the presence of a similar intrusion below the Paleozoic cover. The Alexandria High, a positive residual Bouguer anomaly which extends from Lunenburg to Pointe-au-Chêne, may be explained by the presence of a basic lenticular body of thickness varying from 6.000 to 9.000 feet and width of 50.000 feet at a depth varying from 3.000 to 5.000 feet. The approximate thickness of the Grenville Series is 11.000 to 12.000 feet along the crest of the Alexandria High. The regional gravity gradient which increases from - 30 mgal in the northwest to + 10 mgal in the southeast of the area is correlated with a rise of over 3 kilometres (10.000 feet) of the Mohorovicic discontinuity".

- 53 - BERKHOUT A.W.J. - "The gravity anomaly field of Prince of Wales, Somerset and Northern Baffin Islands, district of Franklin, Northwest territories".
 Pub. Dom. Obs., v.XXXIX, n°7, p.179-209, Ottawa, 1970.

"The area of study covers approximately 360.000 km², comprising Somerset, Prince of Wales, and northern Baffin Islands. A total of 2.700 gravity observations at intervals of 10 to 15 km are included.

Major negative anomalies occur on Borden and Brodeur peninsulas, in the area east of Agu Bay, on northeastern Somerset Island, and on northwestern Prince of Wales Island. These lows are explained by the presence of Upper Proterozoic metasedimentary rocks which underlie some of the lows, but are covered by Lower Paleozoic rocks elsewhere. An important conclusion is that during Upper Proterozoic time vast basins existed which were the sites of accumulation of clastic sediments. The observed gravity field outlines these basins and suggests that they may be interconnected.

A northerly trending gravity high is associated with the Boothia Uplift and two parallel highs occur to the west of it, all three being separated by gravity lows. The density contrast between crystalline rocks of the uplift and the adjacent Paleozoic rocks is not sufficient to explain the change of gravity over the Boothia Uplift. It is suggested that three northerly trending basement uplifts exist, separated by graben in which Upper Proterozoic quartzitic rocks occur. The Boothia Uplift became active again in Paleozoic time and overthrusts the quartzitic rocks in the west ; this is reflected by observed negative anomalies along its western flank.

The gravity high over Prince Regent Inlet may reflect a basement fault block beneath the Paleozoic rocks, whereas adjacent gravity lows represent the depressed areas occupied by thick deposits of Upper Proterozoic quartzitic rocks.

The northerly and northeasterly trends of the two systems of basement fault blocks cut across the generally easterly (Archean) trend of basement structures, as on Baffin Island. Similar observations have been made in the Canadian Shield. These unusual trends may possibly originate along ancient orogenic zones with northerly and northeasterly trends.

Several smaller, local anomalies occur. Two gravity highs on Prince of Wales Island are probably caused by mafic intrusion and a gravity low on Bylot Island is explained by light Mesozoic sedimentary rocks".

- 55 - DoD Gravity Library - Quarterly accession list, 1 Oct.- 31 Dec. 1969.
 USAF, ACIC, 5 p, Saint-Louis, 1969.

