ASSOCIATION INTERNATIONALE DE GÉODÉSIE

BUREAU GRAVIMETRIQUE INTERNATIONAL

N° 25

Bulletin d'Information

Mars 1971

9, QUAI St-BERNARD - Tour 14
PARIS V°

BUREAU GRAVIMETRIQUE INTERNATIONAL

Paris

-=-=-=-=-=-=-

BULLETIN D'INFORMATION

Mars 1971

N°25

TABLE des MATIERES

Ière Partie

* Questions I, III, VIII have been published in the Bull. Inf. n°24.

IIème Partie

Prof. P. TARDI
Dr. S. CORON

A

COMPTE-RENDU of the VIth INTERNATIONAL GRAVITY COMMISSION (continuation)

Paris 7 - 11 September 1970

II - GRAVITY MEASUREMENTS at SEA

Report of the Special Study Group n°4-20 made by Dr. J.L. WORZEL

This report covers the gravity measurements at sea since the fall of 1967, which have come to the attention of the writer, either by publications, or by personal correspondence. Persons believed to have pertinent information for this report were contacted for additional information. The writer wishes to thank all contributors for their help.

Two study meetings of Special Study Group n°4.20, Gravity Measurements at Sea, were held in Paris under the chairmanship of J.L. WORZEL in two sessions during the afternoon of September 8th, 1970

During the first session, the chairman made the following remarks :

The loss of Dr. B.C.BROWNE of Cambridge, England, a member of this study group and his great services to the field of gravity, geodesy and especially gravity measurements at sea will be particularly missed. Dr. D. MATTHEWS of Cambridge, England has agreed to serve in Dr. Browne's capacity on this committee.

Serious attempts at gravity measurements at sea were first begun in 1923 by Dr. F.A. VENING MEINESZ. From 1923 to 1946 approximately two thousand observations were obtained aboard submarines. This period was terminated, of course, by the advent of World War II. After World War II, from 1946 to 1957, about four thousand additional gravity measurements on submarines were made.

In 1957, we made the first gravity measurements at sea on a surface ship. During the period from 1957 until 1970, our own two ships have made about a million gravity observations. Other institutions have made an additional million observations, according to presently available information in our institution, making a total of about two million observations made during the thirteen year period since the advent of the surface ship gravity measurements. Yearly one of our ships covers about 50,000 miles of track, thus contributing about 50,000 data points to the Gravity bank per ship, with three ships (Vema, Conrad and Eltanin) thereby contributing about 150,000 gravity data points per year.

Therefore, it can readily be seen that the gravity data are pyramiding rapidly.

From our data bank, we are producing as a first approximation :
1) World gravity charts for the oceans ;
2) Charts of world geoid heights ; and
3) Deflection of the vertical charts for selected areas.

The gravity data in our gravity bank consist of half a million points with an accuracy of ± 2 or 3 mgal and a position accuracy of about two tenths of a mile, as well as one and a half million points with accuracies of the order of ± 20 mgals and position accuracy of ± 1 to 2 miles. It is important to return and remeasure the one and a half million points to obtain accuracies which are now possible at sea. We will revise our data bank in the next decade and expect to accumulate a data bank of three and a half to four million points with high accuracy in the next decade. The data banks will serve as a control to geoids determined by satellite and will provide a quick result for worldwide geoid computations by combining satellite data with surface gravity measurements. Future oceanographic measurements will need the control that such a survey will provide.

The following abstracts are of the papers presented in the two sessions which followed the chairman's introductory remarks :

"The vibrating string gravity meter system of the Woods Hole Oceanographic Institution".
by C.O. BOWIN (W.H.O.I., Woods Hole, Mass.).

The results of three years of utilization of the vibrating string gravity meter, developed by C. WING of the Massachusetts Institute of Technology, is summarized. The latest version of this meter was operated aboard the R.V. Atlantis II in December, 1969, and it is presently aboard the R.V. Chain conducting gravity measurements in the north and south Atlantic Ocean, and in the western Indian Ocean. The W.H.O.I. system consists of the vibrating string gravity sensor mounted upon a Sperry Mark 19 Gyrocompass. Gravity, magnetic, ship's velocity, water depth, and date and time information are automatically recorded on paper or magnetic tape with the aid of a Hewlett-Packard 2114A digital computer. Another digital computer aboard the ship provides for complete reduction of the gravity data during the progress of a cruise.

"Gravity surveys on the Reykjanes Ridge and between Iceland and the Faeroes".
by U. FLEISCHER (Deutsche Hydrographisches Institut, Hamburg, Germany).

"Gravity surveys in the North Atlantic, carried out by the German research vessel Meteor in 1966, 1968 and 1970 show fundamental differences between the two ridges intersecting at Iceland : the free-air anomalies over the Reykjanes Ridge mainly reflect the differenciated topographic features in a smoothed manner, whereas irregularities in the gravity pattern of the uniform Iceland Faeroes Ridge indicate great subbottom mass deficiencies. There is an analogous difference in the magnetic pattern being linear on the Reykjanes Ridge and irregular between Iceland and the Faeroes. In the latter region a spacing as narrow as 3 miles was chosen to get a true picture of the anomalies

"Recent progress in marine gravimetry and a gravimetric geoid for the Western North Atlantic".
by M. TALWANI, H. POPPE & P. RAVINOWITZ.
(Lamont-Doherty Geological Observatory, Palisades, N.Y.).

"Recent progress in marine gravimetry with respect to improvement in instrument accuracy and increase in areal coverage of data is discussed. Free-air anomalies in the Western North Atlantic including the Carribbean Sea and the Gulf of Mexico have been averaged over 1° squares of latitude and longitude. These data are used to obtain a new gravimetric geoid over the Western North Atlantic. Minimum wavelengths of a few hundred km are represented in this geoid. We compare this geoid with geoids determined from satellite observation data which do not contain the shorter wavelength data and with detailed geoids in limited areas which contain gravimetric information with wavelengths as short as a few tens of km.

"Gravity measurements during Hudson 70".
by R.T. HAWORTH, W.S. von ARX & J.M. WOODSIDE.
(Atlantic Oceanographic Laboratory, Bedford Institute, Dartmouth, Nova Scotia).

"Hudson 70 is the name given to a voyage of the Canadian Scientific ship Hudson through the Atlantic, Antarctic and Pacific Oceans, and the Canadian Arctic Archipelago. Where feasible during this voyage, gravity measurements are being made.

The greatest emphasis thus far has been in the Pacific where continuous gravity measurements were made with an Askania Gss-2 gravimeter together with the Woods Hole vibrating string accelerometer gravimeter. From measurements made along 150°W between 63°S and 57°N it is proposed to obtain a solution for the flattening of the spheroid. Numerous gravity anomalies of geophysical interest were found during and en route to and from the extremities of the 150°W profile. *

Considerable effort will be made to gain additional geophysical information during the return of CSS Hudson and CSS Baffin from Victoria to Dartmouth through the Canadian Arctic Archipelago.

"Seagravimeter GSS 3".
by M.K. HOFFERT (Askania GMBH Berlin, Germany).

"A new seagravimeter developed by Askania is being described. The problem with respect to measuring technique is being defined. Different solutions are discussed and reasons for the choice in each respect are given. Thus beginning with the measuring principle, the instrument is described in detail of mechanical design and electronic servo control. A special feature of the system is the translatory moving proof mass as sensor in a force compensated servo loop, resulting in fast response, high accuracy and flexibility for different modes of data processing which make the instrument suitable for the demands of exploration. Calibration procedure is described and first measuring results are presented".

"Gravity anomalies in the Atlantic Ocean".
by G.L. STRANG Van HEES (Laboratorium voor Geodesie, Technische Hogeschool, Delft, Netherlands).

"During 1964-1965 the Dutsch hydrographic survey vessel H.Ms. Snellius carried out an oceanographic exploration on the Atlantic. The results of the magnetic, gravimetric and bathymetric measurements have been published.

Mean free-air anomalies were estimated for each degree of longitude from the continuous profile measurements. These values were presented at the General Assembly of the U.G.G.I. in Lucerne in 1967. (With reference to the International Gravity Formula of 1930).

* K. LAMBECK emphasizes : "in fact the 150°W is not a quiet line as shown in the 1970 Smithsonian Earth".
R.T. HAWORTH replies : "it was on the basis of previous geoid solutions and in fact there are few long wavelength variations from the trend of either of the ellipsoids shown".

Now additional Bouguer and isostatic anomalies (T = 20 and T = 30 km) have been computed by M. P. KARKI of the Ohio State University by order of Prof. G.J. BRUINS of the Delft Technological University (The Netherlands).

For these computations mean depths were estimated of 0.5° x 0.5° blocks. The effect of these blocks on the Bouguer and isostatic corrections were computed for the Hayford zones A to O (up to 167 km). The influence of the 1° x 1° center zone was computed with the formulae derived by KOCH and by NAGY. For the remaining letter zones formulae as derived by KUKKAMAKI were used.

Beyond zone O, the combined effect of topography and compensation for the zones 1 to 18 was taken from isostatic correction maps".

"The gravity field of the Surinam coast".
by B.J. COLLETTE (Vening Meinesz Laboratorium voor Geofysica en Geochemie der Rijksuniversiteit te Utrecht, Utrecht, Netherlands).

G.L. STRANG Van HEES points out that : "In Surinam very big anomalies turned out to occur. Gradients of 100 mgal at 100 km distance are no exception. These anomalies cause also big plumbline delfections. Difference in plumbline deflections between two points 70 km apart was 11". Astronomical fix-points serving as base-points for the photogrammetric mapping had to be corrected".

"Norwegian marine gravity survey".
by M.S. BAKKELID (Norges Geografiske Oppmåling, Oslo, Norway).

"A joint cooperative marine gravity survey between the U.S. Army Topographic Command (TOPOCOM) and the Norges geografiske oppmåling (NGO), planned to cover the still unsurveyed areas along the Norwegian Coast, some major fiords included, was initiated in the spring of 1970. The first season's work began on 10 March and terminated on 30 May 1970.

A synopsis of the days of this period shows : Measurements at the

Norwegian Sea	22 days
Measurements in the fiords	15 "
In port	45 "

The great number of days spent in ports was a result of too bad weather, lack of sufficient personnel and an excess error in cross-coupling resulting from excessive vertical accelerations due to choppy seas. The measurements at sea were carried out in a grid network, extending from the coast to the 100 fathom contour line. Grid lines were continous in an East-West direction and spaced at five-mile intervals. Additional lines were run across this grid to provide accuracy checks.

A total of 4,465 line miles were covered at a speed of 10 knots mainly between latitudes 59°North and 63°30 North. Positions along the tracks were determined every 15 minutes or more frequently, as necessary.

Measurements were also made in seven major fiords. Approximately 1860 line - miles, at a speed of 8 knots, were covered. Two lines were completed in the fiords, one as close as possible to one side of the fiord and a second one in the center. Where the fiords were wider than usual, additional coverage was made".

"Recent British gravity measurements at sea".
by D.H. MATTHEWS (Department of Geodesy and Geophysics, Cambridge, England).

"Gravity measurements have been made on the continental shelf in British waters by workers from the Institute of Geological Sciences and from various universities. Offshore measurements have been made by parties from the universities of Durham, Birmingham and Cambridge ; these three groups have all used their gravity observations together with seismic data to yield crustal structure information. * Durham have worked in the Iceland-Faeroes Ridge, Birmingham in the Scotia Sea and Cambridge most recently on Rockall Bank and in the Bay of Biscay. Most of the Cambridge tracks in the northeast Atlantic are shown on the I.G.B. track compilation and a free-air anomaly contour chart has been published by DAY and WILLIAMS (1970). Rockall Plateau has been shown to be a continental fragment. A map of free-air anomaly contours in the Bay of Biscay was shown (BACON et al. 1969 and BACON and GRAY, in preparation). Attention was drawn to the remarkable gradients off the northern coast of Spain where values of less than - 150 mgal occur within 15 miles of values greater than + 100 mgal. This linear feature is interpreted as a sediment filled trough".

* Almost all of the offshore measurements have been made with an Askania GSS-2 meter and corrected for cross-coupling.

The Chairman finds that his duties will make it necessary for him to resign as Chairman of Special Study Group 4.20 at the U.G.G.I. meeting in Moscow in the summer of 1971. Therefore, the committee members are requested to consider the nomination and election of another chairman at that time.

The following references are called to the attention of this Special Study Group and are those, that have been brought to the attention of the Chairman by various members of the study group and others, since the last list was published in the report of the committee for the meeting in Switzerland in 1967.

For the papers already mentioned in the bibliography of the previous Bulletins d'Information B.G.I., we refer to these Bulletins.

References

ARTEMYEV M.Y. - "Mean free-air anomalies : sources of information on heterogeneities in the Earth's mantle".
ACIC, T.C. 1216, Translated by D. SHALIKASHVILI
from : Bull. Moscow Soc. Naturalists-Geological Series, v.41, p.83-105, Moscow, 1965.

BEHRENDT J.C. & C.R. BENTLEY. - "Magnetic and gravity maps of the Antarctic".
The American Geographical Society. Antarctic Map Folio Series, Folio 9, 1968.

BELL AEROSYSTEMS Co - "Report on prototype gravity measuring system".
Proc. First Mar. Geod. Symp., Sept. 28-30, p.189-194, 1966.

BACON M., F. GRAY & D.H. MATTHEWS. - "Crustal structure studies in the Bay of Biscay".
Earth & Planet. Sci. Ltrs., v.6, p.377-385.

BERKHOUT A.W.J. & L.W. SOBZAK. - "A preliminary investigation of gravity observations in the Somerset and Prince of Wales Islands. Arctic Canada, with map n°81, Somerset and Prince of Wales Islands".
Gravity Map Series of the Dom. Obs., Ottawa, 10 p, 1967.

BOCK R.O. & C. WING. - "A new ocean-floor gravimeter utilizing a vibrating string accelerometer".
Proc. First Mar. Geod. Symp., Sept.28-30, 1966, p.195-199.

BOWER D.R. & B.D. LONCAREVIC. - Bull. Inf. 16, p.II-17.

BOWIN C.O. - Bull. Inf. 21, p.II-24.

BOWIN C.O., C.B. WING & T.C. ALDRICH. - Bull. Inf. 21, p.II-20.

CAMPBELL A.C. - "Geodetic positioning at sea".
Bull. Geod. n°89, p.293-300, Sept. 1968.

COMOLET-TIRMAN A. - Bull. Inf. 19, p.I-29.

CORDELL L. & R.G. HENDERSON. - "Iterative three dimensional solution of gravity anomaly data using a digital computer".
Geophys. v.33, n°4, p.396-601, August 1968.

COUCH R.W. & D.F. HEINRICHS. - "Oceanic and continental gravity investigations by Oregon State University".
Trans. Amer. Geophys. Union, v.50, n°10, p.546-548, October 1969.

DAY G.A. - Bull. Inf. 17, p.42.

DAY G.A. & C.A. WILLIAMS. - "Gravity compilation in the Northeast Atlantic and interpretation of gravity in the Celtic Sea".
Earth & Plan. Sci. Letter, v.8, p.205-213, 1970.

DRAKE C.L. & H. DELAUZE. - "Gravity measurements near Greece from the bathyscaphe Archimède".
Ann. Inst. Ocean., v.46, n°1, p.71-77, 1969.

