B U R E A U   G R A V I M E T R I Q U E

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B U L L E T I N   d ' I N F O R M A T I O N

Décembre I963

N° 5

INTRODUCTION

Ce Bulletin d'Information fait partie de la série des publications du B.G.I. Il comprend trois parties différentes :

Prof. P.TARDI
Dr. S.CORON

XIII° ASSEMBLEE GENERALE DE L'U.G.G.I.

Berkeley, I9-3I Août I963

Des Compte-Rendus détaillés des différentes Sections de l'Association Intern.le de Géodésie paraîtront ultérieurement dans plusieurs numéros du "Bulletin Géodésique". Aussi, nous donnons ci-après un résumé très court des séances de la Section IV. Nous avons ajouté à ce Compte-Rendu les voeux adoptés à la fin de ces réunions ainsi que le Rapport Général du Groupe Spécial d'Etudes N° 20 "Report on Gravity measurements at Sea", établi après l'Assemblée, par le Dr. WORZEL, Président de ce Groupe.

Compte Rendu de la SECTION IV : GRAVIMETRIE

La Section de Gravimétrie a tenu sept séances dont une avec la Section V, sur les Réductions de Pesanteur.

La première séance a été consacrée à un aperçu d'ensemble sur l'activité gravimétrique mondiale. Le Dr. RICE, Président de la Section, résume rapidement la situation et donne le programme des séances ; le Dr. CORON présente le "Rapport Général sur les mesures relatives de la pesanteur sur terre, effectuées de I960 à I963", en attirant l'attention sur les travaux d'intérêt général et les régions dépourvues encore de réseaux gravimétriques. Elle indique ensuite l'activité du B.G.I. (Paris), mentionnant particulièrement "l'archivage des données gravimétriques sur cartes perforées", et rappelle les voeux adoptés à la fin de la réunion de la Commission Gravimétrique Internationale (Paris, sept. I962). Quelques remarques sont faites et quelques compléments d'information apportés sur ces différents sujets.

La 2éme séance consacrée à la Réduction, l'Interpolation et l'Extrapolation de la pesanteur ainsi qu'à l'établissement d'une nouvelle formule de Pesanteur, fut tenue avec les Sections III et V, sous la présidence du Prof. HEISKANEN.

Le Dr. COOK précise que l'Union Astronomique Internationale, dans un récent Symposium (Paris, mai 1963), a envisagé la révision des Constantes définissant les dynamiques du Système solaire (Terre et Lune comprises); il ajoute que de nouvelles valeurs numériques conventionnelles seront proposées et probablement adoptées à la prochaine Assemblée Générale de l'U.A.I. qui se tiendra en 1964. L'A.G.I. a donc à décider si ces changements doivent entraîner pratiquement une modification de la formule internationale de pesanteur.

De nombreux géodésiens donnent leur avis sur l'utilité d'un changement de l'ellipsoide et de la formule internationale, envisageant tour à tour les points de vue géodésique, physique et pratique. En conclusion, on décide de subdiviser le problème et de maintenir, pour toutes les applications pratiques, la formule internationale de pesanteur (1930) qui a déjà été largement utilisée dans les réductions gravimétriques (Voeu N° 3).

Au commencement de la 3ème séance, le Dr. COOK résume son Rapport "on absolute Measurements of gravity". Il insiste sur l'intérêt croissant de ces mesures absolues qui, combinées avec les mesures de distance à la lune par radar, pourront fournir des indications précises sur la forme de la Terre. Partant des récentes déterminations absolues de g, il résume dans un tableau les différentes corrections qui doivent être apportées à la valeur de référence adoptée à Potsdam. Comme les corrections obtenues à partir des mesures faites en Amérique sont un peu plus fortes que celles obtenues à partir des mesures faites en Europe, ces résultats mettent en évidence un écart systématique entre les mesures relatives faites sur ces deux continents; il souhaite que des déterminations absolues de g puissent être effectuées avec les mêmes appareils transportables sur les divers continents (Voeu N°9).

Le Prof. MORELLI pense que ce désaccord provient, en partie, d'un écart systématique (environ 1 mgal) entre la station de référence Potsdam et la station de remplacement Bad Harzburg utilisée dans les liaisons modernes au gravimètre (valeur Weiken actuellement adoptée : 981 180,40 mgal); les résultats des toutes récentes liaisons effectuées entre ces 2 stations sont consignés dans "The Bad Harzburg gravity value in the present Potsdam system."

Le Dr. WOOLLARD fait aussi remarquer que les résultats de ses propres rattachements (à partir de Madison) à Buenos Aires, Washington, Princeton, Ottawa, Teddington, Paris conduisent à considérer une différence systématique liée à la latitude des points d'observation. Il préconise donc des déterminations absolues de g avec les mêmes appareils, en des points présentant des intervalles de l'ordre de 3 000 mgal.

A propos des appareils de mesure absolue, M.J.E. FALLER expose en détail avec de nombreuses vues, la méthode appliquée à l'Université de Princeton, New Jersey "An absolute interferometric determination of the acceleration of gravity"; de même, M. A. SAKUMA donne quelques précisions sur la nouvelle détermination au Bureau International des Poids et Mesures, Sèvres (lancement d'un trièdre de bas en haut). Dans une séance ultérieure, le Dr. THOMPSON montre quelques vues relatives à la détermination absolue en cours à Cambridge (Etats-Unis) avec des pendules réversibles.

Cette séance a été prolongée (en collaboration avec les Sections III et V) par des exposés sur l'utilisation des satellites artificiels à des fins géodésiques.

Dans la 4ème séance, le Prof. MORELLI, Président du Groupe d'Etudes N° 5, complète le Rapport qu'il a déjà présenté à la réunion de la C.G.I. (sept. 1962, Paris) sur "the first Order and Absolute World Gravity net", il remercie tous ceux qui apportent leur collaboration à cet important travail et expose l'état actuel de la question, insistant sur la dépendance du réseau homogène mondial et du problème d'étalonnage ainsi que sur l'importance de la station de référence : Potsdam. Il reprend en détail cette dernière question : corrections à apporter aux différents sites occupés à Potsdam, valeurs de g obtenues à Bad Harzburg qui s'échelonnent de 981 180,40 à 981 179,44 mgal au fur et à mesure des calculs et des observations.

Ce dernier exposé du Prof. MORELLI soulève de nombreuses remarques relatives à l'évolution technique des appareils (Dr. COOK), à la précision des mesures pendulaires (Dr. WOOLLARD, M. BROWNE), à l'influence du nombre d'observations utilisé dans chaque résultat partiel (Dr. BJHERHAMMAR) et à l'emploi d'une méthode de compensation uniforme pour toutes les mesures pendulaires récentes (Dr. HONKASALO).

Cette séance se termine sur la présentation du Rapport du Prof. GROSSMANN sur les liaisons toutes récentes faites avec un gravimètre Askania GS-12 entre l'Europe et l'Afrique, liaisons destinées à renforcer le réseau de 1er Ordre et à prolonger la chaîne d'étalonnage jusqu'à Johannesburg par Le Caire, Nairobi... "Ergebnisse eineiger Schweremessungen mittels zwei mit veränderlicher Masse arbeitenden Langstreckengravimetern von Typ Askania GS-12 in Europe und Africa."

La 5ème séance a été consacrée à l'établissement des chaînes officielles d'étalonnage pour gravimètres. Le Prof. SOLAINI présente le Rapport du Prof. KNEISSL, Président du Groupe d'Etudes N° 5 (chaîne Européenne), rappelle les objections soulevées par les géodésiens italiens à propos de la précision inégale des diverses parties de la ligne d'étalonnage, les conclusions de la C.G.I. (sept. 1962) enfin celles de la récente réunion tenue à Munich (juil. 1963). Comme on l'a dit précédemment, il mentionne les dernières liaisons internationales de pesanteur qui contribuent à l'extension de cette chaîne européenne sur le territoire africain.

Après un échange d'idées sur la meilleure méthode de compensation des résultats, on décide de transmettre à l'U.G.G.I., le voeu relatif à l'adoption pour tous les points principaux du système européen d'étalonnage, des valeurs de g résultant de la compensation réalisée en 1962 (Voeu N° 2).

M. SZABO ensuite fait part d'un projet d'ensemble concernant l'établissement du réseau mondial de pesanteur homogène et le Dr. HAMILTON expose le résultat de ses observations (avec 2 gravimètres LaCoste-Romberg) sur les 2 chaînes officielles d'étalonnage européenne et américaine. Il conclut à un écart de l'ordre de 1/3 000 entre les unités de pesanteur américaines et les valeurs correspondantes européennes et estime que la valeur de g actuellement adoptée à Bad Harzburg doit être diminuée de 0,92 mgal pour se référer au Système de Potsdam (en accord avec le Prof. MORELLI).

Au cours de la séance générale du 28 août, le Dr. WORZEL, Président du Groupe d'Etudes sur les Mesures en Mer, informe les délégués qu'une réunion préliminaire de travail sur les Mesures de Pesanteur en Mer et dans l'Air, s'est tenue le 22 août; il présente son Rapport Général relatif aux appareils de mesure et aux observations.

Le Dr. LONCAREVIC donne quelques détails sur la croisière qu'il a faite dans l'Océan Indien (International Indian Ocean Expedition); les résultats de ces mesures sont publiés dans un Atlas avec des cartes d'anomalies magnétiques, gravimétriques et des cartes du relief sous-marin.

Le Dr. THOMPSON apporte quelques précisions sur les tests de mesures en avion effectués l'an dernier pour l'AFCRL avec plusieurs gravimètres. En outre, quelques remarques sur la correction d'Eotvös, le système de navigation Decca, puis sur l'étalonnage des gravimètres pour mesures en mer, sont faites successivement par le Dr. THOMPSON, le Prof. BOULANGER, le Prof. MORELLI et M. BROWNE.

Le Dr. WORZEL donne lecture d'une proposition du Prof. KNEISSL recommandant l'établissement, à l'intérieur du Groupe Spécial N° 6 d'un groupe de travail chargé d'étudier le rattachement des mesures en mer au réseau continental européen*. Le Prof. MORELLI, le Dr. WORZEL pensent que le B.G.I. pourrait faire un travail préparatoire à ce sujet et le Dr.RICE recommande que tous les travaux et projets de mesures en mer soient communiqués au B.G.I. pour permettre une meilleure collaboration entre tous les observateurs (Vöeu N°6).

Au début de la dernière séance, le Dr. TENGSTRÖM expose brièvement le processus à utiliser pour résoudre le problème principal de la Géodésie avec les meilleurs anomalies de la pesanteur.

Le Dr. RICE donne lecture des Voeux qui ont été proposés; après discussion, 9 Voeux sont adoptés.

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* Une Circulaire a été envoyée à tous les pays européens intéressés; les réponses seront publiées dans le Bulletin d'Information suivant.

VOEUX

adoptés à la SECTION IV de l'A.I.G.

Berkeley I963

N° I - Cooperation pour les liaisons gravimétriques internationales

L'U.G.G.I.,

Reconnaissant l'importance de l'établissement d'un système standard international d'étalonnage pour gravimètres et d'un réseau gravimétrique mondial de Ier ordre,

Demande que les gouvernements des pays intéressés coopèrent à ce programme international de toutes les manières possibles, en particulier en autorisant l'entrée dans leurs pays aux équipes d'observations avec leurs gravimètres et pendules afin d'y effectuer les mesures de pesanteur nécessaires.

N° 2 - Base d'Etalonnage Européenne

L'U.G.G.I.,

Reconnaissant les bons résultats obtenus dans la compensation du système d'étalonnage gravimétrique en Europe, avec une précision de facteur d'échelle de $2 \times IO^{-4}$ correspondant aux mesures faites avec les pendules actuels,

Recommande que les valeurs de la gravité obtenues pour les points principaux à partir de cette compensation soient utilisées comme données de base pour toutes nouvelles applications pratiques, telles que l'établissement de cartes des anomalies de la pesanteur et la coordination des systèmes gravimétriques nationaux.