- 56 - BONATZ M. - "Eine astasierte Hebelwaage mit hydrostatischem Kompensationssystem zur Direkt-Messung kleinster vertikaler Schwere-Unterschiede".
D.G.K., Reihe C : Dissert., H.n°138, 99 S, München, 1969.
- "The prototype of an instrument for measuring small vertical differences of gravity up to 0,3 mgal is described in detail. The measurement system consists of a lever-arm balance with one fixed and one in vertical direction movable mass, which is completed by a hydrostatic compensation system. The relative and absolute accuracy of one Δg -measurement attainable with the prototype, is about $\pm 6 \mu\text{gal/m}$. Suggestions for an improvement of the accuracy of the instrument are given".
- 57 - ECKER E. - "Sphärische Integralformeln in der Geodäsie".
D.G.K., Reihe C : Dissert. H. n°142, 54 S, München, 1969.
- 58 - BONATZ M. - "Ergebnisse der Horizontalpendelregistrierungen in der Erdzeitenstation Erpel bei Bonn 1965 bis 1967".
D.G.K., Reihe B : Angew. Geod., H.n°173, 50 S, München, 1969.
- "In a closed down railway tunnel near Erpel, about 30 km in the south of Bonn, since autumn 1965 clinometric earth tide measurements were performed. The results of harmonic analysis show partly big differences compared with the results of neighbouring stations. For determination of the possible reasons of these differences further measurements must be carried out. On the basis of longterm recordings it is to check, if certain local effects occur, which among others could be explained by the special topografic and geological situation of the station Erpel".
- 59 - INSTITUTE of GEODESY & CARTOGRAPHY.
Proceedings, t.XVI, Z.3(39), 87 p, Warszawa, 1969.
- 60 - KOMITET GEODEZJI POLSKIEJ.
Akad. Nauk., Geod. i Kart., t.XIX, Z.1, 77 p, Warszawa, 1970.
- 61 - WOLF H. - "Short-arc Methode und räumliche Bahnglättung in der Satellitentriangulation".
Zeit. Vermessungswesen, 95, J.70, H.2, S.37-41, Bonn, 1970.
- "The "short-arc method" as demonstrated shows the inconvenience, that nearly "ill-conditioned" equation systems do arise. This can be avoided perfectly if the author's method of "spatial fitting of the orbit" is used. Between both methods not only a close connection but also a certain sequential order can be established as is shown below".

- 62 - COMMISSIONE GEODETICA ITALIANA. - Verbale della 69e sessione plenaria e privata della Commissione Geodetica Italiana. 57 p, Bologna, 1968.
- 63 - COMMISSIONE GEODETICA ITALIANA. - Verbale della 70e sessione plenaria e privata della Commissione Geodetica Italiana. 21 p, Bologna, 1969.
- 70 - CANER B. - "Long aeromagnetic profiles and crustal structure in Western Canada".
Earth & Planetary Sci. Letters, v 7, n°1, p.3-11, 1969.
"Long-wavelength (>150 km) magnetic anomalies are found to be smoothed in the region southwest of the Rocky Mountain Trench, similar to the pattern observed on the U.S. Transcontinental Profile. The same region is also characterized by high electrical conductivity in the lower crust and uppermost mantle. Possible interpretations are: upwelling of the Curie point isotherm, break-up of structures by tectonic and metamorphic mechanisms, and/or more silicic crust".
- 73 - BULLARD E.D. - Obituary notice : Benjamin Chapman BROWNE.
Quart. J. R. Astr. Soc., v.10, n°4, p.336-340, 1969.
- 74 - GIBB R.A. & J. Van BOECKEL. - "Three-dimensional gravity interpretations of the Round Lake batholith, northeastern Ontario".
from : Canadian J. Earth Sci., v.7, n°1, p.156-163.
Contr. Dom. Obs., n°295, Ottawa, 1970.
"Gravity surveys of the Timmins-Senneterre mining belt of northeastern Ontario and Western Quebec were made by the Dominion Observatory during the period 1946-1964. The Round Lake batholith is one of several composite granitic plutons of the Algoman series which are outlined by intense negative gravity anomalies. The anomaly over the Round Lake batholith can be explained by the large density contrast (0.22g/cm^3) between the granite and surrounding Keewatin volcanic rocks.
Two possible models of the batholith are presented which depend on different assumptions as to the composition of the upper crust. The first model involves normal faulting of the batholith to explain the variations in anomaly level within the batholith. In this model the granite is assumed to be homogeneous in density and extends to a maximum depth of 10 km. Alternatively density variations corresponding to a facies change within the pluton may be the major cause of the local internal anomaly variations. In this interpretation the true thickness of the granite cannot be evaluated as the whole region is assumed to be underlain by granite, but the maximum thickness of the surrounding basic volcanic rocks is 5 km".

- 75 - INSTITUT GEOGRAPHIQUE NATIONAL - "Exposé des travaux exécutés à Madagascar en 1969".

Centre à Madagascar, 15 p, Tananarive, 1969.

- 89 - IRVING E. & W.A. ROBERTSON. - "The Mid-Atlantic Ridge near 45°N, VI. Remanent intensity, susceptibility, and iron content of dredged samples".

from : Canadian J. Earth Sci., v.7, n°2, p.226-238.

Contr. Dom. Obs. n°279, Ottawa, 1970.