ELVERS D.J., C.C. MATHEWSON, R.E. KOHLER & R.L. MOSES. - "Systematic ocean surveys by the U.S.C. & G.S.S. Pioneer 1961-1963".
Operational Data Report C & GSDR-1, Sept. 1967.

FLEISCHER U. - Bull. Inf. 14, p.I-36.

FLEISCHER U. - Bull. Inf. 19, p.II-36.

FLEISCHER U. - Bull. Inf. 24, p.II-12.

FLEISCHER U., O. MEYER & H. SCHAAF. - Bull. Inf. 24, p.II-17.

FRITSCH J. - "Erfahrungsbericht über Messungen mit dem Askania-Seegravimeter".
Dtsch. Hydrog. Z., v.15, p.142, Hamburg, 1962.

GANTAR C., C. MORELLI & M. PISANI. - Bull. Inf. 22, p.I-32.

GRAY F. & A.P. STACEY. - "Gravity and magnetic interpretation of Porcupine Bank and Porcupine Bight".
Deep Sea Res., v.17, p.467-475, 1970.

GREARSON L. - "Discussion on quantitative evaluation of a stabilized platform shipboard gravity meter by T.R. LAFEHR & L.L. NETTLETON".
Geophys., v.34, n°3, p.479, June 1969.

GOODACRE A.K., B.G. BRULE & R.V. COOPER. - "Results of regional underwater gravity surveys in the Gulf of St-Lawrence with map n°86, Gulf of St-Lawrence".
Gravity Map Series of the Dom. Obs., 24 p, Ottawa, 1969.

HAMILTON A.C. & G.G. BRULE. - "Vibration-induced drift in LaCoste and Romberg geodetic gravimeters".
J. Geophys. Res., v.72, n°8, 1967.

HARRISON J.C. & L.J.B. LaCOSTE. - "Performance of LaCoste-Romberg shipboard gravity meters in 1963-1964".
J. Geophys. Res., v.73, n°6, p.2163-2174, March, 1968.

HASTINGS C.E. & A.L. COMSTOCK. - "Pinpoint positioning of surface vessels beyond line of sight".
Hastings-Raydist., 7 p, 1969.

HAWKINS L.V., J.F. HENNION, J.E. NAFE & R.F. THYER.
Bull. Inf. 14, p.I-39.

HAWORTH R.T. - "Notes on the construction and use of a cross-coupling computer".
Unpublished, unedited manuscript for internal circulation of the Bedford Inst. Ocean., Dartmouth 67-5-1, 1967.

HAWORTH R.T. - "An analysis of the errors in gravity measurements at sea". 7 p, 6 illustrations, copy of MS received February 6, 1968.

HAWORTH R.T. - Bull. Inf. 18, p.I-10.

HAYES D.E. - "A geophysical investigation of the Peru-Chile Trench". Marine Geol., v.4, p.309-351, 1966.

HAYES D.E. & W.J. LUDWIG. - "The Manila Trench and West Luzon Trough, II - Gravity and magnetic measurements". Deep Sea Res., v.14, p.545-560., 1967.

HEIFETZ M.E., B.M. MALAHOV & V.P. TERCHOV. - Bull. Inf. 19, p.II-14.

HONKASALO T. - "Underwater gravity measurements in the Baltic Sea and the Barents Sea". Proc. First Mar. Geod. Symp. Sept. 28-30, 1966, p.217-219.

INNES M.J.S. & A.K. GOODACRE, J.R. WEBER & R.K. CONNELL. - Bull. Inf. 18, p.II-25.

INNES M.J.S., A.K. GOODACRE, A.A. WESTON & J.R. WEBER. - Bull. Inf. 22, p.II-14.

KAULA W.M. - "A tectonic classification of the main features of Earth's gravitational field". J. Geophys. Res., v.74, n°20, p.4807-4826, 1969.

KOGAN M.G. & E.A. BOYARSKY. - "Gravity measurements in the southeast Atlantic on R.V. Academician Kurchatov cruise 3, March 1968 - July 1968". J. Geophys. Res. Ltrs, v.75, n°11, p.2137-2140, 1970.

LaCOSTE L.J.B. - "Measurement of gravity at sea and in the air". Review of Geophys., v.5, n°4, p.477-526, 1967.

LE PICHON X., & M. TALWANI. - "Regional gravity anomalies in the Indian Ocean". Deep Sea Res., v.16, p.263-274,, 1968.

MALAHOFF A. & B. H. ERICKSON. - "Gravity anomalies over the Aleutian Trench". Trans. Amer. Geophys. Union, v.50, n°10, p.552-555, 1969.

MATTHEWS D.H., A.S. LAUGHTON, D.T. PUGH, E.J.W. JONES, J. SUNDERLAND, M. TAKIN & M. BACON. - Bull. Inf. 22, p.II-16.

MORELLI C., M.T. CARROZZO, P. CECCHERINI, I. FINETTI, C. GANTAR, M. PISANI & P. SCHMIDT di FRIEDBERG. - Bull. Inf. 21, p.II-26.

NETHERLANDS HYDROGRAPHIC OFFICE - "Navado III, bathymetric, magnetic and gravity investigations , H. Neth. Ms. "Snellius", 1964-1965". Hydrog. Newsletter, Special publ. n°3, 1967.

ORLIN H. - Bull. Inf. 14, p.I-29.

OSTENSO N.A. - "A gravity survey of the Chucki Sea region and its bearing on westward extension of structure in Northern Alaska". Geol. Soc. Amer., Bull. v.79, n°2, p.241-254, 1968.

PHILLIPS J.D., J. WOODSIDE & C.O. BOWIN. - "Magnetic and gravity anomalies in the Red Sea ; in Hot Brines and recent heavy metal deposits in the Red Sea ; a geochemical and geophysical account". Eds. E.I. Vogens & D.A. Ross, p.98-113, Springer-Verlag, New-York, Inc., 1969.

PLAUMANN S. - Bull. Inf. 14, p.I-43.

RUPPERT G., R. BERNSTEIN & C.O. BOWIN. - "Precise positioning of a ship at sea utilizing VLF transmissions". Navigation Journal of the Institute of Navigation, v.16, n°12, p.111-127, Summer 1969.

SAXOV S. - "Gravimetry in the Faroe Islands". Danish Geodetic Institute, Contr. n°43, 24 p, 3 maps, Copenhagen, 1969.

SCHLICHTING K. - "Ein neues Kreiselsystem für den Kreiseltisch zum Askania seegravimeter". Askania-Warte, v.24, n°70, p.10-16, 1967.

SOLOMON S. & S. BIEHLER. - "Crustal structure from gravity anomalies in the Southwest Pacific". J. Geophys. Res., v.74, n°27, p.6696-6701.

STRANG Van HEES G.L. - Bull. Inf. 21, p.II-33.

SZABO B. - "Ocean gravity surveys with airborne systems".
Proc. First Mar. Geod. Symp., Sept. 28-30, 1966, p.201-204, 1967.

TAKIN M. - "An interpretation of the positive gravity anomaly over Bombay on the West Coast of India".
Geophys. J. R. Astr. Soc., v.11, p.527-537, 1966

TALWANI M. - "Gravity anomaly belts in the Caribbean".
Continental Margins and Island Arcs Symposium Proceedings.
Ed. W.H. Poole, Geological Survey of Canada, paper 66-15, p.177, 1965.

TALWANI M. - Bull. Inf. 18, p.II-30.

TALWANI M. - "Experience with U.S. Navy's navigation satellite system".
First Mar. Geod. Symp. Proc., Sept. 28-30, 1966, p.225-227, 1967.

TALWANI M. - "Lamont analog computers and signal monitoring system used with Graf Askania GSS-2 seagravimeter".
Tech. rpt. n°3, CU-3-68-Nonr 266 (79), 14 p, 1968.

TALWANI M. - Bull. Inf. 18, p.I-11.

TALWANI M. - "A computer system for the reduction, storage and display of underway data acquired at sea".
Tech. rpt, n°1, CU-1-69-N000 14-67-A-0108-0004, 1969.

TALWANI M., J.H. DORMAN, J.L. WORZEL & G.M. BRYAN. - "Navigation at sea by satellite".
J. Geophys. Res., v.71, p.5891-5902, 1966.

TALWANI M., J.H. DORMAN & R. KITTREDGE. - "Experiences with computers aboard research vessels Vema and R. Conrad".
Trans. Application of Sea Going computers. Eds. J.D. Mudie
C.B. Jackson, Mar. Tech. Soc., p.17-25, 1969.

TALWANI M., W. EARLY & D.E. HAYES. - "Continuous analog computation and recording of the cross-coupling and off-leveling errors".
J. Geophys. Res., v.71, p.2079-2090, 1966.

TALWANI M. & M. EWING. - "A continuous gravity profile over the Sigsbee Knolls".
J. Geophys. Res., v.71, n°18, p.4434-4438, 1966.

TALWANI M. & X. LE PICHON. - "Gravity field over the Atlantic Ocean". Geophys. Monogr. n°13, The Earth's Crust and Upper Mantle. Ed. Pembroke J. Hart. Amer. Geophys. Union, p.341-351, 1969.

TALWANI M., X. LE PICHON, M. EWING, G.H. SUTTON & J.L. WORZEL. - "Comments on paper by W. Jason Morgan "Gravity anomalies and convection currents 2. The Puerto Rico Trench and Mid-Atlantic Rise". J. Geophys. Res., v.71, n°14, p.3602-3606, 1966.

TANNER J.G. - "An automated method of gravity interpretation". Geophys. J. R. Astr. Soc., v.13, p.339-347, 1967.

TOMODA Y. - Bull. Inf. 21, p.II-12.

TOMODA Y. - Bull. Inf. 22, p.II-21.

TOMODA Y. & J. SEGAWA. - Bull. Inf. 21, p.II-10.

TOMODA Y., K. OZAWA & J. SEGAWA. - Bull. Inf. 21, p.II-14.

Van BOECKEL J. & R.A. LAGGAY. - "Gravity surveys in Surinam and the Netherlands Leeward Islands area, 1958-1965". Netherlands Geodetic Comm. Publ. Geod. New Series, v.3, n°3, 78 p, 1969.

WING C.G. - "MIT vibrating string surface ship gravimeter". J. Geophys. Res., v.74, n°25, p.5882-5894, 1969.

WOODSIDE J. & C. BOWIN. - "Gravity anomalies and inferred crustal structure in the Eastern Mediterranean Sea". Geol. Soc. Amer., Bull. v.81, p.1107-1122, 1970.

WORZEL J.L. - "Structure of continental margins and development of ocean trenches". Continental Margins and Island Arcs Symposium Proceedings. Ed. W.H. Poole, Geological Survey of Canada, paper 66-15, p.357-375, 1966.

WORZEL J.L. - "Survey of continental margins". Geology of Shelf Seas, Ed. D.T. Donovan, p.117-154, Oliver & Boyd, Edinburgh, 1968.

WORZEL J.L. - "Advances in marine geophysical research of continental margins". Canadian J. Earth Sci., v.5, p.963-983, 1968.

-=-=-=-=-=-=-

IV - NEW GRAVIMETRIC INSTRUMENTATION

At the meeting held on Wednesday 9th September (11.15-12.30 a.m.) B. SZABO presents 2 papers concerning : "Cryogenic gravimeter" and "Dynamic gradiometer".

"Cryogenic gravimeter"

(Principle, status and applications)

"A continuously recording, drift-free gravimeter with very high sensitivity is under development at Stanislaus State College, California, for AFCRL.

This instrument is designed primarily to observe the $_0S_2$ and $_0S_0$ radial vibration modes of the Earth which have a period of 53,9 minutes and 20.46 minutes respectively. An upward force is applied to a niobium hollow sphere by a properly designed field and field gradient at 4.2°K. This force is adjusted to be equal and opposite to the gravity force, the weight of the ball. In this manner, the ball floats freely at the center of the instrument. The instrument is shielded from external magnetic field fluctuations by a niobium cylinder and a mu-metal cylinder. The magnetic field solonoid and the gradient pair coils are formed from a niobium-zirconium wire, which produces a very stable field and field gradient once the current inside the coils is made persistent. Such a configuration provides a constant magnetic force which opposes the main gravity field of the Earth. As a result, the minute motions of the ball reflect the small changes in the gravity field as a function of time. The motion of the ball induces magnetic flux change in a pick-up coil which is reflected in a Super-conducting Quantum Interference Device known as "SQUID". With the aid of this unit, we are able to record small motions of the ball as it floats freely in the center of the instrument. Theoretical sensitivity of the instrument for a change of one quantized flux is equivalent to one part in 10^{11} of the Earth gravitational acceleration. Presently we are designing a system to digitize the output signal to make a power spectra analysis.

By analyzing and comparing long records taken by instruments operating at strategic points of the Earth's surface, new information may be obtained to study the following

1) Secular variation of gravity ;
2) Variation of the station positions with respect to the center of mass. or the variation of the Newtonian constant "G" ;
3) Correlations between short and long period variations and the angular velocity of the Earth's rotation ;
4) Dynamic processes occurring inside the Earth".

"Dynamic Gradiometer"

(Principle, status and applications)

"From 1962 to 1966, Dr. R. FORWARD of the Hughes Research Laboratories developed the basic concept of a rotating gravity gradient gradiometer. This effort was supported by internal funding and in part by NASA sponsorship. The basic concept of the rotating gradient sensor is the following : If a system of proof masses is rotated in the static gravitational field of an object, the gravitational force gradient of this field will induce dynamic forces on the proof masses with a frequency which is twice the rotation frequency of the system ; at the same time, inertial effects, caused by accelerations of the proof mass mounting, will induce forces with frequency at the rotational frequency. Therefore, the gravitational gradient can be determined independently of the inertial forces. Analysis showed that the sensing of the gravitational gradient will still occur if the proof mass system is in free fall.

The engineering feasibility of this concept was demonstrated by HUGHES with a torsionally resonant type of rotating gravity gradient sensor using a soft mounted support system. This laboratory prototype sensor consists of a two rigid mass quadrupoles oriented perpendicular to each other and connected at center with a torsionally flexible spring. When the sensor is rotated about its torsionally resonant axis at an angular rate which is exactly one half the torsional resonant frequency, the differential torque between the sensor arms will deflect one quadruple with respect to the other. This angular resonant deflection is extremely small. (Surface gradients produced by the Earth (3000 E.U.) will produce deflections of 3×10^{-8} ; while signals of 1 E.U. produce angular responses of 10^{-11} rad.). To transduce this mechanical motion into an electrical signal, a flexural pivot is used at the torsional spring and a barium titanate strain transducer is affixed to one of the flexural spring leaves. After some experimental work and hardware modifications the sensor detected the gradients of stationary masses ; the noise level was over $\pm$ 100 E.U. The present completely reworked soft mounted system has $\pm$ 1 E.U. noise level. (1 sigma at an integration time of 10 sec ; 1 E.U., the unit of gradient = 10^{-9} sec^{-2}). Fly-by simulation tests were run which fully demonstrated the sensor dynamic response capability.