N° 3 - Maintien de la formule de pesanteur

L'A.I.G.,

Décide que, quels que soient les changements qui puissent affecter les constantes fondamentales du champ de pesanteur extérieur à la terre,

Aucun changement ne doit être apporté pour le moment à la Formule Internationale de pesanteur lorsqu'elle exprime les résultats de mesures de pesanteur.

N° I - Cooperation in International Gravity Connections

The IUGG,

Recognizing the importance of establishing an International Gravimeter Calibration Standard and a first order world gravity net,

Requests that governments of countries concerned cooperate in this international program in all the possible ways, particularly by permitting the gravimeter and pendulum observing teams and instruments to enter their countries to make the required gravity observations.

N° 2 - European Calibration Standard

The IUGG,

Recognizing the successful completion of the adjustment of the gravity calibration system in Europe, with a scale-factor accuracy of 2 x IO^{-4} according to existing pendulum measurements,

Recommends that the gravity values for the principal points obtained from this adjustment be used as the basis for all new practical applications, such as the production of gravity anomaly maps and the coordination of national gravity systems.

N° 3 - Retention of International Gravity Formula

The IAG,

Resolves that whatever changes maw be required in the fundamental constants that describe the external gravity field of the earth,

No change should be made at the present time in the International Gravity Formula when used as a means of describing the results of gravity measuring.

N° 4 - Etablissement du Réseau Gravimétrique Européen

L'A.I.G.,

Considérant que, dans les divers pays européens la pesanteur a été déterminée en de nombreux points fondamentaux au moyen de pendules et de gravimètres modernes, que de plus tous les gravimètres peuvent être étalonnés de manière uniforme grâce à l'utilisation de la nouvelle base européenne d'étalonnage,

Recommande qu'il soit établi un réseau gravimétrique fondamental européen uniforme qui pourrait éventuellement servir de modèle pour la compensation future du système gravimétrique mondial.

N° 5 - Cartes perforées pour "l'archivage" des données gravimétriques

L'A.I.G.,

Ayant considéré le format international proposé par le B.G.I. pour l'archivage des données gravimétriques conformément au voeu N° I4 de la C.G.I. à Paris en septembre I962,

Approuve les deux modèles proposés (carte index et carte complémentaire) sous réserve que quelques détails de la carte complémentaire seront précisés ultérieurement.

L'A.I.G. recommande vivement pour l'avenir l'emploi de ce format par les différentes organisations gravimétriques.

N° 6 - Echange d'informations sur les mesures de pesanteur en mer

L'A.I.G.,

Considérant les délais inévitables avant que les résultats des recherches de pesanteur en mer soient publiés,

Recommande que le B.G.I. soit informé lorsque des mesures de pesanteur en mer de quelque étendue sont projetées, et

Recommande en outre qu'il soit envoyé au B.G.I. de brefs comptes rendus concernant les mesures faites. Plans et comptes rendus devront au moins indiquer les zones couvertes et, si possible, les premiers résultats obtenus.

N° 4 - Establishment of the European Gravity Network

The IAG,

Considering that in the various European countries gravity was determined at numerous fundamental points by pendulum apparatus and modern gravity meters, and that furthermore by use of the new European calibration standard all gravity meters can be calibrated in a very uniform manner,

Recommends that there be established a uniform fundamental European gravity network which could eventually serve as a model for the subsequent adjustment of the world gravity system.

N° 5 - Punch Cards for Compiling Gravity Data

The IAG,

Having considered the international format proposed by the IGB for the compilation of gravity data in accordance with Resolution N° I4 of the IGC at Paris in September I962,

Approves the two models proposed (index card and complementary card) with the understanding that some details of the complementary card will be decided upon later.

The IAG furthermore strongly urges the use of this format by the various gravity organizations.

N° 6 - Exchange of Information on Sea Gravity Measurements

The IAG,

Considering the unavoidable delay before results of sea-gravity investigations can be published,

Recommends that the IGB be informed when sea gravity measurements of some extent are planned, and

Further recommends that the IGB be sent brief reports concerning measurements executed. Plans and reports should at least indicate the areas covered and perhaps the preliminary results obtained.

N° 7 - Chaîne d'étalonnage en Argentine

L'A.I.G.,

Ayant considéré le voeu N° 9 de la C.G.I. à Paris en septembre 1962, et prévoyant qu'une équipe gravimétrique venant des Etats-Unis fera des observations sur la ligne d'étalonnage qui sera établie en Argentine au cours de l'extension de la chaîne d'étalonnage américaine depuis Mexico City jusqu'à la pointe sud de l'Amérique du Sud,

Recommande que l'Institut de Géodésie de la Faculté des Ingénieurs de l'Université de Buenos-Aires collabore avec l'équipe gravimétrique des Etats-Unis en observant simultanément avec leurs gravimètres sur cette chaîne qui sera mesurée plus tard avec différents types de pendules.

N° 8 - Chaîne d'Etalonnage Ouest-Pacifique

L'A.I.G.,

Recommande, qu'en raison de l'importance du problème d'uniformisation de pesanteur,

Les appareils pendulaires japonais soient aussi utilisés sur la Chaîne Ouest-Pacifique entre Fairbanks et Melbourne en passant par Chiose, Tokyo, Kyoto, Manille et Singapour.

N° 9 - Mesures absolues internationales

L'A.I.G.,

Prenant en considération l'importance de connaître au mieux la valeur de la gravité absolue dans de nombreux domaines scientifiques: et reconnaissant que les appareils de mesure absolue de pesanteur actuellement transportables permettent des mesures absolues avec le même appareillage en différents endroits,

Recommande que de telles mesures soient effectuées partout où elles seront possibles.

N° 7 - Argentine Calibration Line

The IAG,

Having considered Resolution N° 9 of the IGC at Paris in September 1962, and foreseeing that a gravity observing team from the U.S.A. will make observations on the calibration line being established in Argentina during the course of extending the American Calibration Line from Mexico City to the southern tip of South America,

Recommends that the Instituto de Geodesia of the Faculty of Engineering of the University of Buenos Aires collaborate with the U.S.A. gravity meter team by observing simultaneously with their gravity meters on this calibration line which will be measured in the future with several types of pendulum apparatus.

N° 8 - West-Pacific Calibration Line

The IAG,

Recommends that owing to the importance of the Standardization Gravity Problem,

It is highly desirable that also the Japanese pendulums participate in the measurements on the Western Pacific Line, between Fairbanks and Melbourne through Chiose, Tokyo, Kyoto, Manila and Singapore.

N° 9 - International Absolute Measurements

The IAG,

Taking into account the importance of the best value of absolute gravity in many fields of science, and recognizing that existing portable absolute gravity equipments permit absolute measurements with the same equipment in different places,

Recommends that such measurements be executed wherever possible.

SPECIAL STUDY GROUP N° 20

Report on Gravity Measurements at Sea

J. Lamar WORZEL

This report covers the gravity measurements at sea since the fall of I960, which have come to the attention of the writer either by publication or by personal correspondence, as well as possible sources of error and their correction. Persons believed to have pertinent information for this report were contacted by mail to enquire for additional information, the writer wishes to thank all contributors for their help.

A study meeting of Special Study Group Number 20, Gravity Measurements at sea and in the Air, was help under the chairmanship of J.L. WORZEL in the evening of Thursday 22nd August I963. The following papers were presented :

1. Hyman ORLIN of the United States Coast and Geodetic Survey presented the results of a test of the accuracy of the LaCoste and Romberg sea gravimeter over a gravity range established off San Francisco. This meter had had correction devices added to counter the difficulties encountered in the work with Sac Lant Research Center, La Spezia. A mean Square error of 9,7 mgal was found. By doubling one of the corrections, the mean square error could be reduced to 6,3 mgal. Accelerometer corrections were encountered as high as 50 mgal. The results were found to be best in a following sea and worst with a head sea.

2. L.G.D. THOMPSON of the Air Force Cambridge Research Center of the United States, reported on airborne measurements with a LaCoste and Romberg gravimeter using its associated horizontal accelerometers, a LaCoste and Romberg gravimeter without the associated horizontal accelerometers mounted on a gyro-stabilized platform, and a Graf-Askania gravimeter mounted on the same gyro-stabilized platform (not simultaneously). The mean observed gravity for all flights with either the Graf-Askania or the LaCoste and Romberg mounted on the stabilized platform agree to ± I mgal with the upwards continued mean value. Allowing for errors introduced by long period accelerations, the mean observed gravity value for the LaCoste and Romberg meter with its associated horizontal accelerometers mounted on its gimbal suspension agrees to ± I mgal with the upward continued value. All configurations showed an RMS deviation close to 6 mgal without regard to sign between each individual flight and the upward continued value. This work was all carried out over a range especially instrumented to provide navigation from the ground. Navigation instruments are under development which should permit similar results to be obtained without the use of a specially instrumented range.

3. T.D. ALLAN of Sac Lant Research Center in Italy presented results of a very detailed survey on board Aragonese in the Red Sea and the Gulf of Aden using two Graf-Askania meters. They found a Bouguer gravity anomaly greater than I00 mgal associated with the central area which topographically resembles a rift valley. Large magnetic anomalies up to I 200 γ are associated with the central area in the southern part of the Red Sea, while the magnetic field is quite featureless in the northern part. In the Gulf of Aqaba the magnetic field is featureless, the Bouguer anomaly is up to -I00 mgal and the free air anomaly is up to -200 mgal.

4. D.C. MORELLI of the Instituto di Geofisica of Trieste reported on his work in the Mediterranean Sea with a Graf-Askania gravimeter. He found Bouguer anomalies rising to +I50 mgal as deeper water was encountered to the south in the Gulf of Genoa. In the Bouguer anomalies, grabens occur extending to the south between Sicily and Tunisia. In the Aegean Sea Bouguer anomalies up to +I60 mgal were observed. To the west of Crete, a large positive anomaly was found while eastwards a large negative anomaly was encountered. He estimates the accuracy between two and four mgal in these areas and finds that measurements can be made in seas up to force 6.

5. M. TALWANI of Lamont Geological Observatory of Columbia University reported on experiments to evaluate the errors encountered in sea gravity measurements. Laboratoty experiments have shown deviations from the vertical that can be encountered with the Anschutz gyro-stabilized table over the range of sea conditions that can be expected to be encountered on a ship of R.V. Vema's size. From sea records of accelerometers made on R.V. Vema the off levelling errors cannot be expected to exceed one or two mgal. Preliminary data at sea, not yet conclusive, indicate that cross-coupling effects are of the same order of magnitude. In tests where quite precise navigation data was available, a spread of values up to 20 mgal was observed at track crossings. It was concluded that some other source of error was responsible for these large deviations. J.L. WORZEL suggested that the impulsive beginnings of "wave packets" through the Highly damped system of the gravimeters might be responsible. Some of the results with the new servo system for the Graf-Askania meter were illustrated.

6. M. CAPUTO of the University of California at Los Angeles reported that continuous measurements along 80 000 miles of track on ships of the Scripps Institution of Oceanography had been made in the North and South Pacific Oceans, the Indian Ocean and the South Atlantic Ocean with a LaCoste and Romberg sea gravimeter. He called attention to the recently published paper in the Journal of Geophysical Research where track crossings showed that 90% of the crossings agreed within I0 mgal and 86% within 5 mgal in the California borderland area. In the Rexberg survey in the Santa Barbara Channel where well controlled navigation was available 96% of the crossings agreed to within 5 mgal. He therefore suggested that the discrepancies are merely due to the navigational errors.