"Results from 27 dredge hauls (75 samples) spaced from 150 km west to 70 km east of the Median Valley of the Mid-Atlantic Ridge at about 45°N and reported. Basalt is the most common rock type. The basalts have a mean remanent intensity of 92×10^{-4} and a mean susceptibility of 0.9×10^{-4} cgs cm⁻³. The remanence varies with distance from the axis, samples from the Median Valley (mean 574×10^{-4}) being ten times more magnetic than samples at a greater distance. Most of this decrease of intensity occurs within a few kilometers (less than 6 km) of the central axis and within the zone of active volcanism. It is suggested that this dramatic drop in intensity is caused by viscous decay enhanced by thermal cycling or by chemical change in the narrow volcanic axial zone.

Certain other properties of the basalts vary with distance ; the blocking temperatures and stability (versus a.f. demagnetization) increase, and the ratio $\text{FeO}/\text{Fe}_2\text{O}_3$ decreases with distance. These changes are most marked at the inner slopes of the Crestal Mountains not within the narrow axial zone, and it is possible that they reflect sampling bias, the samples from the Median Valley being from flow margins, whereas the collections from the flanks contain material from the centers of flows.

Non-basaltic rocks include serpentized peridotite, greenstone, gabbro, and diabase. Serpentized peridotite samples are strongly magnetic and have a mean intensity of 23×10^{-4} cgs cm⁻³. Greenstones, gabbros, and diabases are weakly magnetized, with mean intensities of about 10^{-4} . Moreover, basalt showing partial alteration to greenstone has intermediate intensities showing that such a metamorphic process effectively demagnetizes a rock. This result is more consistent with the idea that Layer 3 is composed predominantly of gabbro and metamorphosed basalt rather than of serpentized peridotite. The remanence and susceptibilities of 18 "erratic" samples, which are thought from other evidence to have been deposited by Pleistocene icebergs, have a wide and irregular spread".

- 90 - Bollettino di Geofisica teorica ed applicata.
v.XI, n°43-44, Trieste, 1969.

- a) CASSINIS R., I. FINETTI, P. GIESE, C. MORELLI, L. STEINMETZ
& O. VECCHIA. - "Deep seismic refraction research on Sicily".
p.140-160.

"In 1968 DSS investigation was performed on Sicily by a cooperation of French, German, and Italian geophysical research institutions. The main refraction line was recorded on Northern Sicily using offshore shots near Trapani and Catania. A second more wide-spread line was recorded along the Southern coast.

An interpretation is presented firstly which is founded only on first arrivals. From a two-layer-model (6.000 m/s resp. 8.000 m/s) results a depth of 38 km for the 8.000 m/s velocity.

Follows a detailed interpretation based on record sections, which yields a very complex crustal structure. The western part is characterized by a thin sialic Crust (about 15 km) and a wide zone forming the transition to the Upper Mantle. In the eastern part of Sicily the sialic Crust has a thickness of 25 km including a distinct low velocity layer. A transition layer (7,2 km/s) exists between 25 and 35 km depth".

- b) GANTAR C. & C. MORELLI. - "First tests on the new bell aerosystems sea gravity meter".
p.173-190.

"The improved version of the BGM-2 sea surface gravimeter manufactured by the Bell Aerosystems Co. has been submitted to a test in the Gulf of Venice, where bottom gravity measurements exist.

The standard deviation computed from the bottom measurements is $\pm 0,6$ mgal, where inaccuracies in bottom data are included. Two repeated profiles show agreement, within ± 2 mgal rms.

Gravity anomaly mapping to 1 mgal contour intervals is now possible also in marine areas, provided navigational aids and computation techniques be adequate to the high inner accuracy of this modern sea surface gravimeter, that appears well suitable for industrial surveys".

- c) RAMBERG I.B. & G. GRONLIE. - "A crustal section across the Caledonian Mountain Belt (Norway) based on gravity data".
p.219-225.

"A gravity profile across the Caledonides in South Norway has been interpreted. Three crustal models which fit the observed gravity anomalies have been computed. The models indicate depths to Conrad (and Moho) across the Caledonides which do not significantly differ from those of the Fennoscandian Shield. They seem to indicate that the Caledonides are isostatically a part of the stable Shield. Together with earlier interpretation of the Jotunheimen anomalies in

central parts of the mountain belt (Smithson, 1964), our models indicate a possible structure similar to that of the Ivrea-zone (Berckhemer, 1968 ; Kaminski and Mehnert, 1968 ; Giese, 1968).