AFCRL supported the Hughes gradiometer effort with two contracts : The first from July 1966 to Sept. 1967 was an analytical effort to determine the feasibility of the sensor for applications in geodetic measurements. The second contract supported the Laboratory development of a hard-bearing sensor. In addition, analytical studies were carried out regarding vibration-isolation requirements. The objective of the "hard mounted" sensor project was to develop a rigid spin bearing support for the previously demonstrated "soft mounted" sensor and to provide the capability of using the sensor in a moving base application. The rigid spin bearing is necessary for the stabilization of the spin axis in any direction, thus allowing measurement of gravity gradient components with reference to any desired orientation. Experiments with the first "hard mounted" gradiometer design gave important information regarding the identification and methods for elimination of various problems such as : the inertial and dynamic balance of the entire rotating assembly ; air bearing ; transducer design ; servo drive ; and supporting structure. Stabilization and isolation studies defined the approaches toward the solutions of the stabilization and isolation system mechanization. The proposed continuation of AFCRL's program encompasses the known major problem areas which require solution for a hard-mounted sensor that is designed for a moving base requirement. The end objective of the program is the development of a prototype sensor for demonstration in a laboratory the capability of detecting a one E.U. range in the gravity gradient at an integration time of ten seconds. This is to done with an arbitrary orientation of its sensitive axis.

Once the basic sensor has been developed, the same sensor can then be applied to a wide variety of systems including both static and moving base configurations. The feasible applications are the following :

1) Gravimetry : airborne, marine, satellite or combined applications.

Gravity determinations can be made by means of moving base (airborne or marine) gradient measurements from an integration of the products of the three navigation coordinate components with the corresponding terms of the second order gradient tensor applying to the vertical direction. Gradiometers used for this application are insensitive to acceleration produced by aircraft or ship motion thereby eliminating a major source of error present in gravimeters. In aerial gravimetry employing a gravimeter, the smallest area anomaly size that can be determined ultimately depends on aircraft speed. Considering 400 knots ground speed, the smallest area mean anomaly that can be determined is theoretically about 30' x 30'. Gradiometer measurements at this speed can produce mean anomalies for areas as small as 5'x 5' because they do not smoothe out the smaller features as much as the gravimeter and do not require long integration times to compensate for aircraft acceleration. Airborne application of a gradiometer system can be used for local, regional and global surveys.

The marine application does not possess the capability for rapid measurements as does the aircraft, but the lower speed and closeness to the mass variations permits the details necessary for downward continuation computations in depth for geophysical prospecting. As with the airborne application, a hybrid gradiometer/gravimeter system will give nost satisfactory results and accuracy.

The same basic sensor can be used for gravity surveys from a satellite. Higher order harmonics (10th to 100th order) can be determined by means of orbiting gradiometers. Terms of increasing order correspond to small scale features on or near the surface ; although the contribution of these harmonic components to the potential is small, their contribution to the force gradient at a point above them is a substantial fraction of the gravitational gradient of the entire Earth. A gradient sensor with a sensitivity of 0.03 E.U. in a 30 sec. averaging period would take about 200 data points during each orbit, giving an average sensitivity of 0.002 E.U. per orbit. The amplitude of the 10th to 100th order harmonics is approximately 3 to 0.3 E.U., therefore, the average sensitivity per orbit is reasonably adequate for the determination of the harmonics even at 400 km altitude.

2) Navigation and guidance by augmenting an inertial navigation system ; by determining and recording the variations of the deflection of the vertical along the path of a vessel ; and as a combined gravity-inertial sensor.

To navigate with respect to the Earth with an inertial navigation system, the centripetal Coriolis and gravitational accelerations must be subtracted from the output of the accelerometers. The first two accelerations are easily obtained, but to obtain the gravitational acceleration, for highly accurate inertial systems, a precise model of the Earth's gravitational field is required. Present day models are not adequate and are unlikely to become better due to large unsurveyed areas. If a set of three orthogonal gradiometers were also on the vehicle they would measure only the gravitational acceleration, ignoring the others. Because of the $1/R^3$ characteristic of the gradiometers they give large response to local anomalies. Such systems can highly increase inertial navigations accuracies.

Employing three orthogonally mounted gradiometers on a gravity surveying vehicle (surface ship, submarine, aircraft) the variation of the deflection of the vertical can be measured and recorded. A traverse starting and ending at locations where gravity is known provides a method for compensating long period drift. The recorded deflections can be used for subsequent ship and submarine navigation as well as for submarine launched missile guidance platform erection. In some areas the variation of the deflection of the vertical with depth is significant. The gradiometer method can accurately determine these variations.

The torsionally resonant rotating gravity gradiometer has a unique mode of operation, namely the spinning of the sensor at an appreciable angular velocity. Thus, the sensor has the inertial angular momentum properties of a gyro in addition to the properties of a gradiometer. In addition, it is possible to modify the inertial structure slightly to provide a flexible component which would respond to accelerations. Therefore, it is conceivable to consider designs, that in addition to measuring the gravity gradient, will also acts as gyros and accelerometers. An orthogonal set of these instruments would constitute the sensing element in an inertial navigation or guidance system completely independent of any outside knowledge of the gravitational field".

-=-=-=-=-=-=-

V - FIRST ORDER WORLD GRAVITY NET (F.O.W.G.N.)

Sp. St. Gr. n°4-05

The following meetings are held on Wednesday 11th September :
- in the morning (9.15-10.45 a.m. ; 11.15-11-30 a.m.)
- in the afternoon (2.30-4.oo p.m.)

The first meeting is opened by Prof. C. MORELLI, Chairman, with the principal contributors : C. GANTAR, R.K. McCONNEL, B. SZABO, J.G. TANNER, U. UOTILA, C.T. WHALEN & G.P. WOOLLARD.

C. MORELLI gives a general view on the progress in the solution of the FOWGN ; then one representative of the different Unities of the Bedford Sub-group in charge of the statistical treatment of all the gravity material, reports on their work, particularly, C.T. WHALLEN (1st Geodetic Survey Squadron, Warren AFB), R.K. McCONNEL (Dominion Observatory, Ottawa), U. UOTILA (Ohio State University).

At the beginning of the afternoon meeting, T. OKUDA presents the paper on "The fundamental gravity value in Japan" by H. SUZUKI (Doc.V-2).

He says that the Western Pacific calibration line project was commenced in 1965 and since then 6 international observations have been completed with the modified G.S.I. pendulums. Comparison between these recent results and those of the former ties for the period 1955-1964 is made.

He concludes that the most probable gravity value at Tokyo old station is : 979.8017 $\pm$ 0.0002 cm/sec.^{2}. If we adopt this result it is necessary to apply a correction of + 0.7 mgal for each current gravity value in our country".

Hereafter, are given :
1) a general view on the FOWGN (D.A. RICE, Doc.V-3)
2) the general report of C. MORELLI (Doc.V-1), and
3) complementary information and remarks made by delegates concerning the accuracy of gravity measurements, the absolute reference system, the calibration lines, the new connections to be added between principal stations...

1) General view about the program of the F.O.W.G.N.
(D.A. RICE, from Doc.V-3).

"Under sponsorship of the International Gravity Commission and under the central direction of Study Group 4.05 of the International Association of Geodesy, a cooperative international program was organized for the establishment of a single worldwide reference system. This effort, supported in part by AFCRL, was begun in 1963 and the final adjustment is expected to be published by the end of 1970. The original plans for this program were published in 1963.

The relative pendulum measurements along the three primary calibration lines (Euro-African, American and West Pacific) and the gravity meter observations for the world first-order network were completed by the Fall of 1967. Figures 1 and 2 (Doc.V-3) show the scheme of the respective measurements. After completion of the field operations, a working group consisting of the actively participating organizations held a special meeting to review the 1963-67 observations. The working group also agreed on methods of incorporating the pre-1963 pendulum and gravity meter data in the final adjustment. Analysis of the selected older measurements was assigned to investigators on a voluntary basis. It was agreed that the Osservatorio Geofisico Sperimentale (OGS), Trieste, Italy, would process the 1963-67 and acceptable older material in a uniform format. During 1968 and 1969 the original field data were collected from the observers, analyzed, catalogued, and in 1970 distributed to four small sub-groups for accomplishment of preliminary adjustments. OGS also completed and distributed the local tie adjustments. The preliminary adjustments carried out by each group using freely selected methods will be studied jointly by the entire working group and a decision will be made regarding acceptance of a final adjustment, or possibly some necessary reworking".

2) General report of Prof. C. MORELLI on the progress in the solution of the First Order World Gravity Net problem.

Foreword :

"After many years we are approaching the solution of the Standardization Gravity Problem : accordingly to the internationally accepted program outlined and approved by the International Gravimetric Commission, all the wanted pendulum - and gravimeter-measurements, and new exceptionally good absolute gravity measurements, are available.

The work was realized by different small Groups, who realized a tremendous work : both in operating and reducing the measurements. Let us recall here only the major contributors to both presentation and investigation of gravity data :

- in the pendulum measurements, the late B.C. BROWNE and T. HONKASALO's (Cambridge pendulums) and the WOOLLARD's groups (Wisconsin and Hawaii University pendulums) ;
- in the gravimeter measurements, the WHALEN's (1st Geodetic Survey Squadron), GROSSMANN and TORGE's (Hannover University) groups ;
- in the adjustment preparation, the so-called "Bedford" Group.

The contribution assigned to the O.G.S., during the Bedford group meeting, was to collect, prepare and redistribute the observations to all the further investigators and to perform the necessary adjustments (pendulums, local gravimeter ties, global one) in parallel with the 1st Geodetic Survey Squadron (C.T. WHALEN), the AFCRL-Ohio University cooperative group (B. SZABO, U. UOTILA) and, possibly, the Dominion Observatory of Ottawa".

"Through international cooperation, the measurements programmed by the International Gravity Commission have been all completed, both with pendulums and gravity-meters.

Pendulum observations

Most of the pendulum observations have been made by Gulf (19 trips) and Cambridge (12 trips) pendulum apparatuses.

Minor contributions have been brought by Japanese (G.S.I. : 9 short trips), Italian Geodetic Commission (5 trips), U.S.C.G.S. (2 trips) and Dominion Observatory (1 trip) apparatuses.

The total number of pendulum stations is 122, 105 of which were observed also by the gravimeters considered for the FOWGN. 58 stations (46 of those measured also by gravimeters) are observed by only one pendulum trip.

The total number of trips is 48, of which 8 can be rejected due to defective pendulum behaviour.

The reduction of the pendulum data is a very delicate problem due to the frequent occurrence of tares and the presence of, sometimes high, creep.

For this reason it is difficult to say a-priori how many useful pendulum ties can be introduced in the FOWGN adjustment without zero weight. It is probable that about 900 ties among 118 primary stations will be used to control the scale of the gravimeter measurements.

Gravimeter observations

Most of the observations were made by LaCoste and Romberg gravimeters. Principal contributors to these observations were the 1st Geodetic Survey Squadron (formerly 1381st GSS), the Dominion Observatory of Ottawa, the Hawaii Institute of Geophysics (formerly University of Wisconsin, the U.S. Naval Oceanographic Office, the Terrestrial Sciences Laboratory of AFCRL-Bedford, the Geodetic

- in the pendulum measurements, the late B.C. BROWNE and T. HONKASALO's (Cambridge pendulums) and the WOOLLARD's groups (Wisconsin and Hawaii University pendulums) ;
- in the gravimeter measurements, the WHALEN's (1st Geodetic Survey Squadron), GROSSMANN and TORGE's (Hannover University) groups ;
- in the adjustment preparation, the so-called "Bedford" Group.

The contribution assigned to the O.G.S., during the Bedford group meeting, was to collect, prepare and redistribute the observations to all the further investigators and to perform the necessary adjustments (pendulums, local gravimeter ties, global one) in parallel with the 1st Geodetic Survey Squadron (C.T. WHALEN), the AFCRL-Ohio University cooperative group (B. SZABO, U. UOTILA) and, possibly, the Dominion Observatory of Ottawa".

"Through international cooperation, the measurements programmed by the International Gravity Commission have been all completed, both with pendulums and gravity-meters.

Pendulum observations

Most of the pendulum observations have been made by Gulf (19 trips) and Cambridge (12 trips) pendulum apparatuses.

Minor contributions have been brought by Japanese (G.S.I. : 9 short trips), Italian Geodetic Commission (5 trips), U.S.C.G.S. (2 trips) and Dominion Observatory (1 trip) apparatuses.

The total number of pendulum stations is 122, 105 of which were observed also by the gravimeters considered for the FOWGN. 58 stations (46 of those measured also by gravimeters) are observed by only one pendulum trip.

The total number of trips is 48, of which 8 can be rejected due to defective pendulum behaviour.

The reduction of the pendulum data is a very delicate problem due to the frequent occurrence of tares and the presence of, sometimes high, creep.

For this reason it is difficult to say a-priori how many useful pendulum ties can be introduced in the FOWGN adjustment without zero weight. It is probable that about 900 ties among 118 primary stations will be used to control the scale of the gravimeter measurements.

Gravimeter observations

Most of the observations were made by LaCoste and Romberg gravimeters. Principal contributors to these observations were the 1st Geodetic Survey Squadron (formerly 1381st GSS), the Dominion Observatory of Ottawa, the Hawaii Institute of Geophysics (formerly University of Wisconsin, the U.S. Naval Oceanographic Office, the Terrestrial Sciences Laboratory of AFCRL-Bedford, the Geodetic

Institute of Hannover, the Expeditions Polaires Françaises and the Osservatorio Geofisico Sperimentale of Trieste.

The total number of gravity observations collected for the FOWGN is over 39000, giving about 13000 gravity differences between FOWGN stations. Remaining are lay-over observations, repeated measurements or local ties (that is, between sites of the same station).

About 85 % of the gravity differences between stations of the FOWGN have been measured by means of 54 LaCoste and Romberg gravimeters. Other 21 instruments of different kind have been employed for the rest of the FOWGN ties.

The primary sites connected by these ties are nearly 790 (some local ties are still lacking, giving "doubles" in the primary site list).

Other 1200 excentre sites have been occupied during FOWGN trips. The total number of the ties between excentres, or from excentre to centre in the same station (namely of local ties) is over 13000, and 379 local adjustments have been performed from these observations.

Accuracies

The pendulum observations will hardly give an accuracy of ± 0.2 mgals all over the range, whereas the gravimeter results can guarantee the ± 0.1 mgal (2.10-5) or better, if properly calibrated. The exceptionally good results of the new transportable absolute gravity measurements (± 0.05 mgals) are providing a new tool, hardly to be hoped only two years ago.

Such (absolute) accuracies will provide new tools also for new geodetic reference systems, to control vertical variations of the continents or of parts of them, secular variation of gravity, ...

Distribution of observations and analysis

The collection, coding and editing phases were made at the Osservatorio Geofisico Sperimentale of Trieste. The last relevant material arrived completed only in December 1969. Minor data were added also at the end of July 1970.

Groups of programs have been written in the meantime to process all the material on the electronic computer (IBM 7044) and the first edition of the data, with the best available scale factors for the gravimeters and consequently the first version of the local tie adjustments (centering corrections to the primary sites), was circulated withing the Bedford Subroup in March 1970. This Subgroup is composed by the units which - following a general agreement - are proceeding independently to the statistical treatment of all the material and to the preparation of the final adjustment : which will be presented jointly to the next Moscow Meeting of the I.A.G., after previous comparisons and discussions of the results".

3) Complementary information and remarks.

On the statistical work of C.T. WHALEN, W. BULLERWELL says :

"The analysis of variance is very interesting, and especially the result indicating that the residual variance correlates with the size of the measured gravity interval. Further examination of the data might be worth while to see whether this correlation implies a secondary dependence on time interval, i.e., drift, or on number of subsidiary links within the measured interval. The result might be relevant to revision in weighting".