7. A.A. CERATO of the Institute of Geodesy of the University of Buenos Aires, Argentina, reported on shallow water gravity meter surveys off the coast of Argentina between Buenos Aires and Mar Del Plata and the Rio de la Plata. These surveys show that the land structures continue out to sea as the seismic results of Lamont Geological Observatory and the Argentine Hydrographic Office have previously shown.

The Chairman pointed out that four papers on gravity at sea were being presented in the sessions of the International Association of Seismology and Physics of the Earth's Interior. Abstracts of these papers were included in the abstracts of that association's meetings.

The papers given were :

I. Gravity measurements and crustal structure in the South-West Pacific, Manik TALWANI and J. Lamar WORZEL.

2. A summary of continuous gravity measurement results obtained on cruise I8 of R.V. Vema, J. Lamar WORZEL and Manik TALWANI.

3. Correction of gravity anomalies at sea for submarine topography, Raoul VAJK.

4. Gravity anomaly maps of the Puerto Rico trench region from new continuous measurements, C. BOWIN.

Besides the papers presented at the study group meeting reported above and in the other sessions of the I.U.G.G. the following reports of interest to this study group have been received :

1. B.D. LONDAREVIC reports that the gravity, magnetic and topographic data taken on H.M.S. OWEN on the cruise made as a part of the International Indian Ocean Expedition has been published as an Admiralty Marine Science Publication, N° 4, Part 2, H.O. 539, Hydrographic department, London, England, I963.

2. Y.D. BOULANGER reports that the gravity at sea work of the U.S.S.R. has been summarised in their national report which was distributed at the XIIIth General Assembly of the I.U.G.G.

3. C. TSUBOI reports that I. TSUBOKAWA, M. TAZIMA, and M. YANAGISAWA have developed a sea gravimeter using three strings mutually perpendicular to support a mass. This instrument is supported on a gyro-stabilized platform, the principal term of the gravity value is determined by taking the mean values of the natural frequencies of the strings. Correction terms can be obtained by suitably processing the data from each string and by photographing the position of a level bubble mounted on the stable platform. This instrument is ready for sea tests.

4. B.J. COLLETTE of the Vening Meinesz Laboratory of Utrecht advises that he has not yet succeeded in overcoming the difficulties encountered with his gravimeter utilizing a rotating liquid surface. He has had to postpone this work temporarily in order to plan a cruise to make observations in the North Eastern Atlantic Ocean between Greenland and Europe.

5. A. GRAF of the Tecknische Hochschule of Munich has made experiments with a device to reduce horizontal accelerations on a sea gravimeter by driving a platform in opposition to the ship motions. So far this device has not succeeded because of impulses introduced by the driving mechanism. A second device which utilizes the sea gravimeter as the mass of a long period (about 30 sec.) pendulum has been partially successful. Further development is required as it is very sensitive to inclination of the pendulum plane. He is also experimenting with pendulums and gyroscopes for measuring the horizontal accelerations.

6. H. HAALCK has reported on the latest developments in the aneroid sea gravimeter.

7. W. LANGE has written a comprehensive review of the history of gravity measurements at sea, the effects and sources of errors in these measurements and of some observations made in the Baltic Sea.

8. P. DEHLINGER reports that Oregon State University has established a coastal gravity range with a LaCoste and Romberg sea bottom gravimeter off the central Oregon coast.

9. The United States Coast and Geodetic Survey and the United States Navy Oceanographic Office have established gravity at sea calibration ranges off Rhode Island, in Chesapeake Bay and off San Francisco with a sea bottom gravimeter.

IO. The Dominion Observatory of Canada reports that measurements have been made across Hudson Bay and in the Gulf of St Lawrence using a LaCoste and Romberg sea bottom gravimeter. An all quartz vibrating string gravimeter has been built by D.R. BOWER which includes a means for correcting for the inherent non-linear response of a vibrating string. A means for isolating the quartz assembly from shock acceleration is now being studied.

MM. BOWER and WATT have published a study of the performance of gimbal suspended and stable platform supported gravity meters subjected to a continuous spectrum of wave accelerations, finding that there is a disturbance in the form of a very long period noise which is of the order of one seventh that of a sinusoidal disturbance.

The list of references which follow are those which may be of some interest to the members of this study group and others of similar interests.

Références

ALLAN, T.D., P. DEHLINGER, C. GANTAR, J.C. HARRISON, C. MORELLI and M. PISANI. "Comparison of Graf-Askania and LaCoste-Romberg Surface-ship gravity Meters on the R.V. Aragonese". Jour. Geophys. Res., (in press).

ADMIRALTY HYDROGRAPHIC DEPARTMENT. "Bathymetric, Magnetic and Gravity Investigations of H.M.S. Owen 1961-1962". Admiralty Marine Science Publication N°4, London.

BAGLIETTO, Eduardo E. Contributions à la Géodésie Appliquée. Institut de Géodésie, Faculté d'Ingénieurs, Université de Buenos Aires, 1963.

BOTT, M.H.P. "A gravity survey off the coast of North East England". Proc. York Geol. Soc., V. 33, pp. 1-20, 1961.

BOWER, D.R. and WATT, P.A. "The Second order errors of sea-surface gravity measurements". Jour. Geophys. Res., V. 68, pp. 245-50, 1963.

BRITISH NATIONAL COMMITTEE FOR GEODESY AND GEOPHYSICS. "United Kingdom Contributions to the Upper Mantle Project". The Royal Society, London, 1963.

CAPUTO, Michele, J.C. HARRISON, R.H. von HUENE and M.D. HELFER. "Accuracy of LaCoste-Romberg Surface Ship Gravity Measurements off the Coast of Southern California". Jour. Geophys. Res., V. 68, pp. 3273-82, I963.

CIANI, A., V. FLEISCHER and C. MORELLI. "Introduzione Al Rilievo Gravimetrico Del Mediterraneo : Premesse Teoriche E Misure Sperimentali con Gravimetro Graf Askania in Adriatico." Instituto Idogrqfico della Marina, Pubbl. Spec. I, I, 2I07, p. I34, Genova, I960.

CIANI, A., C. GANTAR and MORELLI. "Rilievo Gravimetrico Sullo Zoccolo Epicontinentale Dei Mari Italiani". Boll. Geof. Teor. Appl., review of Osser Geof. Sper. Trieste, N° 6, p. I-IOI, June I960.

CORBATO, C.E. and M.D. HELFER "Gravity Measurements on the Cruise of the U.S.S. Gear". Interim rept., Inst. of Geophys. and Planetary Phys., UCLA, (unpublished), I96I.

DEHLINGER, P. and S.H. YUNGUL. "Experimental Determination of the Reliability of LaCoste-Romberg Surface-Ship Gravity Meter S-9". Jour. Geophys. Res., V. 67, p. 4389-94, I962.

FANNING, K.F. and S.K. GAROTTE. "Gravity Meter Operational Check Range, Rhode Island Sound Area". Rept. G-I-62, U.S. Naval Oceanographic Office, Washington, D.C. (unpublished) I962 .

FANNING, K.F. and S.K. GAROTTE. "Gravity Meter Evaluation and Training Range, Chesapeake,Bay". Rept. G-2-62, U.S. Naval Oceanographic Office, Washington D.C. (unpublished)1962 .

GANTAR, C., C. MORELLI and M. PISANI. "Experimental Study of the Response of the Graf-Askania Gss-2, N°13 Sea Gravity Meter". Jour. Geophys. Res., v. 67, pp. 4411-19, 1962.

GANTAR, C., and C. MORELLI. "Misura Di Gravita Sul Fondo Dei Mari Intorno Alla Sardigna Con Gravimetrio Telecomandato". Boll. de Geof. Teor. ed Appli., O.G.S.. Trieste, II, 6, 1962.

HAALCK, H. "Das Aneroid-Seegravimeter". Gerlands Beiträge Zur Geophysik, B. 72, H 2, p. 89-102, 1963.

HARRISON, J.C. and F.N. SPEISS. "Comparison of Readings of Sea Gravimeter, Bottom Gravimeter and Geodetic Gravimeter; and Gravity Survey in the Gulf of California, 1959". Interim Rept, Inst. of Geophys. and Planetary Phys., UCLA (unpublished) 1961.

HARRISON, J.C. "Gravity Measurements in the Northern Continental Borderland Area off Southern California". Interim Rept., Inst. of Geophys. and Planetary Phys., UCLA (unpublished) 1961.

HARTOG, Stephen L. DEN and Ned OSTENSO. "Gravity and Magnetic Observations from Ice Island Arlis II, 1 July to 6 Oct. 1961". Univ. of Wis. Geophys. and Polar Res. Cent., Res. Rept. N° 62-7 (unpublished) 1962.

HELFER, M.D., Michele CAPUTO and J.C. HARRISON. "Gravity Measurements Across the Pacific and Indian Oceans (Monsoon Expedition)". Interim Rept., Inst. Geophys. and Planetary Phys., UCLA, (unpublished) 1960.

HELFER, M.D., C.L. HAGER and Michele CAPUTO. "Gravity Measurements over the Pacific Ocean and the Indian Ocean during 1962". Interim rept Inst. Geophys. and Planetary Phys. UCLA (unpublished) 1962.

HELFER, M.D., R. von HUENE and Michele CAPUTO. "Gravity Survey of the Santa Barbara Channel (California) with the USS Rexburg". Interim rept. Inst. Geophys., and Planetary Phys., UCLA (unpublished) 1962.

KARKI, P. and P. PAANANEN. "Isostatically Reduced Anomaly Fields on the Sea in the Vicinity of South and Central America". Publ. Isostatic Inst. Intern. Ass. Geod., N° 36, p. 31, Helsinki, 1961.

LA COSTE, L.J.B. and J.C. HARRISON. "Some Theoretical Considerations in the Measurement of Gravity at Sea". Geophys. Jour. Roy. Astron. Soc., V. 5, N° 2, p. 89-103, 1961.

LONCAREVIC, B.D. "Sea Gravity Base Stations, H.M.S. Owen 1961-62". Cambridge, England, (unpublished) Dec. 1962.

LANGE, Wolfgang. "Seegravimetrie". Freiberger Forschungshefte C 109 Geophysik, Akademie-Verlag, Berlin, 1961.

Marine Sciences Dept. "Coastal Gravity Survey, Puerto Rico". Rept G-2-63, U.S. Naval Oceanographic Office, Washington, D.C. (unpublished) 1963.

MORELLI, Carlo. "Rilievo Gravimetrico Nei Mari Italiani 1953-1957". Osserv. Geof. Nuova Serie. Pubbl. N° 112B, Trieste, 1961.

MORELLI. Carlo. "Novo Esperienze con il Gravimetro Marino Graf-Askania". Osssrv. Geof. Sper. Trieste, Pubbl. N° 121b, 1961.

ORLIN, Hyman. "Gravity Meter Observations aboard a Surface Vessel and their Geodetic Applications". U.S. Coast and Geodetic Survey, 1962.

ORLIN, Hyman, R.B. JONES, K.F. FANNING and S.K. GAROTTE. "Sea Gravity Phase Oceanographic Equipment Evaluation Range, San Francisco, California". U.S. Coast and Geodetic Survey and U.S. Naval Oceanographic Office, Washington D.C., (unpublished) 1962.

SCHULZE, Reinhard. "Automation of the Sea Gravimeter Gss 2". Jour. Geoph. Res., V. 67, p. 3397-340I, 1962.

TALWANI, M., B.C. HEEZEN and J.L. WORZEL. "Gravity Anomalies, Physiography, and Crustal Structure of the Mid-Atlantic Ridge". Publ. Bur. Cen. Seism. Intern. Serie A. Trav. Sci. Fas. 22, p. 8I-III, I96I.

TALWANI, M., J.L. WORZEL and M. EWING. "Gravity Anomalies and Crustal Section across the Tonga Trench". Jour. Geophys. Res., V. 66, p. I265-I278, I96I.