- 92 - QURESHY M.N. - "Thickening of a basalt layer as a possible cause for the uplift of the Hymalayas. A suggestion based on gravity data". Nat.Geophys. Res. Inst., Hyderabad, Tectonophysics, v.7, n°2, p.137-157, Contr. n°NGRI-68-110, 1969.

"Relationship of free air, Bouguer and isostatic anomalies to the elevation in peninsular India, Himalayas and Indo-Gangetic Basin along with seismological, aeromagnetic and some drilling data demonstrates the general validity of isostasy in India.

A correlation of the Airy-Heiskanen anomaly map with regional geology of the peninsular shield and the Himalayas, indicates a block-like structure for this general region. It is suggested that gravity maxima indicate horsts and the minima grabens.

A detailed analysis of a profile extending from near Gaya on the peninsular shield to a distance of 25 km from the Mount Everest indicates a 6,6 km thickness of light sediments beneath the Ganges Basin. A crustal thickness of 42,5 km beneath the northern peninsular shield, 31,5 km beneath the Indo-Gangetic Basin and of 81 km beneath the middle Himalayas is obtained. It is inferred that the Himalayan block is an activated portion of the peninsular shield, where the crustal thickening has been achieved by thickening of the basaltic layer by an amount of 50 km, which in turn might be causally related to the uplifting of the Himalayas.

The mechanism responsible for such a great amount of thickening is not clear but it seems that isostasy as well as the polymorphic inversion, probably originating in the low velocity layer or in the infra-plutonic shell of Fermor (1914) may be dominating factors. The movement of material from the mantle into the crust and also the uplifting may have been along pre-existing faults. Movement of nappes and formation of recumbent folds might be due to gravity as a consequence of the vertical movements".

- 93 - FLEISCHER U. - "Investigations of rifts by shipboard magnetic and gravity surveys : Gulf of Aqaba - Red Sea and Reykjanes Ridge". D. Hydro. Zeit., Band 22, H.5, S.205-208, 1969.

"The East African Rift and the world-wide Mid-Oceanic Ridge system are connected with each other via the Gulf of Aden. The Reykjanes Ridge south-west of Iceland and the Red Sea not only have a structural connection but are also related in their origin, as can be deduced from gravimetric and magnetic measurements. The East African Graben and its northern part, the Gulf of Aqaba and the Dead Sea, represent a fracture zone which, accompanied by a great mass deficiency, forms a deep and narrow depression.

- 94 - MALIN S.R.C. & S. CHAPMAN. - "The determination of lunar daily geophysical variations by the Chapman-Miller method".
Geophys. J. R. Astr. Soc., v.19, n°1, p.15-35, 1970.

"The Chapman-Miller method is the one most widely used for the determination of lunar daily variations in geophysical data. The joint IAGA/IAMAP committee on lunar variations has suggested that the method would be still more widely applied if a simple up-to-date account were available. This note is an attempt to provide such an account. The Chapman-Miller method is described with minimum mathematical detail, the method of determination of probable errors is improved, and a computer program is appended".

- 95 - COLLETTE B.J., R.A. LAGAAY, A.R. RITSEMA & J.A. SCHOUTEN. - "Seismic investigations in the North Sea". (3 to 7).
Geophys. J. R. Astr. Soc., v.19, n°2, p.183-199, 1970.

"Parts 1 and 2 of this paper explained why a seismic crustal investigation programme was started in the North Sea, and gave a description of the sedimentary structure off Flamborough Head as resulting from five reverse refraction lines. These lines cover the 200-kilometres long crustal refraction line which was shot using a variant of the velocity-depth or common reflection point method. The present paper gives in part 3 the results of this 200-km line. The line appeared to be situated over a zone in which the crust shows a considerable thinning. This violates the presumptions of the velocity-depth method. Structurally, the problem could only be solved by also using the records of the U.K. Atomic-Energy Authority seismic station at Eskdalemuir. Part 4 presents the revision of a crustal refraction line at the Doggerbank, also using the velocity-depth method, and shot in 1964. In part 5 the anomalous station term of Eskdalemuir is discussed. It is suggested that a high velocity/low density body is situated under Eskdalemuir, possibly consisting of anorthosites. Part 6 deals shortly with a crustal reflection experiment in 1966 at the site of the 1965 refraction line off Flamborough Head. The negative outcome of this experiment is ascribed to insufficient instrumentation and strong water reverberations occurring in our region. Part 7 concludes the paper with a general discussion on the structure of the Earth's crust under the North Sea, on structural effects in both the seismic refraction and the reflection method, and on the use of crustal seismic experiments in general".