About the absolute gravity values, J.E. FALLER comments :

"One on comparing the Faller-Hammond measurement, good to say, 5 parts in 10^8 and the Sakuma measurement gives 6 parts in 10^9, one needed to keep in mind that in the case of the first, the value is the experimental accuracy whereas in the second, one is dealing rather with the precision of the measurement. This is in no way meant to detract from the beautiful work of Sakuma at the BIPM but is a point that sometimes is overlooked".

About the absolute values and the stability of gravity.
G.P. WOOLLARD made some remarks :

"It has been shown that the world gravimeter net has now a potential reliability of $\pm$ 0.5 mgal or better and that there is no significant difference with the absolute gravity results obtained by Hammond with the Faller absolute gravity apparatus. This is also substoniatal by the Gulf and Cambridge pendulum results. The problem of datum and scale as well as internal net consistency, it thus appears, can be resolved to within $\approx$0.5 mgals on a global basis in terms of observational measurements.

The problem we now face is the stability of the system and the effect of transient changes in gravity on observational values. A related problem that comes into the observations is the degree to which changes in crustal and upper mantle parameter values affect the tidal response of the Earth. To investigate the last we carried out simultaneous Earth tide measurements over a three month period at Fairbanks, Alaska; Denver, Colorado and Mexico City, Mexico. We also carried out a similar experiment with observations in Nebraska where the crust is thick ($\approx$ 50 km thick) and the mantle a high velocity (> 8.3 km/sec.) and presumably a high density ; in the Rocky Mountains where the crust is about 40 km thick and the mantle velocity normal ($\approx$ 8.15 km/sec.) and the Basia and Rovge area of Nevada where the crust is thin (28 to 30 km) and mantle has a sub-normal velocity (7.8 to 7.9 km/sec.). These data are now in the process of reduction.

In terms of short term effects that will influence observations there are annual changes in water table and consequent dilatency of the sediments and elevation ; there are microseism storms that will influence spring gravimeters and where polarized also can have a marked effect on pendulum period if the pendulums are oriented in the azimuth of the microseism polarity. Earthquakes represent a maximized expression of the microseism problem. Geology also enters into the problem since seismic energy is amplified in unconsolidated sediments and have minimum effect in areas of crystalline rock outcrops.

On a larger term basis there are the effects of the Chandler wobble of the Earth which results in changes in latitude and mass distribution and consequently gravity. As the release of earthquake energy is also related to the Chandler wobble it results in two phenomena affecting gravity.

A third effect of long term significance is plate tectonics as a consequence of crustal spreading and the generation of new crust in the oceans. Where crustal plates converge there is crustal uplift and significant changes in gravity. As most tectonic and orogenic regions are in areas of crustal convergence these areas can be expected to be subject to significant changes in gravity with time· Mexico is a good example where there has been 2.5 mgals change over an 18 year period between Acapulco and Mexico City. Here the uplift has taken place in association with a single geologic fault system about 100 km from the coast.

A further cause is isostatic rebound from former glacial loading as in Fenno-Scandinavia and eastern Canada.

These types of areas should therefore be avoided as areas for first order gravity bases if the fundamental gravity net is to have any degree of time stability".

A. SCHLEUSENER speaks about the <u>change of gravity readings by microseismic.</u>

"I believe microseismic means periods up to about 10". Up to now, we should not worry about disturbing readings as long as we are interested in our usual field work with accuracy of $\pm$ .01 to .02 mgal. These reading accuracies seem not to be doubtful according to the large amount of successful repeated stations. Even at harbor points and for work in volcanic districts it is possible most of the time to reach the limit of $\pm$ .02 mgal. But comming nowadays to the microgal the question of errors by any kind of seismics has to be examined, even if tidal registrations do not give the impression of a serious situation".

J.E. FALLER makes some remarks concerning the absolute gravity Reference System.

"It seems unreasonable to persist very much longer in maintaining a World gravity Network based on a measurement (or a correction to that measurement) made more than 60 years ago at a site almost inaccessible.

If, in fact, a single site must be considered as the basis of a World-wide Network, then, that site should be the one at the B.I.P.M. at which two corroborative absolute determinations have been made.

It is, of course, no longer necessary to have a network based on the value at only one particular site".

J.D. BOULANGER says for the construction of the FOWGN, it is necessary to obtain accurate determinations of correction to adopt Potsdam value. He proposes to carry out connections from Potsdam to stations where absolute gravity values have been or will have been determined. It is :

Potsdam - Helsinki
" - Paris (Sèvres)
" - London, Teddington
" - Washington (or other station in U.S.A.)
" - Tokyo
" - Ottawa

These connections must be carried out with the same type of apparatus and with the same measurements program.

About the Calibration Lines and the new connections.

B.C. BARLOW points out that "the Japanese and Australian Calibration Lines intersect the Western Pacific Calibration Line (WPCL) at Tokyo and Sydney respectively. Because of transportation difficulties neither of these national calibration lines can be included as part of the line of the WPCL. Nevertheless, in view of their importance to the countries concerned, it is requested that these national calibration lines be included in the itinerary of any group making measurements on the WPCL".

After the report of B. SZABO concerning the present standardization network, B.C. BARLOW thinks this network suffers from a major defect in that it lacks measurements in the region of the South Pole (Antarctica) and, of course, in the region of the North Pole. The greatest values of gravity on the Earth's surface are found in the polar regions, which include a large portion of the Earth's surface.

At present we must extrapolate from the well-known values of the existing standardization network to obtain values of gravity near the poles. Priority should be given to establishing accurate base stations in the polar regions".

-=-=-=-=-=-=-=-=-

Papers presented or distributed at the Meeting

V-1) C. MORELLI - "Some notes on the relative gravity measurements and on the agreements for the adjustment of the FOWGN".
(not distributed)

V-2) H. SUZUKI. - "Fundamental gravity value in Japan".

V-3) D.A. RICE. - "Gravimetric activities of the United States, 1965-1970".

VI - SOME PROBLEMS OF PHYSICAL GEODESY

One meeting concerning different questions of physical Geodesy was held on Wednesday 9th September (2.30-4.00 p.m.), under the Chairmanship of Prof. C. MORELLI.

V. BARANOV présente une communication :

"Sur quelques problèmes de la Géométrie de l'ellipsoide, problème de Neumann extérieur". *(a)

"Le potentiel newtonien est développé habituellement en une série d'harmoniques sphériques. Si le potentiel ou une grandeur dérivée, est connu sur une surface d'un ellipsoïde de révolution, les coefficients de cette série ne sont valables que pour cette surface, et non à l'extérieur : ils varient avec l'éloignement.

Comme la surface de l'ellipsoïde n'appartient pas à l'une des trois familles orthogonales définies par les coordonnées sphériques, il faut utiliser les coordonnées sphéroidales. Les formules de transformation pour passer de la sphère à l'ellipsoïde ne sont pas commodes ; il est cependant possible de modifier légèrement ces formules de façon à ce que les mêmes coefficients constants conviennent non seulement à la surface de l'ellipsoïde, mais soient valables pour tout point extérieur.

V. BARANOV insiste sur le fait qu'on n'a nullement besoin de connaître Δg (anomalies) partout sur l'ellipsoïde ; les valeurs manquantes peuvent être remplacées par n'importe quelles valeurs (par exemple zéro). Ceci n'affecte ni Δg, ni ΔW dans les zones où la pesanteur est connue".

K. LAMBECK speaks on the paper :

"Comparison and combination of surface gravity data with satellite data". *(b)

"A new estimate of the Earth's gravity field has recently been obtained by Gaposchkin and Lambeck (1). This solution is based on some 100,000 camera and laser range observations to numerous satellites as well as including information obtained from deep space probes and from surface gravity data. The total field is represented by spherical harmonics complete to degree and order 16 plus a number of higher

*The full text was distributed at the Meeting and will be published in : (a) Bull. Geod. n°99, March 1971, (b) Bull. Geod. n°100 June 1971.

(1) Ref. : E.M. GAPOSCHKIN & K. LAMBECK., Smithsonian Astrophysical Observatory, Special Report 315, May,,1970.

order terms. The accuracy of this global solution is estimated as 3 meters in geoid height and 9 milligals in gravity anomalies.

The satellite solution comprises both dynamic and geometric aspects of satellite geodesy and the solution is for both the gravity field coefficients and coordinates of the tracking stations. All C/S (l,m) terms complete through l = 12, m = 12 except for 11,7 12,6 and 12,9 were determined as well as a variety of higher degree terms.

The surface gravity data used for the combination solution has been prepared by Kaula (2) in the form of 300 by 300 nautical mile square area means. His results are free-air anomalies for 935 squares covering about 56 % of the globe.

Extensive tests of the satellite solution against the surface gravity data before the combination was made have led to the following conclusions :

1) The global field up to 10,10 has been determined almost entirely by the satellite method, the surface gravity data having little influence on these terms. The field up to 10,10 also contains almost all the information that a correct field truncated at this limit would have.

2) With the satellite data presently available it will be difficult to determine the Earth's gravity field completely beyond about 12,12 without using gravity data.

3) The surface gravity data used in this solution contains little information on a global basis beyond about 16,16 or 18,18. For improvements in resolution considerable improvements in both the accuracy of the data and in the coverage of the data is required.

4) With complete oceanic coverage with surface gravity data with an accuracy equal to that which is now regularly obtained, the total global field can be extended to about degree and order 25 and still give significant coefficients".

U.A. UOTILA reads the paper of R.H. RAPP :
"Equal-area blocks". (*)

"Many computations in gravimetric geodesy, satellite geodesy, and other areas require the evaluation of mean gravity anomalies. The simplest region definition is to have the mean anomaly representative of a block bordered by meridians and parallels extended continuously over the Earth. Such blocks have several disadvantages. Because of their non-uniform size in area, mean anomalies defined in meridian and parallel

(2) Ref. : W.M. KAULA, Journal of Geophysical Research, 71, 5303-5314, 1966.

(*) not distributed at the Meeting, The full text will be published in Bull. Geod. n° [illegible], March 1971.

bordered blocks are difficult to analyze statistically. In addition, there are many more mean anomalies of this type than of the type to be described subsequently. This factor arises because as the polar regions are approached each meridian and parallel bordered block becomes smaller in area. In applications such as occur in some problems in the combination of satellite and gravimetric data, the number of observation equations generated in an adjustment will be equal to the number of mean anomalies. It is an obvious advantage in this type of application to use a block type that has a minimum number of mean anomalies covering the Earth, yet yielding the same information as continuously extended meridian and parallel bordered blocks.

A type of block that does not have the disadvantages described above is known as an equal area block. Such blocks have a disadvantage over continuously extended meridian and parallel bordered blocks because there is no unique way to define the coordinates of such blocks.

The most familiar type of existing equal area blocks is the division of the Earth's surface into 410 10° sections proposed in 1952 by ZHONOGOLOVICH (Buzuk, 1967). Another set of essentially equal area blocks has been used by KAULA (1966), who defined a set of 1654 300 n.m. squares. Such squares were essentially 5° equal area blocks.

In attempting to establish a unique group of equal area blocks for international use, several factors must be kept in mind. Such factors to be considered include the following :

1) The borders of the blocks must be easily defined or locatable.

2) The blocks should have approximately the same area.

3) A consistent system of computing the block coordinates for various size blocks should be available.

4) A mean anomaly in a larger block size should be obtained from the mean anomalies of smaller size blocks that fall solely within the larger block.

This paper considers the above factors in examining three forms of equal area blocks that may be suitable for mean anomaly evaluations. A basic premise of these discussions will be that the block must be bordered by meridians and parallels in such a fashion that all blocks are essentially equal area. In addition, the starting longitude for these blocks will be zero degrees Greenwich. Finally, all computations will be carried out for a unit sphere. Although these computations could be done for a reference ellipsoid, such a specification could unduly complicate matters at this time.

The choice of equal area block divisions depends on the weighting given to the advantages and disadvantages of each type of block division.

The subdivision of a 30° block has the advantage that the sub-blocks are established in such a way that the smaller blocks can be meaned to form larger size blocks (up to 30°). A disadvantage of this division is that there may be large numbers (up to 90) of blocks around the pole.

The subdivision of the Zhonogolovich 10° blocks yields a set of sub-blocks that can be meaned to form larger size blocks. The largest size that could be obtained is the original size, 10°, of the Zhonogolovich blocks. If larger blocks 15° or 30° blocks were desired, no unique conversion is possible. The number of blocks surrounding the pole is less than that found in the division of the 30° block but greater than that of the general block division described in section 2. In addition, the division of the Zhonogolovich blocks results in the fewest number of total blocks on the sphere within those types of divisions considered here.

If the largest size mean anomaly to be considered is 10°, the Zhonogolovich blocks and their subdivisions appear suitable as a standard set of blocks.

If the largest size mean anomaly to be considered is 15°, a division analogous to the Zhonogolovich blocks should be derived. The resulting 15° blocks can then be subdivided into equal area sub-blocks.

If the largest size mean anomaly to be considered is 30°, the division scheme described in section three appears appropriate".

Some remarks are made by the Delegates.

K. LAMBECK thinks the question of the choice of block does not appear to be very important provided the adopted choice is indicated by, for example, coordinates of some specified point in the block. It is a trivial matter with computers to convert gravity anomalies from one type of area mean to another. A much more important point is how to compute the area means.

J.J. LEVALLOIS soutient la proposition de R.H. RAPP et estime qu'un modèle commun agréé par tous rendrait les plus grands services en permettant une référence et un langage communs. Il préfèrerait personnellement dans la mesure où c'est possible, une subdivision qui permettrait un calcul d'anomalies dans des régions physiquement homogènes, mais ceci paraît utopique.

Il insiste donc sur l'extrême intérêt de cette proposition et souhaite la création d'un groupe spécial de travail chargé de la question. Ce groupe travaillerait en étroite liaison avec le Sp. St. Gr. chargé de l'étude des anomalies

Le voeu n°5 est alors adopté par la C.G.I. (voir Bull. Inf. n°24, p.I-30).

J.M. MONGET presents the new linear estimation method of G. MATHERON based on the concept of minimum variance :

"A new statistical treatment of gravity data"*.

"In gravimetry it is usual to split the gravity field into two components, a regional one due to deep-seated causes and a local one.

It seems to be interesting to use the same idea in the problems of interpolation and extrapolation of gravity in separating a deterministic component , which is often called a regional trend from a purely non-deterministic component (1), taking into account the local departures from the previous trend.

Presently the most widely used method in the adjustment of a polynomial trend P(u), consists in minimizing the sum of the square of the distances of the experimental data to the trend. Unfortunately, this method is optimal only when the residuals are truly uncorrelated.

G. MATHERON, professor of "Geostatistique" at the "Ecole des Mines de Paris" proposes a method based on the theory of non-stationary random functions that takes into account the correlation function between the residuals.

The stress is also laid on the structural use of the semi-variogram in the Earth Sciences. This new function is simply related to the well-known covariance function.

An illustrative application in automatic contouring is given".

-=-=-=-=-=-=-

* B.G.I., Paris, et Centre de Morphologie Mathématique, Ecole des Mines de Paris, Fontainebleau N-214, Dec. 1970.
(Not distributed at the Meeting).

(1) See Cramer and Leadbetter : Stationary and related stochastic processes, Wiley (1967), p.106.