TALWANI, M. "Gravity Measurements on H.M.S. Acheron in South Atlantic and Indian Oceans". Bull. Geol. Soc. Amer., V. 73, p. II7I-II82, I962.

THOMPSON, L.G.D. "Comparison of LaCoste-Romberg and Askania-Graf Airborne Gravity Meters in Gimbal and Stabilized Mounts." Trans. Am. Geophys. Un., V.44, p. 3I (abstract only) I963.

TSUBOI, Chuji, Y. TOMODA and H. KANAMORI. "Continuous Measurements of Gravity on Board a Moving Surface Ship." Proc. Jap. Acad., V. 37, p. 57I-576, I96I.

TSUBOKAWA, I., M. TAZIMA and M. YANAGISAWA. "Dynamic Sea Gravimeter Using Three Strings". Geographical Survey Inst., Tokyo (unpublished), I962.

von ARX, WilliamS. "Applications of the Gyropendulum". The Seas, Ideas and Observations, (in press).

WORZEL, J.L. and M. TALWANI. "Latest Results of Gravity Observations at Sea from Surface Ships." Ohio State Publ. N° I5, N° 3-4, p. II6-I26, I96I.

WORZEL, J.L. "Gravity Reductions and Observations at Sea". Bull. Geod. N° 63, p. 67-68, I962.

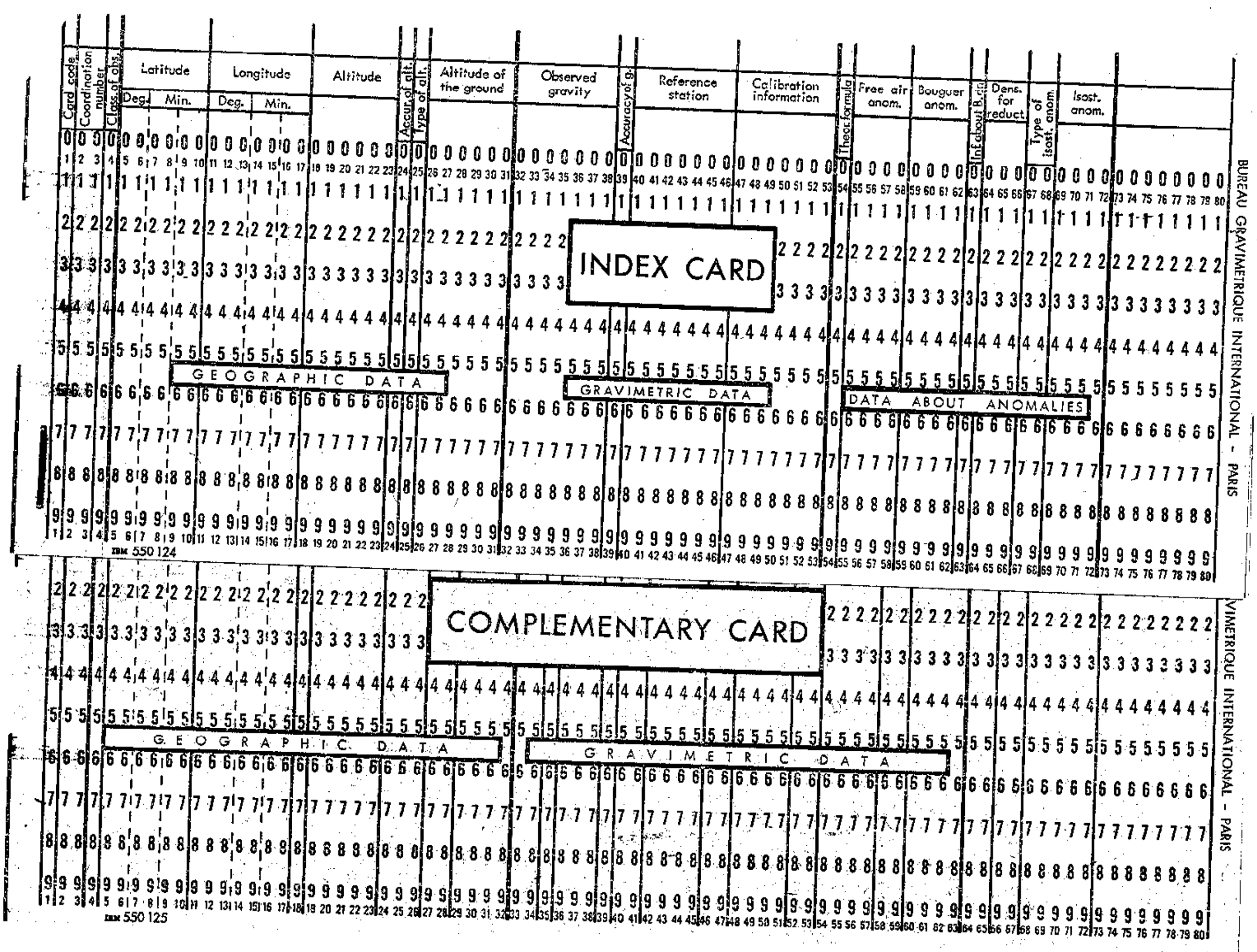
WORZEL, J.L. and P. DEHLINGER. "Comparison of Graf and LaCoste-Romberg Sea Gravimeters". (in press), I962.

WORZEL, J.L. and M. TALWANI. "Investigations of the Cross-Coupling Effect of the Graf Sea Gravimeter". Jour. Geophys. Res. V. 69, p. 36II (abstract only) I962.

YUNGUL, S.H. and P. DEHLINGER. "Preliminary Free-Air Gravity Anomaly Map of the Gulf of Mexico from Surface Ship Measurements and its Tectonic Implications". Jour. Geophys. Res. V.67, p. 472I-4728, I962.

RECORDING of GRAVITY DATA on PUNCHED CARDS

- Dec. 1963 -



RESOLUTIONS

SYMPOSIUM OF CAMBRIDGE, July 196I.

The delegates to the I.A.G.'s Symposium on the reduction of gravity data,

...

III. having considered the rapid increase in the rate at which gravity data arebeing obtained and the advantages to be gained by recording and handling such data by means of modern computing machines, recommend that the International Gravity Bureau should communicate with experts who have used such methods and should prepare a report for presentation at the next meeting of the International Gravity Commission.

I.G.C., PARIS, Sept. 1962.

The I.G.C. desires that all comments on the proposal made by Prof. TARDI about punched cards, should be sent to the International Gravity Bureau before the end of October 1962,

that after having consulted the nominated members, an international format should be adopted, and

that the International Gravity Bureau should collect existing cards and should complete this collection in the agreed form in cooperation with the Ohio State University and the National Services.

I.A.G., BERKELEY, August 1963.

Having considered the international format proposed by the I.G.B. for the compilation of gravity data in accordance with Resolution N° I4 of the I.G.C. at Paris in September 1962,

The I.A.G. approves the two models proposed (index card and complementary card) with the understanding that some details of the complementary card will be decided upon later.

The I.A.G. furthermore strongly urges the use of this format by the various gravity organizations.

We thank all the members of the group nominated by the I.G.C. and all the interested persons who made suggestions or critics and thus contributed to complete and make more accurate the Irst model proposed in Sept. 1962.

The final model of both Cards (index card and complementary card) is presented hereafter with an explaining text.

RECORDING of GRAVITY DATA on PUNCHED CARDS

(Final Text)

GENERAL CONVENTIONS :

After having made many inquiries near the various concerned Services, it seemed impossible to adopt a punching code which could be easily convenient for all types of computing machines now in use.

However we tried to punch the gravity data on such cards that they may be read directly by as many computing machines as possible particularly by all IBM machines.

For that purpose, some modifications have been made to the August 1963 format.

The following general conventions have been adopted :

a) Use of the decimal system on "normal" cards.

b) Columns 73...80 are free because some machines only read 72 columns; but these columns could be used for particular information which would'nt be used for any calculation purpose.

c) Columns 1...72 are punched in numeric, except columns 45 and 52 (Index Card) which are punched in alpha (IBM Code).

d) The minus sign (negative algebric values or distinctive signs used to specify the West longitudes, South latitudes) are punched in the first column of the corresponding zone.
The positive sign is never punched for positive algebric value.

e) When information is not known or does'nt reach the required accuracy the concerned zone will be made up with zeros.
   - no information at all in zone : only the last zero is punched(X-II)
     Ex. 0000$\bar{0}$
   - insufficient accuracy; all unsignificant zeros are punched (X-II)
     Ex. 114°25'$\bar{0}\bar{0}$ (114°25')

VARIOUS CARDS :

A pair of cards is prepared for each published gravity value; the main card (Index Card) gives on one hand all necessary information for approximative geodetic computations and on the other hand all necessary information to reduce the observed g values to an unique system.

The Complementary Card gives all further information about the site of the observation (topographic, geological characteristics...), the measurement itself (apparatus, date), the anomalies computed according to various geophysical hypothesis.

The univoque correspondance between both cards is obtained through the repetition of the geographical coordinates (latitude and longitude, col. 5 to 17) and the additional "coordination number", (col. 2-3).

In future,"special cards" should be prepared for international stations.

INDEX CARD

I) CARD CODE

col. I

I.. Index Card ("bulle" paper)
2.. Complementary Card (green paper)
3.. ...
... ...
... ...

II) COORDINATION NUMBER

col. 2 and 3

The correspondance between both cards concerning the same observation may be obtained through a reference number (col. 73...80).

However as some computing machines read only on the first 72 columns, one should keep the 2 and 3 columns for a coordination number.

That number should be used only to distinguish without error the pair of cards of which the observations have the same geographical coordinates (latitude and longitude). These 2 - 3 columns, at the disposal of the individual user, should be identical on both cards for a particular observation, but should be different for each observation.

We suggest for instance to punch firstly OI for each observation · as soon as identical pairs of cards are punched or detected, numbers such as 2, 3, 4... would be attributed to the observation lately punched.

III) TYPE OF THE OBSERVATION

col. 4

0 current observation of detail
or other observation of a 3rd or 4th order net.

I Observation of a 2nd order national net
or of a secundary national net.

2 observation of a Irst order national net
or of a primary national net.

3 observation being part of a national calibration line.

4 individual observation at sea.

5 mean observation at sea (or in the air) obtained from a continuous recording.

6 coastal ordinary observation (harbour, bay, sea-side...).

7 harbour base observation

8 ...

9 observation being part of international work (international Irst order net, official calibration lines), obtained from specialized publications.

It seems difficult to make a rigorous classification owing to the various ways of carrying out gravity networks. However, in the above mentioned system, punches 9, 7 and 3 will mean stations more accurate than those defined as 0 and 4.

Moreover, an overpunch should distinguish the pendulum observations from the gravity meter ones :

- pendulum apparatus X-II
- gravity meter no overpunch

More accurate information for the apparatus used is given in the complementary card (col. 33-34).

IV) LATITUDE col. 5...10

In degrees, minutes and hundredths of minute.
Latitude S : minus sign (X-II) in the 5 column.

V) LONGITUDE col. 11...17

In degrees, minutes and hundredths of minute.
The reference meridian is Greenwich.
Longitude W.G. = minus sign (X-II) in the II column.

Note : The reference ellipsoid and the basic data are, in principle, those used in the country where the station is located. The geographical coordinates can only be the coordinates in relation to the national system for each country.
As the coordinates are indicated at the best to 20m (0'01 in latitude) it does not seem necessary to give any other precision about the system actually used.

Some free columns in the complementary card have been reserved for later corrections (for instance countries in which triangulation systems offer large discrepancies).

VI) ALTITUDE of the site of the OBSERVATION

1) Altitude col. 18...23
(concerning the g value mentioned further, col. 32...38)
Adopted unit : meter
(cf. Resolution n°4, Helsinki, 1960).
The decimal point is between the 22 and 23 columns.
Minus sign of the altitude is mentioned in the 18 column; this information is also given in the 25 column.