- 101 - INSTITUT FÜR ANGEWANDTE GEODASIE - Nachrichten aus dem Karten und Vermessungswesen.
Festschrift zum 70. Geburtstag von Prof. E. GIGAS.
152 S, Frankfurt, 1969.

- 102 - NATIONALKOMITEE FUR GEODASIE UND GEOPHYSIK. - "Die wissenschaftlichen Ergebnisse der deutschen Spitzbergenexpedition 1964 - 1965".
Geof. Geophys. Veröff., R.III, H.9, 128 S, Berlin, 1969.
- 104 - ROYAL ASTRONOMICAL SOCIETY - The Quarterly Journal.
v.2, n°1, 68 p, 1970.
- 105 - ROYAL ASTRONOMICAL SOCIETY - The Quarterly Journal.
v.2, n°2, p.71-136, 1970.
- 106 - KRAUSE D.C. & N.D. WATKINS. - "North Atlantic crustal genesis in the vicinity of the Azores".
Geophys. J., R. Astr. Soc., v.19, n°3, p.261-283, 1970.

"In terms of current knowledge of crustal genesis in the Atlantic Ocean, several unique or highly anomalous features exist in the vicinity of the Azores. These include the seismically active East Azores Fracture Zone extending from Gibraltar to the Mid-Atlantic Ridge ; the seismically inactive West Azores Fracture Zone which is offset northwards from the trend of the East Azores Fracture Zone ; the transverse island chain of the Azores islands which trends south-east-northwest across the Mid-Atlantic Ridge ; the marked change in direction of the Mid-Atlantic Ridge from northeast-southwest to north-south ; and the broadening of the Mid-Atlantic Ridge to the east.

Bathymetric and magnetic data from surveys of the Mid-Atlantic Ridge in the Azores area by R.V. Trident, the U.S. Naval Oceanographic Office, and other sources have been compiled. These, together with the previously published data are compatible with a basic model consisting of a Mid-Atlantic Ridge migrating eastwards at the local crustal spreading rate, which is greater to the north than to the south of an east-west transverse fracture system. Superimposed on this is the development of a northwest-southeast trending secondary spreading centre of triple junction, within a "leaky transform" system (Menard & Atwater 1968) which would have developed as the result of a change in the local crustal spreading direction south of the east-west transverse fracture system from mainly east-west to mainly northwest-southeast. Simple geometrical considerations, when combined with the length of a newly proposed "Terceira Rift" and independent estimates of local crustal spreading rates suggest that the change in crustal spreading direction and triple junction development began at least 45 My ago".

- 107 - MENAHEM A. & M. ISRAEL. - "Effects of major seismic events on the rotation of the Earth".
Geophys. J. R. Astr. Soc., v.19, n°4, p.367-393, 1970.

"A spherical theory is advanced for perturbations of the Earth's rotation by major earthquakes and explosions. Explicit expressions are obtained for the dependence of the secular polar shift on the dimensions, depth, and location of the seismic event. Numerical results show that a single shallow earthquake of magnitude 8.5, occurring at a suitable latitude and with a favourable strike-azimuth, may suffice to maintain the Chandler wobble for about one year. Hence, it is deduced that earthquakes may at most account for 30 % of the observed secular polar shift".

- 108 - ROTHE J.P. - "The seismicity of the Earth, 1953-1965".
UNESCO, Paris, 336 p, 1969.
C.R. : Geophys. J., Astr. Soc., v.20, n°1 p.99, 1970.

"This represents a continuation of the classic work of Gutenberg and Richter (Seismicity of the Earth, 2nd edition, 1954). The book has three introductory chapters, the second of which is especially interesting, putting on record the major seismic happenings of this 13-year period.