VII - AIRBORNE GRAVITY MEASUREMENTS

One meeting was held on Thursday 10th September (9.15-10.45 a.m.) under the Chairmanship of O.W. WILLIAMS.

B. SZABO reports on "Results of AFCRL's experimental aerial gravity measurements". (B. SZABO & D. ANTHONY). *

"The AFCRL made aerial gravity measurements over selected areas of the United States in 1965 through 1968. The results given here are from a test area in the south-central United States (35° - 40°N, 97° - 102°W) where surface gravity measurements of very high density are available. Mean anomalies for areas as small as 2.'5 x 2.'5 were computed from the surface data and upward continued by Ohio State University using a form of the Poisson Integral equation (1). The error in the uplifted point values is about one milligal and the error of the mean value of a profile is negligible. Four gravimeters : the LaCoste and Romberg, Askania-Graf, Worden and PIGA-25 pendulous gyro accelerometer were used during different portions of the test program.

A total of 34 profiles possessing the required data were reduced in the southern test area. There are 14 west, 6 east, 9 north and 5 south profiles. These data were observed during the first two years of the test period using a KC-135 four engine jet aircraft. The LaCoste and Romberg was the only gravimeter that was used for all 34 profiles.

...

An adjustment of doppler radar, astrotracker, hypsometer, terrain clearance radar and aerial camera data was made to obtain the navigation data used for the Eötvös correction. An ellipsoïdal Eötvös correction was used.

...

The flight elevation for most aerial gravity measurements was about 8 kilometers. A vertical gradient of 0.3074 mgals/meter was used to reduce the flightline gravity values to a mean flight elevation.

* The full text will be published in Bull. Geod. n°100, June 1971.

(1) RAPP R.H. - "Upwards continued gravity in the Oklahoma area". Dept. Geod. Sci., Rep. n°56, Ohio State Univ., Oct. 1965.

For the problem of obtaining 5° and longer mean gravity anomalies, a simple averaging of the point anomalies of the flight profile may be made. To obtain the most representative profiles or 1° and smaller mean anomalies a smoothing of the point anomalies is required. The LaCoste and Romberg results for the 34 flightlines were smoothed using four different sets of weights :

1. Zero frequency cutoff (a)
2. 0.00295 Hertz cutoff (a)
3. Moritz least squares (b)
4. Moritz equal spectrum (b)

The first two methods for determining numerical filter weights to use on the measured gravity anomaly data is based on minimizing squared differences between true and measured values after filtering thereby producing the best separation of signal and noise in the least squares sense.

...

Many slides show the unsmoothed gravity anomalies for four profiles and smoothed anomalies according to each of the above methods.

...

The means of the 34 smoothed five degree LaCoste and Romberg profiles were larger than the uplifted means in 21 cases (62 %) and smaller in 13 cases (38 %). These 34 five degree profiles produce 561 different combinations of profile pairs. Profile pairs are used because the standard error of letting one central profile represent the mean anomaly of a 5° x 5° area is an unpermissible 13.4 milligals based on global covariance of gravity anomaly data. The standard error of representation for two optimally positioned profiles (d - 2d - d spacing) is a more permissible 6.4 milligals. The average error of a profile pair taken without regard to sign is 11.67 milligals. This average error converts to a standard error of 14.63 milligals. Combining this error with the global representation error of 6.4 milligals produces a total standard error of 15.96 milligals. For the southern test area the representation error is only about 0.2 milligals and the total error for the area remains 14.63 milligals. The errors for the 561 profile pairs contain a bias of + 6.49 milligals. Frey and Harlan (c) found a bias of + 6.25 milligals for 14 different five degrees profiles with the PIGA-25 and C-130 aircraft. They reported three possible sources, all additive, for the positive bias found.

(a) BEHANNON K.W. & N.F. NESS. - "The design of numerical filters for geomagnetic data analysis". NASA Technical Note TN D-3341, Washington, D.C., July 1966.

(b) MORITZ H. - "Optimum smoothing of aerial gravity measurements". AFCRM-67-0169, March 1967.

(c) FREY E.J. & R.B. HARLAN. - "Airborne gravimetry program". AFCRL-69-0316, March 1969.

The average error of the 10 five degree profile pairs that can be made from the 5 Askania-Graf profiles included in the 34 profiles processed is 12.94 mgal. The corresponding standard error is 16.22 mgal and the total error after combining with the 6.4 mgal global representation error is 17.44 mgal. The average error of the 23 one degree Askania-Graf profiles is 15.76 mgal and the corresponding standard error is 19.75 mgal.

The PIGA-25 results were not smoothed. Instead the five degree mean values were computed by averaging the value between chosen end points where zero vertical velocity was estimated based on examination of the PIGA output.

...

The average error of a profile pair based on the 120 pairs that can be made from the 14 profiles is 7.9 mgal and the corresponding standard error is 9.9 mgal. Combining with the 6.4 mgal representation error gives a total 5° x 5° error of 11.8 mgal.

The errors in the aerial gravity measurements most probably result from several sources. Navigation is undoubtedly a major error contributor. Estimates of the navigation accuracy achieved and the corresponding gravity errors are :

ground speed	± 1.3 knot	= 3 to 10 mgal
azimuth	± 0.3 degree	= 0 to 12 mgal
position	± 0.5 nautical mile	= 0 to 1 mgal
elevation	± feet	= 3 mgal

Simulation tests with the ART-57 stabilized platform show verticality errors of up to 5 minutes of arc that coupled with horizontal accelerations could cause errors in the mean gravity values of several mgal. Errors caused by nonlinearities in the gravimeters used are estimated to contribute an error of no more than one milligal. The errors of smoothing are estimated to be negligible because the four smoothing methods gave comparable results and the well surveyed test area permitted calculation of the power spectra of known as well as measured gravity anomalies for use in Moritz's smoothing methods. The 1° and 5° means from the four smoothing methods were not significantly different and errors with respect to the uplifted gravity anomalies did not indicate a preference for any one smoothing method. This result was anticipated by MEISSL (1) and makes the observing problem easier by not requiring that good estimates of the power and cross spectra of the real and measured gravity anomalies be known".

(1) MEISSL P. - "Probabilistic error analysis of airborne gravimetry". AFCRL-70-0396, June 1970.

M. WILLIAMS presents the paper :

"Navigation and altimetry systems for operational airborne gravimetry". *

by J.E. FREY & R.B. HARLAN.

"The specific questions addressed here are those of stabilization, navigation, altimetry, and filtering. Stabilization is required to align the sensitive axis of the gravimeter along some reference direction. Navigation is required to control the path of the aircraft, to locate the observations with respect to the Earth and to compute the normal gravity value which varies with latitude, and finally to compute horizontal velocities for use in the Eötvös correction. Altimetry involves the vertical coordinate in navigation and is required to control the aircraft path, to compute the normal gravity as a function of altitude, and finally to provide a means of separating the vertical accelerations from the gravity field in the gravimeter output. The last procedure is a filtering process which must be applied to gravimetric data collected on a moving vehicle. Even a static measurement requires some observation time ; in a moving vehicle the vertical accelerations during the period of observation affect the measurement very seriously, and altimetry is so closely involved with separating the accelerations from the gravity that the subjects of altimetry and filtering are considered together.

Stabilization

It is shown that errors due to stabilization can be kept negligible compared to other errors by use of an inertial navigation grade servo system and an 84 minute period platform. This eliminates the need for Brown corrections by elimination of coherent horizontal acceleration and angular motion.

Navigation

The most stringent horizontal navigation requirement arises in calculation of the Eötvös correction from aircraft velocity. The combination of an inertial navigation system with occasional position fixes produces a navigation system of adequate accuracy, except for the 84 minute period oscillations of the inertial navigator. These oscillations result both from imperfections in the inertial navigation system and from the effects of deflections of the vertical upon the navigation system.

* The full text will be published in Bull. Inf. B.G.I. n°26, June 1971.

A variety of position fixing radio and radar navigation systems are available (1). Short-range systems such as DME (Distance Measuring Equipment) are not suited for aerial gravimetry. Some of the hyperbolic systems such as LORAN-C/D have longer range coverage, but LORAN is limited to the North Atlantic and is excluded for this reason. This leaves two systems with world-wide possibilities ; the satellite navigation system TRANSIT (2) and the very low frequency system OMEGA (3).

...

Finally, the OMEGA Navigation system will offer a low coast and reasonably precise means of navigation, with world-wide capability when all eight planned transmitters are in use. Position fixes are available continuously, but the system accuracy is not as great as that of TRANSIT. The system operates at approximately 10 Khz and is subject to diurnal ionospheric variations which can introduce position errors of 10 or 15 kilometers. Compensation for the repeatable nature of these errors can reduce these errors to no more than 3 kilometers, with root mean square values somewhat lower and dependent on the time of day and the geometry of transmitting station and aircraft location. This performance, coupled with the continuous availability of position fixes, makes OMEGA a useful adjunct to TRANSIT by permitting flight planning without consideration of the availability of good TRANSIT fixes.

In summary, an eminently suitable navigation system for aerial gravimetry would consist of an inertial navigation to provide velocity and position information for use to control the aircraft in flight, and three auxiliary radio systems for post flight data reduction purposes : doppler radar to reduce the 84 minute oscillations in the inertial navigation velocity data, and TRANSIT and OMEGA to correct the position and the mean velocity errors of the inertial data. With suitable experience, it would be possible to eliminate either the doppler or one of the position fixing systems without reducing the accuracy of gravity determination

Altimetry

A radar altimeter currently offers the best results, particularly for sea use. Over land the terrain clearance value furnished by the radar is of limited use, and barometric altimetry must be combined with occasional radar fixes over points of known altitude. Lakes offer particularly good choices for such points, since the radar return is clear ;however, the altitude of the lake surface must be known. Errors due to altimetry are discussed for both overland and sea flights.

(1) KAYTON M. & W. FRIED. - "Avionics navigation systems". Wiley, New York, 1969.

(2) STANSELL T.A. Jr. - "The navy navigation satellite system : description and status". J. Inst. Nav., 15(3), 1968.

(3) SWANSON E.R. & M.L. TIBBALS. - "The Omega navigation system". J. Inst. Nav. 12(1), 1965.

Simulation and error analysis

The following Table shows r.m.s. values and correlation times and distances used. The gravity anomaly correlation function is assumed to be exponential in form (4) with mean square value of 1000 $mgal^2$ and two different values of correlation distance, 22 and 110 kilometers (corresponding to correlation times of 91 and 455 seconds for the aircraft speed assumed).

Error study statistics

Phenomenon	r.m.s. value	correlation time or distance
radar altimeter error	0, .06, .05, .3, 1.0 m	negligible
isobar undulation	120 m	4300 sec. (860 km)
sea state	0	
gravimeter error	0, 10 mgal	negligible
gravity anomaly	31 mgal	22, 110 km

The author presents also some results of the study, in the form of root mean square errors in estimation of gravity anomaly (E_{GA}), altitude (E_h), and vertical velocity ($E_{\dot{h}}$) derived from the error covariance matrix for the Kalman estimator. In addition the time(T) required for the error in estimating the gravity anomaly to reach within 0.1 mgal of its final value is shown. A sampling interval of one second was used in the study".

J.A. KOZLOSKY reports on :

"Helicopter gravity measuring system". ✱

W.R. GUMERT & G.E. COBB

and shows many slides.

"After three follow-on tests and careful selection of instrumentation, an efficient integrated Helicopter Gravity Measuring System (HGMS) was constructed and tested under a variety of operating conditions. The HGMS consists of a LaCoste & Romberg stable-platform gravity meter, a Spectra-Physics laser altimeter, a Rosemont pressure port calibrator, a 35 mm strip camera or Bendix infrared scanner, a HIRAN navigation system, a Lancer digital data logger, and the necessary interface and analog recording monitors.

(4) KAULA W.M. - "Statistical and harmonic analysis of gravity". Army Map Service, Technical Report n°24, March 1959.

✱ distributed at the Meeting.

This system was installed in November 1968, by Aero Service Corporation under the direction of the U.S. Army Topographic Command (TOPOCOM), in a U.S. Air Force CH3E helicopter. The vehicle flew over a gravity test range set up in the Maryland, Virginia, Deleware area, bounded roughly by 67°W to 70°W and 37°N to 39°N. In this area are several large gravity features, varying terrains, and well-controlled sea and land data for evaluation purposes. Approximately 100 flight hours were performed over a 2 1/2 month period. Three blocks of data were given concentrated attention - rolling terrain, a continental slope area, and a rugged region in the Appalachians around Luray Caverns.

Results of the test indicate that accurate gravity measurements can be made in this manner by careful survey procedures and effective data handling. Gravity values sufficiently accurate for geodetic purposes may become routinely possible with this system.

...

Particularly, it is pointed out that :

"Tests of the gravity meter in the hover mode, using a UHID helicopter, show that 3 to 6 stations can be measured in one hour with an accuracy of better than one milligal. These trials were performed at Fort Belvoir in March 1969. The helicopter would hover in ground effect, 5 to 15 feet above the ground or water.

Elevation changes were monitored by the pressure port calibrator and were negligible. Several sites were reoccupied in this manner and the one-milligal accuracy cas determined. The only problem encountered on this test was that vibration affected the meter during the first day. Adequate shock mounts were installed and the instability disappeared. Profiles were attempted, but with no auto-pilot, it was impossible to control the vertical variations of the helicopter".

IX - SECULAR VARIATION OF GRAVITY

One meeting was held on Friday 11th September (11.15-12.30 a.m.), under the Chairmanship of Dr. G. BARTA.

He comments his report "On the hypothesis of the secular variation of gravity field". *

"If we don't consider the tidal effects as causing variations of the gravitational field, those can be produced by :

1) variation of the gravitational constant,
2) alteration of the Earth's dimensions and mass,
3) redistributions of masses in the proximity of the surface. Those can be :

   a - meteorological motions (circulation of air masses, precipitation, motions of eroded masses, accumulation, melting or motion of glaciers and ice covers, etc.)

   b - geological motions (earthquakes, volcanic eruptions, sedimentation, compaction, motions of the Earth's crust, slow currents of magma, etc.),

4) general variation of the mass distribution of the Earth.

The variations mentioned under 1) and 2) (if they are existing), acting even collectively do not cause 1 μgal variation in a year.

Because its character, this variation could not be demonstrated but by absolute measurements. At the present, their investigation by measurements, in thus hopeless.

Group 3) of the phenomena can cause already variations of greater order in g and so, it can be demonstrated by relative measurements. But those variations have a local character ; they can last through a short period or even geological ages, they have no secular character or at least it is hardly recognizable.

To group 4) are belonging the redistributions of masses which can take place mainly in the core and eventually in the deep mantle. The arising variations - owing to the plasmatic state of the outer core - may have secular character. In some geophysical phenomena there is noticeable a slow undirectional change what can indicate processes of great inertia in connection with unidirectional motions of big masses.

The great-sized secular variation of the geomagnetic fields, known long ago, has been interpreted by convectional currents which are connected with mass transfer taking place in the Earth's plasmatic core".

* distributed at the Meeting.

But naturally, from the considerable and relatively fairly known magnetic variation we have to conclude also to secular variations of other geophysical phenomena.