The mentioned altitudes are, in principle, the ordinary orthometric altitudes. For the altitudes as well as for the geographical coordinates we shall mention the national results of the official publications.

2) Accuracy on the altitude mentioned col. I8...23 : col. 24

The error e on the altitude will be defined by the following code :

I	e $\leq$ 0,I m
2	0,I $<$ e $\leq$ I
3	I $<$ e $\leq$ 2
4	2 $<$ e $\leq$ 5
5	5 $<$ e $\leq$ IO
6	IO $<$ e $\leq$ 20
7	20 $<$ e $\leq$ 50
8	50 $<$ e $\leq$ IOO
9	error superior to IOOm

3) Type of the mentioned altitude (or geographical characteristics of the site in view of the gravity reductions). col. 25

0 ordinary measurements at the surface of the Earth, on land.
I tower, building.
with an overpunch X-II for airborne measurements.
2 mine, tunnel.
3 at the bottom of a lake.
4 at the surface of a lake.
5 on a glacier.

(0 to 5: $h_s > 0$)

6 on land, under the level zero
7 beneath the ground
8 at the bottom of the sea or of a lake

(6 to 8: $h_s < 0$)

9 at the surface of the sea * $h_s = 0$

* An overpunch (X-II) will specify the observations which have not been made at the surface of the sea, but of which the g values have been reduced to this surface :
- case of all measurements in a submarine (the published values are those obtained at the surface)
- case of several measurements with an underwater gravity meter on the bottom. ("Gravity expeditions I948-I958", Vol. V, part II, Delft, Pays-Bas), 1959

4) Altitude of the Earth's surface at the vertical of the station : col. 26...3I

In some cases defined in the 25 column, the altitude of the ground is not the same as the altitude of theeobservation station; this information is necessary to allow the gravimetric reductions.

Therefore, the meaning of the here mentioned altitude will be dependant on the case of the 25column :

in the above defined cases 0 and 6
= same value as the altitude of the station,
in the above defined cases 1, 2 and 7 (tower, tunnel, mine)
= altitude of the external surface of the ground,
in the above defined cases 3 and 8 (bottom)
= altitude corresponding to the mean altitude of the lake or altitude zero (ocean),
in the above defined cases 4 and 9
= altitude of the bottom of the lake or depth of the sea,
in the above defined case 5 (glacier)
= altitude of the rock surface.

The decimal point is between the 30 and 31 columns. Minus sign will be mentioned, for each negative altitude, in the 26 column.

VII) OBSERVED g VALUE ✱ col. 32...38

1) The figure mentioning the hundreds of gals is suppressed (always 9)
Results are given to 0,01mgal.
The decimal point is between the 36 and 37 columns.

2) Accuracy of g value col. 39
(when all systematic corrections have been applied)
0 standard error $\leqslant$ 0,05mgal
1 0,05 < error $\leqslant$ 0,1
2 0,1 < error $\leqslant$ 0,5
3 0,5 < error $\leqslant$ 1,0
4 1,0 < error $\leqslant$ 3,0
5 3,0 < error $\leqslant$ 5,0
6 5,0 < error $\leqslant$ 10,0
7 10,0 < error $\leqslant$ 15,0
8 15,0 < error $\leqslant$ 20,0
9 error superior to 20mgal.

That error corresponds to the apparent relative accuracy of the measurement deduced from the closing or the adjustment of the nets.

✱ When the published g value is not exactly the value of the observation point (submarine measurements, some results with underwater gravimeters), a special sign is punched col. 25.

VIII) REFERENCE STATION col. 40...46

This station is the base station to which is referred the concerned station. This station will be :

- generally the reference station of the national network (principal or auxiliary site : exterior point, airport)
- sometimes, a station of the primary national network, a harbour (measurements at sea)
- in a very few cases (prospecting gravity surveys), an ordinary station which would be connected later on to the reference national station.

For those stations, the following system has been adopted : *

- 6 columns to define the site of the station :
- a 7th column to differenciate the various values adopted at each site by the observers (the number of those values being considered as smaller than IO).

A) Definition of the site :

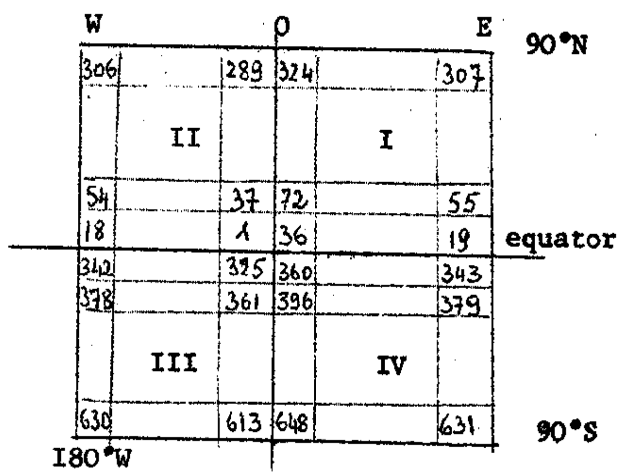
a) The three first figures mean the square of IO° in which the station is located.

Those three figures are given by the following formula, according to the quadrant :

for quadrant I $36 + 36(\varphi x) - \lambda x$
for quadrant II $I + 36(\varphi x) + \lambda x$
for quadrant III $325 + 36(\varphi x) + \lambda x$
for quadrant IV $360 + 36(\varphi x) - \lambda x$

φx = figure of the tens of degrees of latitude without taking the sign into account

λx = number of tens of degrees of longitude, including the figure of the hundreds without sign.
Ex : I68° = I6



That method allows a regular and continuous numeration of geographic squares of IO°. So the squares of the Northern hemisphere are numbered from I to 324 and those of the Southern hemisphere from 325 to 648.

b) The 4th and 5th figures mean :
the figure of the units of degree (latitude)
the figure of the units of degree (longitude)

Therefore, those 5 figures differenciate the site of the station by square degree.
Ex : Paris (Sèvres) = 48°49'45" N 2°I3'I4" E.G.
The five figures are : I80 82

c) The 6th figure is used to distinguish the various sites situated in the same square degree.

It has been asked to each nation to fix the code (alphabetical) for each site which has been used. *

We suggest the use of letters A to I for the stable sites (Observatories, Institutes...) and the last letters of the alphabet for the provisional sites (airports, railway stations...). In both cases, one should let free letters in view of further sites not yet defined. The following exemple is given :

Paris (Sèvres, pt.A)	I80 82 A
...	...
...	...
Paris (Obs., pt.A)	I80 82 D
Paris (Obs. pil.E, anc. salle)	I80 82 E
Paris (Obs., pt.C)	I80 82 F
Paris - Orly (anc. aérod. gare Nord)	I80 82 O
Paris - Orly (nouv. aérod. salle 4)	I80 82 P

B) <u>Adopted value</u> :

The value used as base value is defined on the 7th column by means of a numerical code specific for each site.

So, for Paris (Observ., pt.A) :
- figure 0 means the value 980 943,00 mgal
- figure I means the value 980 943,I5 mgal
- figure 2 means the value 980 943,35 mgal

etc...

<u>Note</u> : In this head as well as in the head "Calibration Information", the sites occasionally or provisionally occupied near the <u>principal</u> sites will not be mentioned; those latter will only be mentioned because the connexion between such sites is always made with a great accuracy.

* The list of the answers will be published later

IX) CALIBRATION INFORMATION (Station or Base) col. 47...53

This zone will permit to know the scale of the gravity network in which the concerned station was observed and to achieve the necessary corrections to get an homogeneous system.

In most cases this information will be a station connected to the reference station ("calibration station" defined by the same system as the reference station), permitting to know the scale of the network.

It is to be noticed that the "calibration station" may be actual or fictious :

- either it may have been actually occupied during the gravity survey (secundary station such as the g value in this point would be different enough from the g value of the reference station; if no special station is indicated, it is possible to choose among the reoccupied stations.)

- or its site (and adopted value of g) may bave not been actually occupied but used (previously or afterwards) to determine the constants of the apparatus (calibration) or to check the gravity survey.

This station could be a point of the national calibration line.

Ex. : In France, Toulouse (Obs.) 980 443,10 mgal.

In few cases, when the gravity network is defined by a reference station and by a calibration base well known, but quite independant from the reference station this calibration line will be indicated in this zone by means of a code which will be precised later.

In the case of measurements at sea, the 2 stations (reference and calibration) will be generally the reference station of the national network and a harbour station near the concerned station :

Ex. : stn 119 (Gedenkboek F.A. Vening Meinesz, p. 114) :
Washington, Com. Build. 980 118 mgal
Port of Spain 978 177 mgal

N.B. In case there would not be any information about the reference station or the calibration information, the zone will be punched 0 000 000 with an overpunch (X-II) in the last column.

X.) COMPUTATION of REDUCTIONS and ANOMALIES

A) Theoretical gravity formulae used in the reductions col. 54

Many formulae have been defined :

- without term of longitude :
  Helmert I90I - Bowie I9I7 - Heiskanen I928 - Krassowsky I938 - Heiskanen I938 - Heiskanen, Uotila I957 - International I930.
- with term of longitude :
  Helmert I9I5 - Heiskanen I924 - Heiskanen I928 - Niskanen I945 - Uotila I957.

We have selected the following formulae which have been used in the past :

0 = Internatioaal (I930)

$$\gamma'_o = 978.0490\ (I + 0{,}005\ 2884 \sin^2\varphi - 0{,}000\ 0059 \sin^2 2\varphi)$$

I = Helmert I90I

$$\gamma_o = 978.030\ (I + 0{,}005\ 302 \sin^2\varphi - 0{,}000\ 007 \sin^2 2\varphi)$$

2 = Bowie I9I7

$$\gamma_o = 978.039\ (I + 0{,}005\ 294 \sin^2\varphi - 0{,}000\ 007 \sin^2 2\varphi)$$

3....

4....

5 = Helmert I9I5

$$\gamma_o = 978.052\ (I + 0{,}005\ 285 \sin^2\varphi - 0{,}000\ 0070 \sin^2 2\varphi + 0{,}000\ 0I8 \cos^2\varphi \cos^2(\lambda + I7°))$$

6 = Heiskanen I924

$$\gamma_o = 978.052\ (I + 0{,}005\ 285 \sin^2\varphi - 0{,}000\ 0070 \sin^2 2\varphi + 0{,}000\ 027 \cos^2\varphi \cos^2(\lambda - I8°))$$

7.....

.....

Note : In case various formulae would have been used, the following preferential order would be adopted : International Formula (I930) - Helmert (I9I5)......

The code figures not used yet will be reserved for formulae to be determined.

B) Free air anomaly (to 0,I mgal) col. 55...58

The decimal point is between the 57 and 58 columns.
The minus sign is overpunched in the 55 column.

Classical free air anomaly : $(g_{obs} + F.h_s) - \gamma'_o$

h_s = altitude of the station.

$$F = 0{,}308\,5507 - 0{,}000\,000\,07254\, h_s + 0{,}000\,2270 \cos 2\varphi - 0{,}000\,000\,000II\, h_s \cos 2\varphi - 0{,}000\,0005 \cos^2 2\varphi \quad (*)$$

N.B. This exact coefficient F is seldom used by the authors; in most cases, the approximated coefficient used is the following : F' = 0,3086.

In some cases, this coefficient F' brings large errors :

e.g. : 45°	2000m	0,4mgal
65°	1000m	0,3mgal

So, an overpunch will be put in the column 35 of the Complementary card when the use of a simplified formula for the free air reduction brings an error exceeding 0,Imgal.

Moreover, it will be easy, if the accuracy of the other data admits it, to compute exactly the free air anomaly with an appropriated IBM program.

The free air anomalies which could be defined in the future through other methods (mean height of the area instead of h_s ... etc) would be mentioned in the Complementary Card.