The bulk of the book consists of regional tables of earthquakes. The 51 regions are almost identical to those used by Gutenberg and Richter and are numbered in a similar way. There are listed 5329 earthquakes with magnitude greater than or equal to 5 for the period 1953 through 1965. Of these, 2750 have magnitude greater than or equal to 6, and 4041 of the shocks are shallow (h less than 70 km). The origin times are mostly given to 0.1 s and the latitudes and longitudes to 0.1°. The epicentres for 1953-1959 are recomputed I.S.S. and for 1960-1965, U.S.C.G.S. For earthquakes before 1960, the accuracy of the epicentres is considered to be ± 0.4 to 0.5° and after 1960, ± 0.1 to 0.2° . Each table is followed by a set of useful notes and a good bibliography.

At the end of the book there is a series of 24 maps, again corresponding to those of Gutenberg and Richter. Although these do not have the highest quality computer determined epicentres, they are remarkable in clearly defining the boundaries of the rigid plates. The continuity and narrowness of the seismic zones become more and more marked with the acquisition of more and better data.

Mention is made of the so-called "New global tectonics". Those studying plate theory in detail will need more refined computer determined epicentres, but this work is extremely valuable for filling the gap for the period from the end of Gutenberg and Richter's work to the introduction of the W.W.S.S.N. in 1963. It is well produced and full of interesting notes and snippets of information".

R.W. GIRDLER

- 109-- WALCOTT R.L. - "Isostatic response to loading of the crust in Canada".

from : Canadian J. Earth Sci., v.7, n°2, p.716-727.

Contr. Dom. Obs., n°298, Ottawa, 1970.

"A smoothed free air anomaly map of Canada indicates that the central part of the region occupied by the Laurentide Ice Sheet is over-compensated. Due to the close association of the free air gravity, the apparent crustal warping, the time of deglaciation, and the congruence of the gravity anomalies and the Wisconsin Glaciation, it is concluded that the over-compensation is due to incomplete recovery of the lithosphere from the displacement caused by the Pleistocene ice loads. The amplitude of the anomalies, about - 50 milligals, suggests that a substantial amount of uplift has yet to occur and that the relaxation time of crustal warping is of the order of 10.000 to 20.000 y.

The profile of the ground surface at the edge of a continental ice sheet on an elastic lithosphere is assessed using a value of the flexural parameter of the lithosphere calculated from gravity and deformation studies in the Interior Plains. The conclusions are :

- a) a purely elastic forebulge is not likely to reach an amplitude of more than a few tens of meters ;
- b) the crust will be depressed for a considerable distance beyond the edge of the ice sheet and,
- c) for large ice sheets crustal failure will probably occur in a preferential zone several hundred kilometers inside the maximum ice limit".

- 110 - SPECTOR A. & R.W. HORNAL. - "Gravity studies over three evaporite piercement domes in the Canadian Arctic".

from : Geophys., v.XXXV, n°1.

Contr. Dom. Obs., n°300, 9 p, Ottawa, 1970.

"Reconnaissance gravity surveys over three evaporite piercement domes in the Canadian Arctic Islands have been interpreted. Each dome was considered as a right-vertical cylinder divided into two homogeneous regions, a high density anhydrite zone (2.9 gm/cm^3) overlying a low density gypsun and/or rock salt zone (2.3 gm/cm^3). The cylinder is surrounded by a sedimentary sequence which has a uniform density of 2.4 gm/cm^3 . Interpretation involved a least-sum-of-squares approach to estimate the thickness of the anhydrite and gypsun-rock salt zones. The three sets of estimates gave a range of 200 to 550 m. for the anhydrite thickness and a range of 700 to 5.500 m. for the vertical extent of domes. In each case the depths were less than expected on the basis of estimates from seismic and geological data. Possible explanations for this are :

- a) the cross-sectional area of each dome decreases with depth ;
- b) the existence of a transition zone where a gradation occurs between the high and low density zones and ;
- c) the effective density contrast of the low density zone is less than 0.1 gm/cm^3 ".