Afterwards G. BARTA points out that the inhomogeneity and asymmetry of the Earth's body can be directly observed on the surface. Particularly, he says that the greatest anomaly of the geoid falls just into the direction of the magnetic eccentricity (about 450 km towards Australia) and in the case of causal connection of the two phenomena we may conclude to the secular variation of gravity field and geoid figure.

It is of crucial importance to determine some way the depth of the factors causing the anomalies of the geoid.

Supposed that the anomalies change their place with the speed of the magnetic dipole, we can empirically deduce the maximum of the variation of the gravity field too.

Making computations over the equatorial cross-section of the "Smithsonian Standard Earth 1966" geoid we found some surprising symmetries.

Weighing that we searched for the solution in a way that we approximated to the equatorial section of the geoid starting simultaneously from two directions with zonal spherical functions. After several trials we started from directions $\lambda_0 = 70°$ and $\lambda_1 = 140°$E.G. with a fifth order spherical function and received that the approximating and approximated curves are running surprisingly identical around the whole Earth and the greatest deviations even exceptionally do not reach 20 m.

Thus, the more or less complicated equatorial geoid section can be constructed as the sum of two mathematically strict symmetrical pictures of anomalies. From that we can conclude that probably the equatorial geoid anomalies on the territories of the East Pacific, South America, Atlantic and Africa take their origin from the superposition of the opposites of Indian and Australian main anomalies and so they have no own backgrounds of mass - or energy - inhomogeneity.

In conclusion, it is to be seen that starting from the surface ever deeper asymmetries and inhomogeneities are recognizable in the Earth's interior. To the deepest inhomogeneity - seated probably in the core - our attention is called by the permanent geomagnetic field.

With its big mass and plasmatic state, the Earth's core can play essential part in the Earth's processes, and can affect also the formation of the surface, and so, tectonic motions, too. It appears that the observational matter, which has been collected by various scientific sections over the general inhomogeneity of the Earth's body and its secular variations, respectively, makes already possible the comprehensive, complex researches in this range.

But the specialists, working on their own themes, are carrying out their researches rather isolated from each other, this is why it would be desirable to bring into existence an interdisciplinary and international working group in order to investigate uniformly and systematically the material and energetic inhomogeneity of the Earth's body".

J.D. BOULANGER presents the paper :
"On secular changes of gravity". ✱
J.D. BOULANGER & S.N. SCHEGLOV.

Particularly, he says that the new Gravimetrical Laboratory of the Academy of Sciences of U.S.S.R. has made new equipment to obtain an accuracy of measurements to tenth parts of mgal.

In 1954-1955 the authors had the possibility to accomplish highly accurate relative determinations of gravity along the parallel between Riga and Petropavlovsk-on-Kamchatka, and also in some points in the Middle Asia and in the Caucasus. The points were located both in seismoactive regions and in aseismic ones. The measurements were carried out by the GAE-3 gravitymeter of original construction.

In 1965-1967 these measurements were repeated by the instruments of the same type, but with higher accuracy, the GAG-1 and GAG-2 gravitymeters. In the second case, as in the first, the measurements were conducted by the method of group (7-9 gravitymeters) repeated (3-5 measurements).

The comparisons of the values shows that the "change" of gravity only in Moscow is somewhat greater than the error of this measurement.

According to the complex of all accomplished determinations we can thus state that on the territory of the Soviet Union in relation to Potsdam, the gravity field from 1955 till 1967 was constant with the accuracy $\pm$ 0.13 mgal.

In case we assume that the gravity field changes linearily then its changes do not exceed 0.01 mgal per year.

The obtained results did not confirm, therefore, the theoretical calculations based on the Barta hypothesis".

✱ distributed at the Meeting.

Some Delegates make remarks concerning the accuracy of gravity measurements.

Particularly, M. BONATZ says :

"The problem of measuring secular variations of gravity become the more difficult and delicate the smaller the amounts of variations are. As long as one does not know the influence of microseism on the beam-positions of the gravitymeters it can not be neglected that perhaps the measured values are disturbed by microseism and secular variations of microseism. As I have observed with horizontal pendulums and recording gravity meters the microseismic amplitudes can reach 1 mgal, so one can expect a cross-coupling effect, because the situation is principally the same as with sea gravitymeters, that is measuring on a non-stable underground. Measuring in the 10^{-2} mgal range the influence of microseism seems not to be so important but, as the discussions have shown that one starts to reach a new order of magnitude in gravimeter measurements, the µgal range, one must start to look after new possible disturbing effects. µgal range means a stability of the counterforces of the gravimeter within 10^{-9}, 0,1 µgal range 10^{-10}, and when we look that in measurements of absolute value of gravity the influence of microseism was taken into account (accuracy 10^{-7} to 10^{-8}) it is obvious that also in relative measurement one must be the more careful against distrubing effects the higher the wanted accuracy becomes, and in addition, one must look after physical principles which can be applied to gravimeters to get better information about the really achieved accuracy (until now all gravitymeters are spring-meters, applications of classical mechanics).

In any case we must not make the Earth responsible for effects which in reality are errors in our instruments".

K. HOFFERT points out that the Askania is basically working on the problem of electrostatic force compensation substituting the spring (Feder) in gravimeters. A fundamental problem up to now is to get voltage stabilization which allow measurements of 10^{-9} or better over a long period".

-=-=-=-=-=-=-=-

X - VARIOUS ITEMS

We indicate hereafter some other papers which were distributed at the Meeting.

"A long pipe tiltmeter", J. KÄÄRIÄINEN

Abstract in Bull. Inf. n°23, p.I-15.

"Gravimetric terrain corrections", S. CORON, B.G.I., 1970.

Bibliography concerning the most important publications on the different procedures for calculating terrain corrections with electronic computers.

Commission Cassinis, Association Internationale de Géodésie

Minutes of the Meeting held in London, April 1970, concerning mainly :

- the study of the structures of the I.A.G. and namely to define the numbers and the content of the Sections, the outlines of their areas of interest, the junctions with the Commissions, the structure of the Study Groups ;

- the proposals for adequate modifications to by laws, and so on ...

-=-=-=-=-=-=-

B

MESURES EN MER

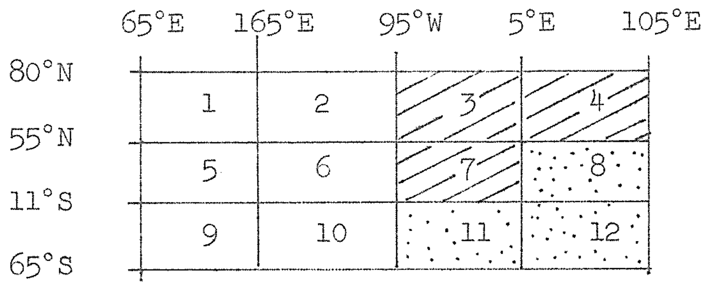
I - CARTES DES TRAJETS N°8 - 11 - 12

A la Commission Gravimétrique Internationale de Septembre 1970, le B.G.I. a présenté la collection de 12 Cartes Mondiales sur lesquelles sont reportés les profils de pesanteur en mer.

Les cartes n°3, 4, 7 (format réduit) ont déjà été publiées dans le Bull. Inf. n°22, Mars 1970. Ces cartes concernent l'Atlantique Nord et Centre.

Les cartes n°8, 11, 12 sont insérées à la fin de ce Bulletin ; elles concernent l'Atlantique Sud, la mer Méditerranée et l'Ouest de l'Océan Indien.

Tableau d'assemblage



Les pages suivantes donnent un tableau récapitulatif qui permet d'identifier le tracé des profils gravimétriques, l'organisme qui les a effectués et la source d'information.

C O N T I N E N T A L   S E A S

Region of gravity traverse	Organization	Reference
Black Sea	W.H.O.I., U.S.A. [long-dash line]	BOWIN, Atlantis II, Medoc 69 Snd leg of Atlantis II 49 (Bull. Inf. 20, p.I-17)
Mediterranean Sea	CNEXO, France [short-dash line]	CHO.1 (Bull.Inf.20, p.I-19)
	Univ. Cambridge, G.B. [dash-dot line]	RRS Discovery Cruise 16, January - May 1967
	Oss.Geof.Sp., Italy [hatched area]	Boll.Geof.Spe., v.X, n°32, Juin 1968 and v.XII & XIII
	Lamont D.Geol.Obs., U.S.A. [solid line]	TALWANI, Conrad Cruise 9 (Bull.Inf.16, p.II-8 & 13)
	W.H.O.I., U.S.A. [long-dash line]	BOWIN, Atlantis II, Medoc 69 (Bull.Inf.20, p.I-17)
Red Sea	Oss.Geof.Sp., Italy B.f.B., Hannovre, All. D.H.I., Hamburg, All. [line with tick marks]	"Concrete Cruise" 1961 Saclant ASW Res. Center, La Spezia Bull.Inf.14, p.I-43 " " 22, p.I-15-24 " " 24, p.II-12
	Oss.Geof.Sp., Italy [hatched area]	Boll.Geof., v.XIII
	Univ. Cambridge, G.B. [long-dash line]	R.R.S. Discovery Cruise 16, May 1967
	Lamont D.Geol.Obs., U.S.A. [solid line]	TALWANI (Bull.Inf.22, p.I-19)
	W.H.O.I., U.S.A. [long-dash line]	BOWIN (Bull.Inf.20, p.I-18)
Red Sea and Persian Gulf	B.f.B., Hannovre [dash-dotted line]	PLAUMANN, information received in July 1970.

SOUTH ATLANTIC OCEAN

Region of gravity traverse	Organization	Reference
Rio de la Plata	Fac.Ingen.Inst.Geod., Argentine	1962-69 (Bull.Inf.22,p.I-15)
S. Atlantic Ocean	Univ.Birmingham, G.B.	1965-1966 HMS, HECLA 1966 PROTECTOR 1967
Seychelles to S.Am.	Tokyo Univ., Japan	(Bull.Inf.22, p.I-24)
S. Atlantic Ocean	Lamont D.Geol.Obs., U.S.A.	TALWANI, cartes 1969
	Akad.Sc.URSS, URSS	BOULANGER, 1969.
PACIFIC OCEAN		
E. Pacific	Lamont D.Geol.Obs., U.S.A.	TALWANI, 26.11.69 (Bull.Inf.22, p.I-19)

INDIAN OCEAN

Region of gravity traverse	Organization	Reference
Arabian Sea	Univ. Cambridge, G.B. Hydro. Dept., G.B. —·—·—·—·—·	1962-1963 HMS, OWEN, 1962 to 1963
	Lamont D.Geol.Obs., U.S.A. ————	R/V ARGO, 1962-1963
W. Australia to S. Africa	Lamont D.Geol.Obs., U.S.A. ————	TALWANI, Cartes 1969 MONSOON, 1960 LUSIAD, 1962-1963 ARGO, 1962-1963
W. Australia to I. Kergulen to S. America	Tokyo Univ., Japan —/—/—/—/—/—	(Bull. Inf.22, p.I-24)
Off S. Africa Agulhas Bank Area	Bern.Price.Inst., U.S. Africa —\\—\\—\\—\\—	(Bull. Inf.22, p.I-19)

Points pendulaires

- ○ VENING MEINESZ (Pays-Bas)
- ⊙ Cambridge University (G.B.)
- ● WORZEL, Columbia University (U.S.A.)

II - NOUVELLES INFORMATIONS
depuis le Bulletin d'Information n°23

RECTIFICATIF

Carte n°7

There was an "omission of our Bay of Fundy survey area and the addition of three survey lines completed during 1970 (BAFFIN 02-70)".

Canada, R.T. HAWORTH, July 1970.

"Regional gravity coverage of the Gulf of St-Lawrence is now complete ; lakes Erie and Ontario have been completely covered with stations at 10 - 15 km intervals".

Canada, M.J.S. INNES, Aug. 1970.

"There are a great number of deviations between mapped lines and actual tracks" modifications will be made on the future issue of map 7.

"Do not use the reprint "Die Atlantische Expedition 1965 mit dem Forschungsschiff METEOR", this paper contains also tracks on which no gravity measurements were made at all".

Allemagne, U. FLEISCHER,
July and October 1970.

ADDITIF

Carte n°8

"Sur la carte n°8 est indiquée l'aire au Sud du 55ème parallèle mesurée en été 1970".

Danemark, E. ANDERSEN, July 1970.

Carte n°11

On signale la zone des nouveaux travaux gravimétriques sur la plateforme sous-marine Atlantique de la mer de la Plata.

Argentine, E.E. BAGLIETTO, July 1970.

Carte n°3

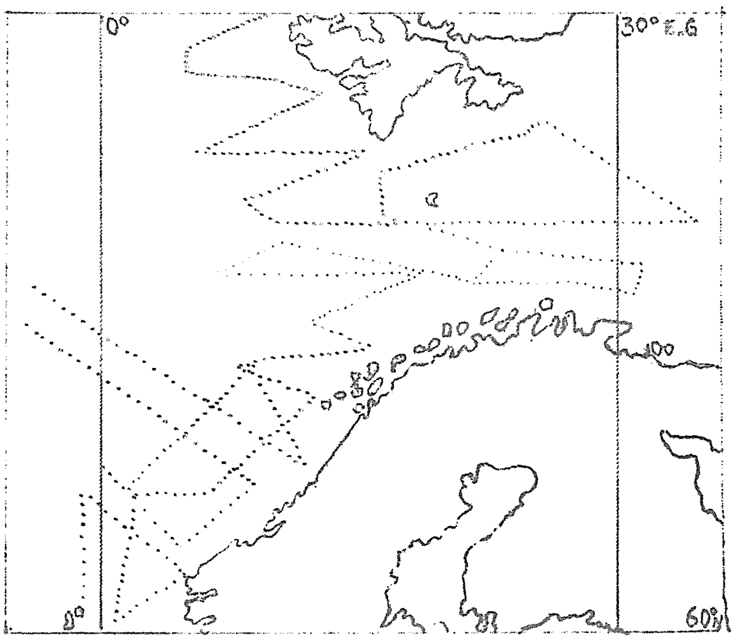
"Campagne NESTLANTE II de 2 mois et demi en Mer de Norvège, 19 Août au 31 Octobre 1970".

Les principaux objectifs scientifiques de la campagne sont :

- L'étude des éventuels bassins sédimentaires du plateau continental.
- L'étude des anomalies gravimétriques associées au bord du plateau.
- L'étude du passage marge continentale, bassin océanique.

Les techniques maintenant classiques de mesure "en route" permettent de recueillir des informations sismiques magnétiques et gravimétriques sur plus de 10.000 km ".

France, Bull. 21, CNEXO, Sept. 1970.