Remarks on the anomalies at sea (cf Bul. Inf. I96I, p. 65-70)

1) In all cases of sea measurements, the "free air" anomaly reported on the punched card, will be the difference between the value of g at the surface of the sea (observed or reduced value) and the theoretic value of g on the same surface.

That anomaly is equal to :

$g_o - \gamma'_o$ (g_o observed at the surface)

$g_{p'} - 0{,}2223\, p' - \gamma'_o$ ($g_{p'}$ observed at the depth p')

That reduction (0,2223 with δ = I,03) takes into account the depth p' (approximately 0,3086 p' in meters) and the double attraction of the mass of water between the sea surface and the surface through the observation point ($2 \times 0{,}04I9 \times \delta p'$).

2) Some authors have taken for the "free air" reduction :

a) $g_{p'} - 0{,}3086\, p'$ (only taking into account the distance at the center of the earth as in earth measurements).

b) $g_{p'} - 0{,}3086\, p' + 2\pi k \delta p'$ or $g_{p'} - 0{,}3086\, p' \left(1 - \frac{3}{4} \cdot \frac{\delta}{5{,}52}\right)$ (taking into account the attraction of one spherical layer)

δ = density of the water = I,00 to I,04

The results thus published (Cf. 1 and 2), will therefore be modified before being reported on punched cards.

(*) R.A.HIRVONEN "New theory of gravimetric geodesy" - Pub. Inst. Geod. Phot. & Cart., n°9, Ohio St. Univ., U.S.A., 1960.

C) Bouguer anomaly (to 0,I mgal) col. 59...62

The minus sign is punched in the 59 column.

The expression of the "complete" Bouguer anomaly is :

Free air anom. - Infinite plane slab attraction + b + c_t
or Free air anom. - spherical cap attraction + c_t

Boug. anom. = $g_{obs} + 0,308...h_s - (0,0419d + b)h_s + c_t - \gamma'_o$

h_s = altitude of the station
d = density
c_t = topographic (or terrain) correction
b = Bullard's term. (*)

This term b is the difference between the effect of the spherical cap (external radius of the zone 0_2) and the Bouguer's plate. It removes the effect of the plate which is outside zone 0_2 and adds the correction caused by the curvature of the earth.

An approximate relation of this term is given in the following form : (+)

$$b = 2\pi kd.h_s \left(\sin \frac{1°29'58''}{2} - \frac{hs}{R} + \frac{1}{3}\frac{hs^2}{R^2} + ...\right)$$

This term reaches I,2mgal - I,7mgal - I,5mgal respectively for h_s = I000m - 2000m - 3000m.

Moreover, in many cases, the "complete" Bouguer anomaly defined above is not calculated; the curvature of the earth is neglected (with d = 2,67 the simplified coefficient 0,III8 is often used), the terrain correction is not calculated or not expanded to the zone 0_2. So, the column 63 is reserved ~~for these~~ information.

Remarks on the anomalies at sea. (Cf. Bul. Inf. I96I, p. 65-70)

The Bouguer anomalies at sea are obtained from "free air" anomalies by filling the oceanic regions with masses of a density (d - δ) and by suppressing the action of topographic masses above the geoid.

They are "complete" or "simple" as the topographic irregularities with reference to a surface of an equally high plate (c_t) are or not taken into account.

The Bouguer anomaly can be thus evaluated :

Free air anom. + 0,0419 (d - δ) p + c_t

i.e. $g_p' - 0,2223\ p' + 0,0419\ (d - \delta)\ p + c_t - \gamma'_o$

$g_p' - 0,1536\ p' + c_t - \gamma'_o$ (p' = p; d = 2,67; δ = 1,03)

d - δ = difference between the mean density of the crust (2,67 or local density) and the density of water δ
p' = depth of the observation point ($g_{p'}$ = gravity value)
p = depth of the sea to the vertical of the observation point, in meters.

(*) E.C.BULLARD " Gravity measurements in East Africa" - Phil. Trans. Royal Soc., Serie A, 1936, n°235, p.445-531.

(+) V.VYSKOCIL "Anomaly field of Gravity in gravimetric prospecting" Trav. Inst. Geoph. Acad. Sci. Tchec. 1960; n°131, p.190, Prague, 1961.

D) Information about Bouguer anomaly — col. 63

$\bar{0}$ = no Bouguer anomaly

Horizontal plate without Bullard's term :

0 = without topographic (or terrain) correction c_t
I = c_t computed for a radius of about 5km (zone H)
2 = c_t computed for a radius of about 30km (zone L)
3 = c_t computed for a radius of about I00km (zone N)
4 = c_t computed for a radius of about I67km (zone O_2)

Horizontal plate including Bullard's term (or spherical cap) :

5 = without c_t
6 = c_t computed for a radius of about 5km (zone H)
7 = c_t computed for a radius of about 30km (zone L)
8 = c_t computed for a radius of about I00km (zone N)
9 = c_t computed for a radius of about I67km (zone O_2)

Cf. References (*) (+)

E) Density for the Bouguer reduction (g/cm^3) — col. 64...66

The decimal point is between the 64 and 65 columns.

The density mentioned is that used for the plate correction (for measurements at sea, it is d previously defined).

In case the Bouguer anomalies have been computed in different hypothesis, the Bouguer anomaly computed with the density 2,67 (or about 2,67) will be preferentially punched.
In case various densities would have been used for the plate correction, one should mention the most important density in the reduction; for instance :

- density of the layers beneath the arbitrary mean level (some german maps...)
- density of the ice ....

and one should add an overpunch X-II in the 64 column.

Note : The density used for topographic correction will not be mentioned : actually in the mountainous areas, it has practically the same value as that used for the plate correction ; in the flat areas, the variation of density is of small importance.

Tables for Bouguer reduction and Bullard's term :

(*) "Corrections d'altitude diminuées de l'attraction d'une calotte sphérique d'épaisseur h_s et de rayon 166,735km, en 0,1mgl" - P.LEJAY - "Développements modernes de la gravimétrie" - Gauthier-Villars, Paris 1947.

(+) "Bullard's difference in 0,01mgal for density 2,67g/cm^3" and "Bouguer reduction and Bullard's term in 0,1mgal for density 2,67g/cm^3" - M. PICK, J. PICHA, V. VYSKOCIL, Trav. Inst. Geoph. Acad. Tch. Sci., 1960, n°129, Prague, 1961.

F) <u>Type of the isostatic (or other) anomaly</u> hereafter mentioned. col. 67-68

00 = no isostatic anomaly computed

0...: <u>Pratt-Hayford hypothesis</u> : (*) and (+)

OI = 50 km including indirect effect (Lejay's tables)
02 = 56,9km
03 = 56,9km including indirect effect
04 = 80 km including indirect effect (Lejay's tables)
05 = 96 km
06 = 96 km including indirect effect
07 = II3,7km
08 = II3,7km including indirect effect (Lejay's tables)

1...: <u>Airy hypothesis</u> (equality of masses or pressures) (+) and (‡)

I0 = T = 20km (Heiskanen's tables, I93I)
II = T = 20km including indirect effect : (Heiskanen's tables I938 or Lejay's)
I2 = T = 30km (Heiskanen's tables, I93I)
I3 = T = 30km including indirect effect : (Heiskanen's tables I938 or Lejay's)
I4 = T = 40km (Heiskanen's tables, I93I)
I5 = T = 40km including indirect effect : (Heiskanen's tables I938 or Lejay's)
I6 = T = 60km (Heiskanen's tables, I93I)
I7 = T = 60km including indirect effect : (Heiskanen's tables I938 or Lejay's)

(*) J.F. HAYFORD and W. BOWIE : "The effect of topographic and isostatic compensation upon the intensity of gravity" - USC & GS n° IO, I9I2.

(+) P. LEJAY : "Tables pour le calcul de l'effet indirect et la déformation du géoïde" - Bul. Geod. n°8, I948.
"Tables pour le calcul des corrections isostatiques compte tenu de l'effet indirect" - Ass. Int. Geod., pub. spéciale n°4, Paris I950.

(‡) W. HEISKANEN : "Isostatic tables for the reduction of gravimetric observations calculated on the basis of Airy's hypothesis" - Bul. Geod. n°30, I93I.
"New isostatic tables for the reduction of gravity calculated on the basis of Airy's Hypothesis" - Pub. of the Isost. Instit., Helsinki, n°2, I938.

2) <u>Vening Meinesz Regional hypothesis</u>, T = 20km (*)

R = radius of regionality; T = normal thickness of the crust.

20	=	R	=	0
2I	=	R	=	29,05km
22	=	R	=	58,I0km
23	=	R	=	II6,20km
24	=	R	=	I74,30km
25	=	R	=	232,40km

...

3) Vening Meinesz Regional hypothesis, T = 30km

30	=	R	=	0
3I	=	R	=	29,05km
32	=	R	=	58,I0km
33	=	R	=	II6,20km
34	=	R	=	I74,30km
35	=	R	=	232,40km

...

4) Vening Meinesz Regional hypothesis, T = 40km

40	=	R	=	0
4I	=	R	=	29,05km
42	=	R	=	58,I0km
43	=	R	=	II6,20km
44	=	R	=	I74,30km
45	=	R	=	232,40km

...

5) <u>Regional hypothesis of M. Lehner</u> (Switzerland) (+)
according to the surface A considered for the altitude and to T, normal thickness of the crust :

50	=	A	=	8 x 8km	T =	80km
5I	=	A	=	8 x 8km	T =	I00km
52	=	A	=	8 x 8km	T =	I40km
53	=	A	=	64 x 64km	T =	80km
54	=	A	=	64 x 64km	T =	I00km
55	=	A	=	64 x 64km	T =	I40km
56	=	A	=	I28 x I28km	T =	80km
57	=	A	=	I28 x I28km	T =	I00km
58	=	A	=	I28 x I28km	T =	I40km

(*) F.A. VENING MEINESZ : "Tables for regional and local isostatic reduction (Airy system) for gravity values" - Pub. of the Netherlands Geodetic Comm., Delft I94I.

(+) M. LEHNER : "Beitrage zur Untersuchung der Isostatischer Kompensation der Schweizerischen Gebirgsmassen" - Verhandl. Schweiz. naturforsch. Ges., I930.

6... Combined Anomaly or <u>Quasi-Isostatic anomaly</u>
not taking into account the isostasy of the neighbouring masses in a given radius r.

This is a transition between the Bouguer and the Isostatic anomalies : one computes only the topographic influence of the neighbouring masses and the topo-isostatic influence of the remote masses external to the area, of radius r.

60 = Glennie hypothesis "Modified topo anomaly" (*)
r = 36,5km
D = II3,7km (isostatic reduction on the Pratt-Hayford system)

6I = } other hypothesis, more complex (Glennie, Survey of India)
62 = }

...

65 = Vening Meinesz hypothesis "Modified Bouguer anomaly" (+)
{ r = I66,7km
{ D = II3,7km (isostatic correction on the Pratt-Hayford system)

...

7... <u>Other regional hypothesis</u> : correction of the superficial and/or compensating masses computed in relation <u>with a mean height Hm to be precised</u> according to the authors.

70 = Putnam-Faye hypothesis :
$g - \gamma_0' + 0{,}3086\ h_s - 0{,}04I9\ d\ (h_s - H_m)$

H_m = mean height of the area for a radius r = I66,7km (zone O_2)

7I = Same hypothesis (Born), H_m being evaluated for a radius r = 25km

72 = Putnam hypothesis (I928) = isostatic anomaly (‡)
isostatic correction of the neighbouring masses evaluated in relation with H_m determined from a circle r = I66,7km (when $h_s > I000m$)

73 = Same hypothesis as above with r = 58,8km (when $h_s < I000m$)

74 = }
75 = } <u>"Model Earth" hypothesis</u> (De Graaff Hunter, Glennie) :
76 = }
complete Bouguer anomaly +0,04I9 d.H
(H = weighted average topographic height)
H evaluation to be precised

(*) E.A. GLENNIE : "Gravity anomalies and the Structure of the Earth's Crust" - Survey of India, Profes. pap. n°27, I932.