- 111 - HERRING J.C., D.G. ABBY & J.A. COOK. - "Time synchronization of primary geodetic sites through use of artificial satellites". AFCRL, 70-0333, n°220, Office Aerospace Res., 13 p, Bedford, 1970.

"Geodetic measuring techniques, especially those making use of the artificial satellite, have advanced to the point where timing requirements once fulfilled by such systems as WWV no longer can provide the accuracies currently required. Geodetic field teams dispersed on a worldwide basis have in their inventory time standards ranging from crystal oscillators to cesium beam standards. Each must be synchronized to some basic standard. The advent of the synchronous communications satellite has provided the geodetic community and others with a real time, economical and highly precise means of synchronizing these same time standards. One such technique utilizing these communications satellites as a link in the synchronization process is reviewed".

- 112 - FLEISCHER U., O. MEYER & H. SCHAAF. - "Über den Aufbau der untermeerischen Tafelberge südlich der Azoren anhand eines gravimetrisch-magnetischen Nord-Süd profils über die Grosse Meteor-Bank". Sond. : Meteor Forschung. R.C., H.3, S.37-47, 1970.

"On the structure of the submarine tablemounts south of the Azores as derived from a gravimetric-magnetic north-south profile across the Grosse Meteor Bank (30°N, 28°5 W.G.)

Partial results of the Atlantic Expedition 1965 (IQSY) conducted with the Research Vessel "Meteor".

In the case of the Grosse Meteor Bank, this plateau has a N-S extension of approx. 30 nautical miles and an E-W extension of approx. 20 nautical miles and reaches a height of 275 m. in water depth.

The gravity measurements yielded a density of the topographic masses of 2.6 g/cm³ for the Grosse Meteor Bank. Magnitude and shape of the measured free-air anomaly are very well shown in a model computation with this density. The theoretical gravity effects of the seismically detected swell of cristalline rock and of the Moho depression (mountain root) are not indicated by the observational data. It can, therefore, be assumed that the latter two neutralize each other. It seems, accordingly, that there is no local isostatic compensation of the topographic masses. Hence, the density of 2.6 g/cm³ obtained would be about the true density of rock. In connection with the mean velocity of P waves (K. ARIC & al., 1968) obtained by seismic refraction methods it must be concluded that the material of the 1200-4000 m. thick surface layer of the Grosse Meteor Bank consists of consolidated sediments.

This finding is supported by the total intensity of the Earth's magnetic field over the grosse Meteor Bank. On the assumption of a homogeneous magnetization in the direction of the present Earth's field, the computed anomaly of the massif deviates considerably

from the measured anomaly while the magnetic field of the seismically detected cristalline body is capable of interpreting the observed data.

Deviating from the prevailing interpretation of the seamounts' plateau as a volcanic cone with submarine abrasion, the Grosse Meteor Bank and the seamounts in the vicinity are assumed to be of continental origin. The questions whether these seamounts submerged later on or whether the sealevel has risen subsequently are, therefore, largely nonexistent".

- 114 - SCHWEIZEISCHEN GEODATISCHEN KOMMISSION - Astronomisch-geodätische Arbeiten in der Schweiz.
Längen, Azimut und Breitenbestimmungen 1961-1964.
Band 28, 151 S, Zurich, 1969.
 - 115 - MELCHIOR P. - Marées terrestres.
Bull. Inf. n°56, p.2689-2715, Bruxelles, 1969.
 - 116 - MELCHIOR P. - Marées terrestres.
Bull. Inf. n°57, p.2717-2780, Bruxelles, 1969.
 - 117 - SOCIETE BELGE d'ASTRONOMIE de METEOROLOGIE et de PHYSIQUE du GLOBE.
Ciel & Terre, Bull. v.86, n°2, p.85-176, Bruxelles, 1970.
 - 118 - WORLD DATA CENTER A. - "Gravity, Tsunami, Seismology, Longitude & Latitude, Meteorology".
Catalogue of data received by WDC A during the period 1 July 1957 - 31 December 1969. 62 p, Washington, 1970.
 - 119 - SOCIETE HELVETIQUE des SCIENCES NATURELLES - Procès verbal de la 115ème séance de la Commission Géodésique Suisse tenue au Bernerhof à Berne le 14 Juin 1969.
80 p, Zurich, 1970.
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