Campagne NORATLANTE

LISTE DES PUBLICATIONS

reçues au

BUREAU GRAVIMETRIQUE INTERNATIONAL

(Juillet à Septembre 1970)

CONCERNANT LES QUESTIONS DE PESANTEUR

LISTE DES PUBLICATIONS

* 121 - Professor Dr. Ing. H. WOLF zum 60. Geburtstag, Bonn, 1970.

a) GOTTSCHALK H.J. - "Das lokale Verhalten des vertikalen Schweregradienten".
S.33-39.
"It is shown that local variance of the vertical gravity gradient is so large that even for small regions it is impossible to reduce gravity values using the mean gradient value of the region. In a test area differences between gradient values up to |36 mGal/km| are found for points of 5 meters horizontal distance".

b) GRAFAREND E. - "Fehlertheoretische Unschärferelation".
S.40-54.
"The confidence intervals of NEYMAN are used to find mean value and variance of parent population from sample values. In order to determine them it is necessary to give probability with which the unknown statistics do not occur in the interval. It is shown that in principle it is not possible to minimize both the number of observations and the confidence interval when probability is given or both the probability and the confidence interval when the number of observations is given. It is more meaningful therefore to use the term uncertainty coefficient for probability or instead of complementary probability the term confidence coefficient and to formulate an uncertainty relation between uncertainty coefficient, confidence interval and number of observations. With the given uncertainty coefficient for the uncertainty relation there is a smallest value which is finite and positive. This smallest value is defined as an error constant and calculated. Examples are discussed".

c) KOCH K.R. - "Eine Bestimmung des Schwerefeldes der Erde aus Satellitenbeobachtungen und Schweremessungen".
S.82-93.
"Optical satellite observations and gravity anomalies are combined to computed 192 density values of the potential of a simple layer used to represent the gravitational potential of the Earth. From the density values harmonic coefficients are computed up to the 15th degree and order. The resulting geoid is compared with existing satellite and combined solutions for the geopotential".

* Les numéros font suite à ceux indiqués dans le Bull. Inf. n°24, Nov. 1970.

d) SCHUSTER O. - "Erdgezeiten - Registrierung auf Spitzbergen". S.121-132.

"On the occasion of a short abstract of earth-tide research at the Institut für Theoretische Geodäsie in Bonn earth-tide recording in the arctic region are covered upon".

e) WITTE B. - "Die Berechnung des Vertikalgradienten der Schwere im Aussenraum". S.133-142.

"The extended STOKES' formula is used to derive a method for the computation of the vertical gravity gradient in the external field of the moon or the earth. For the purpose of comparison the first derivative of POISSON's integral is also used to express external vertical gradients. In order to check both formulas a sphere is used as a model for the numerical computations. The effect of the heights above the surface and the influence of the distant zones on the results are investigated".

122 - BULLETIN GEODESIQUE de l'ASSOCIATION INTERNATIONALE de GEODESIE, n°95, 1970.

a) A.I.G. - Symposium on Physical Geodesy, September 22 - 28, 1969., Prague, Czechoslovakia, p.9-14.

b) U.G.G.I. - VIème Symposium International sur les marées terrestres, Strasbourg, 15 - 20 Septembre 1969, p.15-20.

c) KUBIK K. - "The estimation of the weights of measured quantities within the method of least squares". p.21-40.

"This paper proposes an extension of the familiar method of least squares : for in addition to the more commonly computed unknowns, the variances of the original measurements and the relationships between these variances are estimated in this method...".

d) GRAFAREND E. - "Fehlertheoretische Maxwell-Boltzmann-Verteilung". p.41-49.

"The probability to find an error vector in multiples of the Helmert-Maxwell-Boltzmann point error $\sigma^2 \delta_{ij}$ (δ_{ij} Kronecker symbol) is calculated. It is found that the probability is for σ 39%, for 2 σ 86% and for 3 σ 99% in two dimensions, for σ 20%, for 2 σ 74%

and for 3σ 97% in three dimensions. The fundamental Maxwell - Boltzmann - distribution is tabulated 0,02 (0,02) 4,50".

e) BENNETT G.G. - "The least squares adjustment of a lightly damped simple harmonic motion".
p.51-69.

"The centre of oscillation of a lightly damped simple harmonic motion as derived from a number of successive observations made in the region of either the maximum or minimum velocity of the motion has been investigated by many writers. A rigorous solution of this problem does not present any difficulty now that the high speed electronic computer is generally available. However, it is of practical advantage to consider alternative approximate solutions when observations must be assessed under field conditions and sophisticated computational aids are not available. It is the purpose of this paper to show that these latter calculations can be made quickly using simple arithmetic operations on small numbers, whilst at the same time preserving accuracy and rigour in a least squares adjustment process. Examples are given which illustrate the technique for observations made at the extreme positions or near the centre of the oscillation".

123 - <u>BULLETIN GEODESIQUE de l'ASSOCIATION INTERNATIONALE de GEODESIE</u>, n°96, 1970.

a) TROMBETTI C. - Notice nécrologique : Prof. P. DORE (1892-1969).
p.97-98.

b) GROTEN E. - "On the spherical harmonics series expansion of the geopotential".
p.169-181.

"The spherical harmonics development of the gravitational potential at the earth's surface and on the geoid is discussed. First, the effect of Kelvin transformations is studied; secondly, numerical information as obtained from satellite and other data is investigated".

c) MORITZ H. - "A new series solution of Molodensky's problem".
p.183-195.

"On déduit une série qui donne une solution complète du problème de Molodensky, en utilisant, au lieu d'une équation intégrale, la continuation analytique par une série de puissances. Il s'ensuit que cette solution est équivalente à la série de Molodensky-Brovar, mais elle est plus simple et plus pratique".

124 - BURSA M. - "Sur certaines relations entre les paramètres de l'ellipsoïde terrestre et le champ de gravité, en particulier par rapport au Système de Référence A.I.G. 1967".
Bull. Géod. A.I.G., n°97, p.261-290, 1970.

"Par ce complément nous avons seulement voulu montrer (nullement en contradiction avec la résolution de l'A.I.G.) que si dans l'avenir, il apparaît nécessaire d'introduire pour les besoins de la dynamique des satellites, un champ de pesanteur normal tel qu'il puisse mieux remplacer le champ réel, que c'est possible (même sans changements de paramètres déjà adoptés a, J_2, ω, GM) sans que les problèmes purement géodésiques (détermination des hauteurs du géoïde et des déviations de la verticale par rapport à l'ellipsoïde, détermination de la pesanteur normale et des anomalies de pesanteur etc...) subissent un accroissement de complications plus graves".

125 - DUCARME B. - "La gravimétrie à l'Observatoire Royal de Belgique".
Obs. Roy. Belgique, Comm. Ser. B, n°51, Ser. Geophys. n°97, 18 p.
from : Ciel & Terre, v.LXXXVI, n°2, Bruxelles, 1970.

"The Earth's gravity field is examined according to three main topics : absolute measurements, variations at the surface and periodic changes of g under the action of the Sun and of the Moon. These gravimetric tides are studied at the Royal Observatory of Belgium since the I.G.Y. in connection with the internal constitution of the Earth".

126 - MELCHIOR P., M. BONATZ & J. BLANKENBURGH. - "Astro-geo project Spitsbergen 1968-1970".
Obs. Roy. Belgique, Comm., Ser. B, n°52, Ser. Geophys. n°98, 15 p, from : Ciel & Terre, v.LXXXVI, n°2, Bruxelles, 1970.

"The aims endeavoured to obtain by this mission are : the study of the characteristics of the Earth tides in the neighbourhood of the North pole, the slow movements of the Earth's crust and an attempt to make a junction of this region to Europe by satellite triangulation".

127 - The Geophysical Journal of the Royal Astronomical Society, v.19, n°5, 1970.

a) LAMBERT A. - "The response of the Earth to loading by the Ocean tides around Nova Scotia".
p.449-477.

"The tidal loading effects on gravity and tilt caused by the large amplitude tides in the Bay of Fundy have been separated from the effects of the tides in the larger scale Gulf of St Lawrence and the North Atlantic Ocean".

b) SEARLE R.C. - "A catalogue of gravity data from Kenya".
p.543-545.

128 - McQUILLIN R. & M. BROOKS. - "Geophysical surveys in the Shetland Islands".
Inst. Geol. Sci., Geophys Paper n°2, 22 p, London, 1967.

"The results of regional gravity and magnetic surveys made during 1961-1962 over the entire Shetland group of islands, including Fair Isle and Foula, are presented as Bouguer gravity anomaly and total force magnetic anomaly maps and profiles. Supplementary data from a few short detailed traverses and rock density measurements are also presented and discussed.

Within a complex pattern of gravity anomalies, Bouguer values range from + 2.0 to + 46.9 mgal. Several large magnetic anomalies were discovered, particularly strong gradients being recorded over the central fault zone of Unst. In some districts the geophysical results can be correlated with mapped geology, but in other places some prominent anomaly features must relate to structures not manifest at the surface and, to account for these, new geological interpretations are advanced".

129 - McQUILLIN R. - "Geophysical surveys in the Orkney Islands".
Inst. Geol. Sci., Geophys. Paper n°4, 18 p, London, 1968.

"Regional gravity and ground magnetic surveys over the Orkney Islands and Sule Skerry were made during 1963 and the results are presented as Bouguer anomaly and total-force magnetic anomaly maps with appropriate profiles. Tests were made on rock samples to determine density, porosity, seismic velocity and magnetic susceptibility values.

Bouguer gravity values range between + 20 and + 40 mgal. The pattern of anomalies is simply related to mapped surface geology. Gravity interpretations provide data on the depth to the base of the Upper Old Red Sandstone beds in Hoy, and on structural relationships between Eday Beds and underlying Rousay and Stromness

Beds in the Middle Old Red Sandstone. Prominent gravity anomalies occur over the Eday Syncline and around Scapa Flow.

The magnetic and gravity results are used to interpret an easterly trend of increasing thickness in the Old Red Sandstone across the islands. Some areas of intense local magnetic anomalies are due to igneous intrusive and extrusive rock bodies, and detailed traverses were surveyed over a number of these".

131 - COLLIGNON F. - "Carte gravimétrique du Gabon".
Echelle : 1/1.000.000°, densité : 2,67,
O.R.S.T.O.M., Bangui, 1970.

132 - COLLIGNON F. - "Gravimétrie de reconnaissance : CAMEROUN".
O.R.S.T.O.M., 37 p, 1968.

1°) Données gravimétriques
2°) Anomalies de la pesanteur
- Anomalie de Bouguer totale
- Précision des résultats
- Vue d'ensemble sur la carte gravimétrique.
3°) Etudes régionales
- Les bassins de Douala, Campo et la bordure littorale
- La région montagneuse de l'Ouest
- Le Sud Cameroun
- Le Cameroun Central
- Le Nord Cameroun.

133 - COLLIGNON F. - "Contribution géophysique à l'étude du Bassin de la Bénoué".
O.R.S.T.O.M., 31 p, 1969.

1°) Aperçu géologique
2°) Les sondages mécaniques
3°) Les sondages éléctriques
- Rappel de quelques propriétés des terrains homogènes et isotropes. Applications.
- Essais d'étalonnage
- Etude régionale
4°) La gravimétrie
- Carte de l'anomalie de Bouguer
- Coupe Tchéboa - Kalgué - Pitoa
- Failles de Pitoa et Boumedje.

134 - COLLIGNON F. - "Rapport sur quelques profils gravimétriques et magnétiques dans la Vallée de la M'Béré".
O.R.S.T.O.M., 26 p, 1970.

1°) Gravimétrie
- Anomalie de Bouguer
- Anomalie isostatique
- Construction d'un modèle et anomalie correspondante.

2°) Magnétisme
- Méthode utilisée
- Résultats.

137 - MORITZ H. - "Non-linear solutions of the geodetic boundary value problem".
AFCRL-69-0528, Rep. n°126, Sci. Rep. n°2, 55 p, Columbus, 1969.

"A complete series solution of Molodensky's boundary value problem is derived using, instead of an integral equation, analytical continuation by means of power series. This solution is shown to be equivalent, term by term, to the Molodensky-Brovar series, but is simpler and practically more convenient. This equivalence gives a physical explanation of the divergence of the Molodensky series. The exclusion of topographic masses to improve convergence is discussed, and computational formulas for height anomalies and deflections of the vertical are given.

In the appendix, structural similarities between the series of celestial mechanics and of physical geodesy are used to get an insight into the convergence behavior of these series. Another argument for the divergence of series of Molodensky type is given".

138 - MORITZ H. - "Least-squares estimation in physical geodesy".
AFCRL-70-0202, Rep. n°130, Sci. Rep. n°4, 51 p, Columbus, 1970.

"A powerful and simple least-squares estimation method for the gravitational field, due to T. KRARUP, is presented and applied to such different problems in physical geodesy as the geodetic boundary-value problem according to A. Bjerhammar, the application of aerial gravimetry, the geodetic use of gradiometer measurements, and the combination of gravimetry with satellite harmonics and with astro-geodetic data".

The algorithm is formally identical to that of usual least-squares gravity estimation ; it is only necessary to interpret the covariances in a different way. The data may be errorless or affected by observational errors".

139 - RAPP R.H. - "Methods for the computation of geoid undulations from potential coefficients".
AFCRL-70-0281, Rep. n°132, Sci. Rep. n°5, 15 p, Columbus, 1970.

"The undulations of the geoid may be computed from spherical harmonic potential coefficients of the Earth's gravitational field. This report examines three procedures that reflect various points of view on how this computation should be carried out. One method requires only the flattening of a reference ellipsoid to be defined while the other two methods require a complete definition of the parameters of the ellipsoid It was found that the various methods gave essentially the same undulations, provided that correct parameters were chosen for the reference ellipsoid. A discussion is given on how these parameters are chosen and numerical results are reported using recent potential coefficient determinations".

140 - MORITZ H. - "Eine allgemeine Theorie der Verarbeitung von Schweremessungen nach kleinsten Quadraten".
D.G.K., Reihe A : Höhere Geod., H.n°67, 56 S, München, 1970.

142 - AL-SHAIKH Z.D. - "The geological structure of part of the Central Irish Sea".
Geophys J., R. Astr. Soc., v.20, n°2, p.233-237, 1970.

"Gravity measurements in the eastern part of the Central Irish Sea show two gravity "lows" with a Caledonoid direction. These "lows" are interpreted as sedimentary basins with a fill of possible Carboniferous and Triassic age".

145 - <u>The Geophysical Journal of the Royal Astronomical Society</u>, v.20, n°5, 1970.

a) ARKANI J.H. - "Lateral variations of density in the mantle". p.431-455.

"The lateral variations of the Earth's gravitational field, deduced from orbital data of artificial satellites, indicate the existence of lateral density variations within the Earth. A density model is computed for the mantle with the following constraints :
1 - The model presents perturbations to Gutenberg's earth model which are specified by spherical harmonics through the sixth order and degree.
2 - The density anomalies are confined to the mantle and the crust.

3 - The anomalies of the crust are determined for $n = 2, \ldots 6$ and $m = 0, \ldots n$ from crustal thickness, crustal P wave velocity, and P_n velocity, and those of the upper mantle for $n = 2$ and 3 and $m = 0, \ldots, n$ are related to the lateral variations of seismic travel-time residuals.
4 - The unknown density anomalies of the mantle are determined such that the total shear strain energy of the Earth is a minimum.
5 - The gravitational potential of the deformed Earth (subject to the density anomalies) on its surface equals the first six orders of the spherical harmonic representation of the measured geopotential and ;
6 - An isotropic, elastic, and cold mantle, and a liquid core are assumed in the stress analysis.

The density anomalies thus obtained exhibit a decreasing feature with depth. In the crust they are of the order of 0.3g cm^{-3}, in the upper mantle 0.1 g cm^{-3}, and in the lower mantle 0.04 g cm^{-3}, which are within the values deduced from independent seismic measurements.

The lateral variations of the associated stress differences at shallow depths correlate with the surface feature of the Earth. This correlation disappears in the deep mantle".

b) KEEN C. & C. TRAMONTINI. - "A seismic refraction survey on the Mid-Atlantic Ridge".
p.473-491.