(‡) G.R. PUTNAM : "Regional Isostatic Reduction of Gravity Determinations" - Proc. Nat. Acad. Sc. n°I4, p.407-4I8, I928.

(+) F.A. VENING MEINESZ : "Gravity Expeditions at sea I923-I938", Vol.IV, Delft, I948.

8... Various hypothesis

80 = Helmert hypothesis (condensation for 21km depth)

81 = Helmert hypothesis (condensation at the sea level)

...

84 = Rudzki hypothesis (inversion) - Klavido's tables (*)

...

88 = Cizancourt hypothesis. (+)

...

9... Future hypothesis.

G) Isostatic anomaly (to 0,1 mgal) col. 69...72

The decimal point is between the 71 and 72 columns.

In case various isostatic anomalies would have been computed, one should adopt the following preferential order :

Airy 30 km (or Vening-Meinesz, T = 30km, R = 0)
Airy 40 km
Pratt 113,7 km

XI) The columns 73...80 are free to remain at anyone disposal.

(*) B. KLADIVO : "Réduction de la pesanteur d'après Rudski" (Tables) Nàkladem vlastim, Novina, Brno 1940.

(+) H. de CIZANCOURT : "Deep tectonics and Isostasy" - Am. J. Geol., vol. 59, n°1, 1951.

COMPLEMENTARY CARD

I) CARD CODE — col. I

I .. Index card ("bulle" paper)
2 .. Complementary card (green paper)
3 .. ...
4 .. ...
....

II) COORDINATION NUMBER — col. 2 and 3

(See Index Card).

III) ACCURACY ON THE GEOGRAPHICAL DETERMINATION — col. 4

(for sea and aerial measurements)

The site of the gravity measurement (single measurement or mean result) is defined in a circle of radius r dependent on the accuracy of the navigation, the distance to coastal points etc.

0	reserved for land observation
$\bar{0}$	no information on the accuracy for sea or aerial measurements
I	... $r \leq 20$ m (approximately 0'I)
2	$20 < r \leq 100$
3	$100 < r \leq 200$ (approximately 0'I)
4	$200 < r \leq 500$
5	$500 < r \leq 1000$
6	$1000 < r \leq 2000$ (approximately I')
7	$2000 < r \leq 5000$
8	$5000 < r$
9	...

N.B. The project that defined the accuracy with the navigating system has been left aside because it needed too complex a code (navigating system. distance from the observation station to the reference points...).

IV) LATITUDE — col 5...IO

(See Index Card)

V) LONGITUDE — col. II...I7

(See Index Card)

VI) ALTITUDE

1) col. 18

Classification of the determination of the previously mentioned altitudes. (Index Card, col. 18...23).

Ō ... no information

0 ... geometrical levelling (bench mark)
1 ... barometrical levelling
2 ... trigonometrical levelling
3 ... data obtained from topographical map
4 ... data directly appreciated from rhe mean sea level; (the concerned site being very close of the sea)
5 ... data measured by the depression of the horizon (marine)
6 ... nautical sounding
7 ... depth directly measured
8 ... measurements with radar
9 ...

2) col. 19...23

Mean regional Hm surrounding the observation point (in meters).

radius of approximately	10 km	no overpunch
" " "	100 km	II-X
" " "	200 km	12-R

3) col. 24...26

Eventually a correction should be added to the above mentioned altitude (Index Card, col. 18...23) when this altitude has been referred to an entirely conventional level such as some levelling in the Antarctica etc.

That correction would only be used as an indication for later geodetic computations : the anomalies punched on the concerned card being computed with the previously mentioned altitude (Index Card, col. 18...23).

Decimal point between the 25 and 26 columns.

VII) ... col. 27 - 28

Free columns for additional corrections in order to allow accurate geodetic computations, for instance to transfer the geographical coordinates into a more general system.

VIII) GEOLOGICAL INFORMATION col. 29...32

... To be precised later.

IX) APPARAUS USED FOR MEASUREMENTS of g   col. 33-34

O.. Pendulum apparatus constructed before 1932

00	Repsold pend. (used by Borrass, Albrecht, Barraquer, Oppolzer,...)	
0I	Defforges pendulum	
02	Sterneck's first apparatus	
03	Sterneck's apparatus (with Helmholtz coil)	
04	U.S.C.&G.S. Mendenhall apparatus	(bronze pendulum)
05	" " "	(invar pendulum since 1920)
06	Lenox-Conyngham apparatus	
07	Mioni apparatus	
08		
09	Vening Meinesz tripendulum apparatus (pendulum made of brass, therefore practically nonmagnetic)	

I.. Pendulum apparatus recently constructed (1930 - 1960)

10	Askania	(4 Invar pend.) without Helmholtz coil
11	Askania (4 bronze pend. or Invar pend.	with " ")
12	Cambridge, England	(3 Invar pend.) without Helmholtz coil
13	Cambridge, England	(" " ") with " "
14	U.S.C.&G.S. Mendenhall	(4 Invar pend.)
15	Dominion Observatory, Canada	(2 bronze pend.)
16	Com. Geod. Ital.	(3 molybdenum pend.)
17	Gulf	(2 quartz pend.)
18	G.S.I., Japan	(3 quartz pend.)
19	PAS, U.R.S.S.	(6 quartz pend.) constructed in 1957

2.. Pendulum apparatus lastly constructed (after 1960)

20
21
...
...

3.. Gravimeters for continental measurements, in which the variations of g are equilibrated or detected through the following methods :

30	torsion balance (Thyssen, ...)
31	elastic rod (Ising pend. and Holweck-Lejay inverted pend. ...)
32	...
33	gas-pressure (Haalck, ...)
34	capacity of a condenser (Lindblad, Boliden, ...)
35	vibrating string (Gilbert, ...)
36	...
37	...
38	bifilar system (Schweydar, Berroth, Tomaschek, ...)
39	...

4.. Metal spring gravimeters for continental measurements

40 few seldom used apparatus : Hartley, Truman, Magnolia, Atlas, Mott-Smith, ...
41 ...
42 Askania (Gs 4-9-11-12 ...), Graf
43 Gulf, Hoyt, (Helical spring)
44 North American
45 Western
46 ...
47 LaCoste-Romberg
48 ....
49 Milligal/sweet

5.. Quartz spring gravimeters for continental measurements :

50 few seldom used apparatus : Frost, ...
51 Norgaard
52 GAE - 3
53 ordinary Worden
54 Worden (additional thermostat)
55 World Wide
56 GAK (3M - 4M - 6M - HP)
57 Canadian Gravity Meter
58 ...
59 ...

6.. Gravimeters for underwater measurements (at the bottom of the sea or of a lake) :

60 Gulf
61 ...
62 Western
63 North American
64 LaCoste-Romberg

(60–64) - Remote - control type

65 ...
...
69 ordinary Worden (bathyscaphe)

7.. Gravimeters for measurements on the sea surface or at small depth, (submarines ...)
(See the Index Card, col. 25, 9, to distinguish the exact observation site.)

70 Graf-Askania
71 ...
72 LaCoste-Romberg
73 ...
74 GAL and GAL-F (used in a submarine)
75 ...
76 Tokyo Surface Ship Gravity Meter
...

8.. Gravimeters for aerial measurements

80 airborne LaCoste-Romberg
81 ...
82 airborne Graf-Askania
...
...

Remarks : 1) The same code with more details (one number added) might be later employed in "special" cards referring to Irst order stations, main stations...

2) An overpunch (X-II) might indicate that the apparatus has not bean used in usual conditions, for ex. :
- Oscillation of a single pendulum in Sterneck pendulum apparatus (connexion Uccle - Leopoldville)
- Use of a sea gravimeter for airborne test-measurements.

X) INFORMATION ON THE REDUCTIONS AND ANOMALIES

1) col. 35
Accuracy of free-air anomalies :

Although that information is but a repetition for continental observations, (accuracy on g, accuracy on altitude), it seemed useful to keep a column for that because several publications dealing with sea gravity measurements only mention that accuracy.

0..... error $\leqslant$ 0,05
1..... 0,05 $<$ error $\leqslant$ 0,1
2..... 0,1 $<$ error $\leqslant$ 0,5
3..... 0,5 $<$ error $\leqslant$ 1,0
4..... 1,0 $<$ error $\leqslant$ 3,0
5..... 3,0 $<$ error $\leqslant$ 5,0
6..... 5,0 $<$ error $\leqslant$ 10,0
7..... 10,0 $<$ error $\leqslant$ 15,0
8..... 15,0 $<$ error $\leqslant$ 20,0
9..... error higher than 20 mgal

An overpunch (X-II) indicates an additional error exceeding 0,1 mgal, owing to the use of a simplified formula (See Index Card, col. 55, p. 36).

2) col. 36...38
Value of the topographic correction (to 0,1 mgal) computed inside the previously mentioned radius. (Index Card, col. 63, p. 38)

3) col. 39

Gravimetric relief or rate of significance of the Bouguer anomaly :

Gradient of the anomaly $\frac{\text{Var}\Delta g}{\Delta s}$ for each km computed on the normal direction of the isanomals, at a distance of 5 km on both side from the observation point.

0	gradient $\leqslant$ 0,01 mgal/km
1	0,01 < gradient $\leqslant$ 0,05
2	0,05 < gradient $\leqslant$ 0,1
3	0,1 < gradient $\leqslant$ 0,5
4	0,5 < gradient $\leqslant$ 1,0
5	1,0 < gradient $\leqslant$ 2,0
6	2,0 < gradient $\leqslant$ 3,0
7	3,0 < gradient $\leqslant$ 4,0
8	4,0 < gradient $\leqslant$ 5,0
9	gradient higher than 5,0 mgal/km

XI) OTHER ANOMALIES (to 0,1 mgal)

It seems useless to give further information on Bouguer anomalies computed with a density different from that registered on the Index Card.

1) col. 40-41

- Type of the local isostatic anomaly to be chosen among the anomalies n° 01 to 20 (code, Index Card, p. 39)
- Value of that anomaly col. 42...45

  The group (Pratt or Airy) not yet considered (Index Card, col. 69...72) should be prefentialy used.

2)

- Type of a first regional isostatic anomaly col. 46 - 47
- Value of that anomaly col. 48...51

3)

- Type of another regional isostatic anomaly col. 52 - 53
- Value of that anomaly col. 54...57

If it is possible the anomalies of the group 30, n° 33 and 35, (code, Index Card, p. 40), should be mentioned at first.

4)

- Type of any other anomaly col. 58 - 59
- Value of that anomaly col. 60...63

XII) REFERENCES FOR THE INFORMATION

1) - Year of the observation (19..) Overpunch X-II for 18..	col. 64 - 65
2) - Year when the information was registered (19..)	col. 66 - 67
3) - Source of the information Individual Code for each Service	col. 68...72

XIII) As in the Index Card, the columns 73...80 are free   col. 73...80

CARTES d'ALTITUDES MOYENNES

d'EUROPE et d'AFRIQUE

A maintes reprises, des géodésiens ou géophysiciens se sont informés auprès du Bureau Gravimétrique International, des cartes d'altitudes moyennes alors existantes, car un grand nombre de ces cartes ont été primitivement établies pour le calcul de réductions gravimétriques et ont été envoyées à la cartothèque du B. G. I.

Pour faciliter les recherches des géodésiens et éviter que de nouveaux calculs soient inutilement recommencés, on dresse ci-après la liste de toutes les cartes d'altitudes moyennes s'étendant sur l'Europe et l'Afrique.

Cette liste a pu être complétée et mise à jour grâce aux informations complémentaires qu'ont bien voulu nous faire parvenir les services compétents.

Remarques générales :

1) Les valeurs reportées sur ces cartes (à l'exception des carreaux mixtes) sont des altitudes et profondeurs brutes résultant de la lecture de cartes géographiques, et ne tenant pas compte de la densité superficielle des terrains.

2) Toutes les valeurs reportées sont en mètres.

3) Dans les carreaux mixtes (continents et mers), sont indiqués :

a) ou 3 nombres - altitude moyenne de la portion continentale
- altitude moyenne de la portion océanique
- fraction de la surface occupée par le continent.
(3),(3') et (3")

b) ou 1 nombre : altitude ou profondeur moyenne du carreau entier calculée en tenant compte du pourcentage des 2 fractions et de leur densité relative.

Les nombres positifs représentent toujours la cote moyenne du terrain au dessus du niveau de la mer, et les nombres négatifs une profondeur moyenne réelle (et non pas une profondeur fictive ramenée à la densité continentale. (8), (9), (16) et (17)

c) ou 2 nombres : altitude et profondeur moyennes (évaluées comme en (b), de fractions égales de carreau, subdivisé dans le sens du relief. (2), (7), (11), (11')

d) ou Un nombre positif correspondant à l'altitude moyenne de la fraction continentale répartie sur tout le carreau.

Un nombre négatif correspondant à la profondeur moyenne océanique répartie sur tout le carreau. (12)

4) Pour chaque carte, les dimensions des carreaux ont été reportées dans le tableau ci-après et les plus utilisées ont été soulignées.

Pays	Echelle	Longitude Latitude	Dimension des carreaux	Ref.
Europe centrale	1/2 000 000	2°20'-24°20'EG 46°-58°N	6' x 10'	(1)
Europe méridionale et Afrique du Nord	1/5 000 000	25gW-20gE 20g-50gN méridien 0 = Paris	1g x 1g	(2)
Italie, régions et mers environnantes	1/1 000 000	3°30'W-21°20'EG 34°-49°N	6' x 10' 10' x 15' 5' x 7'5 20'g x 20'g	(3)
Italie, régions et mers environnantes	1/2 000 000	11°E-11°W 32°-51°N méridien 0 = Rome	10' x 15' 12' x 20' 20'g x 20'g	(3')
Italie, régions et mers environnantes	1/4 000 000	18°E-18°W 28°-56°N méridien 0 = Rome	20' x 30 24' x 40' 20'g x 20'g	(3")
Allemagne de l'Ouest	1/2 000 000	6°-14°EG 47°30'-55°N	6' x 10'	(4)
Allemagne de l'Ouest	1/4 000 000	2°-18°EG 46°-56°N	12' x 20'	(4')
Autriche	1/500 000	frontières	6' x 10'	(5)
Espagne	1/500 000	3°20'-9°20'WG 36°-43°30'N	3'20" x 5'	(6)
France (6 feuilles)	1/6 000 000	2gW-9gW 54g-58gN 7gE-1gW 54g-58gN 2gW-9gW 50g-54gN 7gE-1gW 50g-54gN 1gW-8gW 47g-50gN (8gE-7gE Corse) 46g-48gN) 7gE-1gW 47g-50gN méridien 0 = Paris	2'g x 5'g 4'g x 5'g 20'g x 20'g	(7)

Pays	Echelle	Longitude	Latitude	Dimension des carreaux	Ref.
France et régions limitrophes	1/2 000 000	11gE-12gW méridien 0 = Paris	43g-60gN	20'g x 20'g 1g x 1g	(8)
Norvège (4 feuilles)	1/1 000 000	5°-12°30' 4°30' - 13° 9°-17°EG 12°E-31°EG	56°- 60°N 60°-64°N 64°-68°N 68°-72°N	5' x 10'	(9)
Pays Bas	1/1 000 000	3°30'-7°30'EG	50°30'-53°30'N	3' x 5'	(10)
Portugal, mers et pays environnants	1/1 000 000	4°10'-11°30'WG	35°30'-44°N	10' x 10' 5' x 5'	(11)
Portugal, mers et pays environnants	1/2 000 000	4°10'-11°30'WG	35°30'-44°N	10' x 10' 5' x 5'	(11')
Suède et mer Baltique	1/1 000 000	10°-24°EG environ	55°-69°N	5' x 10'	(12)
Suisse	1/2 000 000	3°5-12°5EG	44°5-49°N	8 x 8km 64 x 64km 128 x 128km	(13)

Pays	Echelle	Longitude	Latitude	Dimension des carreaux	Ref.
Afrique du Nord	1/2 000 000	14gE-16gW méridien 0 = Paris	30gN-44gN	10'g x 20'g 20'g x 20'g 1g x 1g	(14)
Afrique Occidentale	1/5 000 000	12°E-16°WG	4°-24°N	30' x 30'	(15)
Madagascar (3 feuilles)	1/1 000 000	43°- 52°EG 42°-52°EG 44°-51°EG	16°-11°30'S 21°-16°S 27°-21°S	5' x 5' 30' x 30' 1° x 1°	(16)
Madagascar	1/2 000 000	40°-54°EG	28°-10°S	10' x 10' 1° x 1°	(17)

REFERENCES

(1) - "Karte der mittleren Höhen von Zentraleuropea" - A.SCHLEUSENER - Veröff. d. DGK, Reihe B, Heft 60, Frankfurt/M, 1959.

La partie principale est basée sur les cartes topographiques d'Allemagne au 1/200 000 "Topographische Ubersichtskarte des Deutschen Reiches".

Pour les autres pays concernés, on a utilisé des cartes d'échelle variable (1/25 000 à 1/2 000 000) suivant les régions, mais généralement de 1/200 000.

(2) - "Altitudes moyennes" - Bureau Gravimétrique International, Paris, 1959.

Cette carte est tirée de la carte d'altitudes moyennes au 1/2 000 000 et complétée au moyen des cartes suivantes :

cartes d'Afrique	1/500 000
cartes d'Europe (IGN)	1/1 000 000
cartes Sahara	1/2 000 000

cartes du Service Hydrographique (différentes échelles).

(3), (3') et (3") - "Carta quadrettata delle altitudine medie dell'Italia e delle regioni limitrofe e delle profondità medie dei mari circostanti" - S. BALLARIN, Commissione Geodetica Italiana, Pise, 1959.

La partie italienne est tirée des cartes topographiques au 1/25 000 de l'Institut Géographique Militaire Italien.

Les régions voisines sont complétées au moyen des cartes de A. SCHLEUSENER et de P. LEJAY.

Sur les cartes (3') et (3") les carreaux ont été groupés par 4 et par 16.

(4) "Mittlere Höhen von Westdeutschland fur Gradabteilung 6' x 10' (etwa 130qkm)" - Institut für Angewandte Geodäsie, Frankfurt/M.

Les évaluations ont été faites à partir de la carte de A.SCHLEUSENER (cf.1) complétées par des cartes topographiques au 1/25 000 et des cartes hydrographiques.

(4') - "Mittlere Höhen von Westdeutschland für Gradabteilung 12' x 20' (etwa 500qkm)" - K. GERKE, H. WATERMAN, D.G.K., Reihe B, n°46-III, Frankfurt/M, 1960.

Les évaluations ont été faites de la même manière que pour la carte (4).

(5) - Bund. für Eich und Vermessungswesen, Wien, (en préparation).

Les évaluations ont été faites à partir de la nouvelle carte d'Autriche en 213 feuilles, échelle 1/50 000.

(6) - "Instituto Geografico y Cadastral" - Madrid.

Les évaluations ont été faites à partir de la carte d'Espagne au 1/50 000, de cartes françaises et portugaises.

(7) - "Carte d'altitudes moyennes" - R.P. LEJAY,
Comité National Français de Géodésie et Géophysique, 1947-48.
Les évaluations ont été faites à partir de la carte de France au 1/200 000 de l'Institut Géographique National (équidistance des courbes 20m et 40m) et ont été complétées avec des cartes espagnoles (1/50 000), des cartes européennes (1/1 000 000) et des cartes du Service Hydrographique de la Marine.

(8) - "Cartes d'altitudes moyennes - France et pays limitrophes"- R.P.LEJAY, Comité National Français de Géodésie et Géophysique, 1948.
Cette carte a été établie à partir de la carte précédente, complétée au moyen de la carte au 1/1 000 000 (Inst. Géog. Nat., Paris), et de nombreux documents du Service Hydrographique de la Marine.

(9) - "Norway mean height" - Geographical Survey of Norway,Oslo.
feuille 2105 (Jotunheimen); feuille 2151 (Skagerak);
feuille 2090 (Kiruna);
Feuille 2052 : en préparation.
Les évaluations ont été effectuées à partir de la carte topographique au 1/100 000 de Norvège, dont les courbes de niveau sont équidistantes de 30m.

(10) - "Maps of mean elevations, free-air and Bouguer anomalies for a grid of 3' lat. by 5' longt." - Geodetic Institute of the technicological University of Delft, 1963.
Les évaluations ont été effectuées à partir des cartes topographiques au 1/25 000.

(11) et (11') - "Rapport National sur les travaux Géodésiques, présenté à la XIIIème Assemblée Générale de l'U.G.G.I., Helsinki, 1960" - Instituto Geografico e Cadastral, Lisboa.
Les évaluations ont été faites à partir de la Carte militaire du Portugal 1/25 000, de cartes hydrographiques du Ministère de la Marine, de la carte d'Espagne au 1/500 000 de l'Instituto Geografico y Catastral de Madrid.

(12) - Rikets allmanna kartverk, Stockholm : Meddelande n° 30; sous presse.
Les évaluations ont été faites à partir de cartes au 1/50 000 et 1/100 000 (équidistance des courbes : 33m) et de cartes hydrographiques au 1/20 000 et 1/500 000.

(13) - "Travaux astronomiques et géodésiques en Suisse" - Vol.XVII Th.NIETHAMMER, Com. Géod. Suisse.
"Beitrage zur Untersuchung der isostatischen Kompensation der Schweiz Gebirgsmassen" - M. LEHNER, Verhandl. Naturf. Gesellsch. Basel, Band 41.
Ces valeurs moyennes (transformées en courbes de niveau équidistantes de 200m dans l'hypothèse de 128 x 128km) ont été évaluées à partir de :

cartes	1/200 000	(équidistance 100m)	pour	la Suisse
"	1/500 000	(" 100 à 400m)	"	" l'Italie
"	1/200 000	(" 20 à 40m)	"	" France
"	1/200 000	(" 20m)	"	l'Allemagne.

(14) - "Cartes des altitudes moyennes de l'Afrique du Nord" - S.CORON, Bureau Gravimétrique International, 1950.

Cette carte fait suite à la carte établie pour la France (voir N°8); les évaluations ont été faites sur les cartes au 1/500 000 de l'Afrique du Nord (Inst. Géog. Nat. Paris), sur les cartes du Serv. Hydrog. de la Marine (échelle variable) et sur les cartes au 1/1 000 000 internationales.

(15) - "Carte d'altitudes moyennes" - O.R.S.T.O.M., Paris, (dernier dessin : 1962).

Cette carte est tirée de cartes d'altitudes moyennes régionales au 1/1 000 000 (non publiées).

Les évaluations ont été faites à l'aide de cartes géographiques (1/200 000) et de cartes d'itinéraires gravimétriques dans les zones sahariennes.

(16) - "Madagascar" - S.CORON, B.G.I., Paris, 1955.

Les évaluations ont été faites à l'aide des cartes du Service Géographique de Madagascar (1/100 000 et 1/500 000 provisoire) et de cartes du Service Hydrographique de la Marine.

(17) - "Madagascar" - S.CORON, B.G.I., Paris, 1956.

Cette carte est tirée de la carte précédente (16) et complétée à l'aide de cartes au 1/1 000 000.