"A detailed seismic refraction experiment has been performed on the Mid-Atlantic ridge near the median valley at 45°N, using two ships and anchored sono-radio buoys. Both the slope-intercept and the time-term methods were used to interpret the data. The time-term analysis indicated a continuous M discontinuity at a mean depth of 7.5 km with a mean velocity of 7.9 km s^{-1} for the underlying material. This result was substantiated by the time-distance plots with the exception of the line of shots nearest the median valley which gave a velocity of 7.5 km s^{-1}. Evidence for anisotropy of the 7.9 km s^{-1} material was found, the velocity deviation being $\pm$ 0.25 km s^{-1} and the azimuth of maximum velocity, 080°. Two crustal layers, the upper having velocities in the range 3.5 to 5.4 km s^{-1} and the lower velocities around 6.6 km s^{-1} were observed but one or both of these are absent on many of the time-distance plots. No evidence was found for anomalous mantle material except within the immediate vicinity of the median valley and a density model of the upper mantle beneath the ridge which is consistent with this observation and other recent geophysical measurements is presented. The model implies an upwelling of partially melted mantle material from the low velocity zone".

c) PAYO G. - "Structure of the crust and upper mantle in the Iberian shield by means of a long period triangular array". p.493-508.

"Phase velocity methods, using the long period triangular array formed by the Standard stations TOL, MAL and PTO, have been used to study the crust and upper mantle under the Iberian Peninsula shield.

To determine the phase velocities, Fourier analysis techniques have been applied to the Rayleigh waves recorded at the stations. The long period triangular array has allowed us to study the differences in structure under the legs of the triangle...".

d) SCLATER J.G. & J. FRANCHETEAU. - "The implications of terrestrial heat flow observations on current tectonic and geochemical models of the crust and upper mantle of the Earth". p.509-542.

"The average heat flow through continental orogenic belts decreases with the age of the orogeny to an approximately constant value for the Precambrian shields and platforms. The average heat flow for provinces of the North Pacific decreases with the age of the province...

Two geophysical and geochemical models of the oceanic and continental crust and upper mantle are presented. Both can explain the near equality of heat flow through the Precambrian shields and the old ocean basins when plates of continental and oceanic lithosphere are allowed to move. The oceanic lithosphere is approximately 100 km thick and the mantle is assumed to be the same under both the continents and oceans. The models differ principally in the condition assigned to their lower boundary. These conditions result in two different geochemical compositions for the oceanic lithosphere. Both oceanic models can explain the flow of heat through the North Pacific and the topography of the East Pacific Rise. If the effects of water in the mantle and subsolidus phase changes are considered, the lithosphere could be as thin as 75 km and still consistent with the heat flow and topographic anomalies.

The models also account for the elevation of the mid-Atlantic ridge and the gross structure of the heat flow through the South Atlantic. The loss of heat in creating oceanic lithosphere may be as much as 45 per cent of the total average heat flow of the Earth. Heat lost by this process can no longer be ignored in models of the thermal history of the Earth".

146 - Geophysics, v.35, n°1, 1970.

a) MILCOVEANU D. - "Some formulas useful in the interpretation of gravitational and magnetic profiles". p.66-79.

"General formulas for the calculation of the gravimetric quantities g, g_x, g_{zz}, and g_{zx} caused by two-dimensional models bounded by certain analytical curves are presented. Model curves show anomalies in these gravimetric quantities for the case of circular segments.

On the basis of the well-known Poisson formula relating magnetic and gravimetric potentials, formulas are derived fro the calculation of magnetic quantities produced by two-dimensional models bounded by certain analytical curves. Examples illustrate the case where the analytical curve is an arc of circle. Model curves show anomalies in the magnetic quantities for circular segments.

The model curves representing theoretical gravimetric and magnetic anomalies can be used for practical interpretation problems".

b) HAMMER S. - "The anomalous vertical gradient of gravity". p.153-157.

"The model study reported in this paper is easily extended to single masses of other geometrical forms and depth. In such cases, "R" is any characteristic dimension (size or depth) of the model. For an assumed model and a given value of the axial anomalous vertical gradient at a known elevation, the magnitude of the associated gravity anomaly and a complete and unique interpretation (both R and σ) are derivable for any assumed value of the dimensionless ratio h/R.

The relationships between vertical gradient and areal gravity are easy to understand from basic principles. Minor exceptions which may occur (Kumagai et al, 1960) do not apply to localized features. Isolated anomalies in the vertical gradient must correlate directly with associated gravity anomalies. If they do not the data in one or the other or both are inadequate.

Nonlinear behavior of a vertical profile of the vertical gradient can occur only near localized (shallow) mass anomalies. Vertical gradient effects of strong, broad gravity anomalies tend to be small and vertically linear.

Vertical gradient measurements in tall buildings (and also in underground mine shafts and boreholes) should be supplemented with an areal gravity survey to define the locally anomalous gravity field in the vicinity. To check the reality of nonlinear vertical gradient effects by an areal gravity survey it is good practice to have the horizontal station spacing in the immediate vicinity closer than the nonlinear elevation intervals in the gradient data".

c) JACQMIN A. & L. PEKAR. - "Reflections on the use of the Fourier transform in seismic and gravimetric surveying".
Abstract p.171.
from : Geophys. Prospecting, v.17, n°3, 1969.

"Numerous studies have already been carried out on the Fourier Transform and its geophysical applications. The utilization of computers has brought with it the digitalization of the major method, reflection shooting, and the different handling techniques for numerical data have given birth to numerous papers on the subject. Gravimetric surveying has always been a numerical method, but it is evident that for it, too, new possibilities have been opened...

The purpose of the present paper is to reconsider the philosophy of the seismic and gravimetric methods, starting with data recording, then dealing with the most important data processing systems, and finally ending with the interpretation. The paper bases its approach on two points of view which are in fact complementary :

- Although digital data processing is almost always effected in the functional sphere by convolutions, it is much easier to understand and to conceive these systems if one reasons alternately in the functional and frequency spheres ; this is possible by using the Fourier Transform.
- By considering the problem in frequencies, there is no fundamental difference between the seismic and gravimetric methods. A curve plotted in gravity units, as a function of the distance, and a seismic trace which represents the variations of the output of a galvanometer, as a function of the time, are identical from the point of view of the Fourier transform.

With these ideas in mind, the following problems are dealt with :

- Seismic and gravity signals ;
- The sampling problem in gravimetry (data sampling rate non-constant) ;
- Presentation and discussion of spectra of some synthetic and practical examples ;
  . Wave number filtering,
  . Frequencies filtering,
  . The problem of the frequency 0 (horizontal and vertical derivatives),
  . Continuation = deconvolution".

147 - GENDZWILL D.J. - "The gradational density contrast as a gravity interpretation model".
Geophys., v.35, n°2, p.270-278, 1970.

148 - Geophysics, v.35, n°3, 1970.

a) JACOBY W.R. - "Gravity diagrams for thickness determination of exposed rock bodies".
p.471-475.

"Sets of diagrams of the normalized peak gravity effect of exposed rock bodies can be used to determine the depth to which the bodies extend. The advantages of the method are :
1 - Straightforward and easy application,
2 - Clear display of the uncertainty of the result, and
3 - Applicability to any shape rock bodies.

b) KLEINKOPF M.D., D.L. PETERSON & G. GOTT. - "Geophysical studies of the Cripple Creek mining district, Colorado".
p.490-500.

"Integrated geophysical, geochemical, and geological interpretations expand the knowledge about the localization of the ore deposits in the Cripple Creek district, Colorado. The principal gold deposits occur in a Tertiary volcanic subsidence basin within Precambrian granite, gneiss, and schist. The basin is filled with volcanic breccia and is intruded by dikes and irregular masses of phonolite, latite-phonolite, syenite, trachydolerite, and basalt. The volcanic complex gives rise to a broad 10 mgal gravity minimum anomaly upon which are superimposed local minima believed to be related to deep mineralized fissure zones.

A negative magnetic anomaly over the volcanic subsidence basin probably reflects the degree of alteration of rocks in the subsurface. Two local closed magnetic lows may represent highly altered volcanic centers in the bottom of the basin. The gravity and magnetic anomalies of the basin correlate geographically with positive geochemical anomalies for gold, silver, and tellurium.

Just east of the volcanic basin, a prominent negative magnetic anomaly and a corresponding gravity low may represent an altered zone in the granite subsurface".

c) BODVARSSON G. - "A surface integral in potential theory".
p.501-503. (Short note).

152 - STACEY R.A. & L.E. STEPHENS. - "Procedures for calculating terrain corrections for gravity measurements".
Pub. Dom. Obs., v.XXXIX, n°10, p.349-363, Ottawa, 1970.

"The published methods of computing terrain corrections for Bouguer anomalies from topographic data based on hollow cylinder, vertical prism, frustum of a cone and inclined plane models are reviewed. The method used at the Dominion Observatory is based on a combination of the hollow cylinder model for representing the local terrain and the prism model for the regional terrain. This method has been developed specifically for use in the Cordilleran region of western Canada and is intended to give final Bouguer anomalies as accurate as those based on measurements in the Prairie and Shield regions of Canada where the topography is more subdued. It is concluded that this accuracy is only possible if :

1 - The observed gravity values are of the same accuracy throughout Canada;
2 - The coordinates and elevation of stations in the Cordillera are accurate to 100 m and 7 m, respectively ;
3 - 1/50.000 topographic maps are available for the area of the gravity survey ; and
4 - The resulting terrain correction is less than 12,5 mgal.

The specifications for the computer programs developed in conjunction with the methods used at the Observatory are given in an appendix to the report".

155 - BOWIN C.O. - "Experience with a sea-going computer system : lessons, recommendations and predictions".
Applications of sea-going computers,
Contr. W.H.O.I., n°2274, p.141-157, 1969.

"The development of three shipboard oceanographic data processing and control systems (ODPCS) at Woods Hole Oceanographic Institution since 1961 is outlined. The first two ODPCS's utilized an IBM 1710 computer system, and the third ODPCS presently being implemented uses a Hewlett-Packard 2116 A computer system. The lessons learned from the past years of experience are discussed in relation to utilization, operation, maintenance, and cost of equipment ; printed and graphic output ; a comment-logging system experiment ; and editing, correcting, and analyzing real-time data. Recommendations now being followed in the development of System III are presented. Predictions concerning portability, peripheral devices, and the cost /size/ reliability / growth relations of future sea-going systems are offered".

156 - ROSENFELD M.A. & C.O. BOWIN. - "Computers in oceanography".
Computer applications in the Earth Sciences,
Contr. W.H.O.I., n°2381, p.205-222, 1969.

... "The unique aspects of computers in oceanography are probably those based on tactics rather than on science. We take computers and plotters on ships to aid in data acquisition problems. It may be necessary, as in gravity or acoustic work, to do much computation to verify the working status of instruments and to make wise decisions about future actions. Shipboard computers also are used for satellite navigation to obtain immediate fixes. The Glomar Challenger uses a sp cial computer system to control its dynamic positioning while drilling.

Unattended data acquisition systems, such as currentmeters on moored buoys, collect data on special digital magnetic tapes. Other devices, both on board ship and on land acquire data on analog tapes. These tapes must be translated to computer compatible tape for analysis.

A major national issue in the marine community is the data-management problem. Perhaps this does not differ technically from the well-data problem in the petroleum industry. However, because most work in oceanographic science is funded by the federal government, the problem is approached from a federal viewpoint. Today, the Fleet Numerical Weather Facility is an example of essentially a real-time distributor of certain oceanographic measurements.
On the other hand, the National Oceanographic Data Center serves as an archive from which a wide variety of data can be obtained but not in real time".

158 - EMERY K.O., E. UCHUPI, J.D. PHILLIPS, C.O. BOWIN, E.T. BUNCE & S.T. KNOTT. - "Continental rise off eastern North America". The American Ass. Petroleum Geol. Bull., v.54, n°1, p.44-108, 1970.

"During mid-1967 two cruises of the Woods Hole Oceanographic Institution's R/V Chain provided nearly continuous seismic geomagnetic, and gravity measurements along 8.000 km of ship track. These measurements supplement earlier ones from various sources to provide a comprehensive picture of the composition and geologic history of the continental margin off eastern North America, an area that is much larger than all of the United States east of the Mississippi River.

The geomagnetic profiles portray a systematic pattern of positive and negative anomalies that are in accord with the concept of seafloor spreading, whereby North America separated from Europe and Africa at the beginning of the Permian Period, and drifted westward from the site of rifting (the Mid-Atlantic Ridge) at average rates of 0.8-1.4 cm/year. During all this time the continent has been coupled firmly with the adjacent sea floor, as though both continental and sea floor were on the same conveyor belt.

Gravity information suggests that a relict structure of the original rift is preserved in the same general area as the geomagnetic slope anomaly, beneath the seaward part of the continental shelf, the continental slope, or the upper continental rise. It has the form of a complex linear ridge of crystalline rocks that rises above the zone of sharpest landward slope of the Mohorovicic discontinuity. Seismic refraction measurements support the presence of such a ridge, bordered on both sides by linear trenches. The continuous seismic reflection profiles measured during the cruises reveal shallow acoustic basement in the form of a ridge complex that is shallower, but in the same general area, and probably is related to the deep ridge. The ridge and associated trenches served as dams and basin sinks to trap land-derived sediments during the Mesozoic Era, so that only pelagic silts and clays could reach and be deposited on the irregular oceanic basement seaward of the barrier. During Late Cretaceous to middle Eocene time one or more thick deposits of probably chemical origin formed blankets of deep-sea chert throughout broad abyssal plains, which produce the acoustic reflector known as Horizon A.

About middle Eocene time the land-derived sediments filled the trap west of the ridge and prograded eastward over the ridge top and built the present continental rise atop the Mesozoic abyssal plain. Continuous seismic reflection profiles show that the rise is a huge prism of generally seaward-dipping, interbedded pelagic sediments and turbidites that contain many masses of sediemnt displaced from higher on the continental rise and from the continental slope. Such slides continue to occur, a large one having occurred in 1929. The volume of the Cenozoic continental rise in the study region is nearly 3 million km^3 , about half the volume of all sediments deposited on basement during Mesozoic time.

The interbedding of sandy turbidites with organic-rich silts and clays displaced from the continental slope may constitute a thick sequence of oil reservoir and oil source beds, but no exploratory drilling into them has been done".

159 - DRAGICEVIC M.S. - "Carte gravimetrica de Los Andes meridionales e interpretacion de las anomalias de gravedad de Chile Central". Univ. Chile, Dept. Geof. Geod., Pub. n°93, p.5-42, Santiago, 1970.

"During 1958-1963 the Department of Geophysics and Geodesy of the University of Chile collected gravity data of the Southern Andes. Results are presented in form of two maps of simple Bouguer anomaly scale 1/5.000.000 (1963) and 1/10.000.000 (1968).

Interpretation of two gravity profiles through the Andes Mountain Range at latitude 18° and 33°S. is given.
In Central Chile lat. 32° to 42° S., where the measurement density is higher, local anomalies are sketched".

160 - <u>Geodezja i Kartografia, t.XIX, Z.2, Warszawa, 1970</u>.

a) MILBERT S. & M. ODLANICKI-POCZOBUTT. - "Sur l'interprétation du système de référence géodésique 1967". p.83-87.

"La résolution de l'Union Astronomique Internationale de l'année 1964 sur l'acceptation des valeurs nouvelles pour la partie d'un ensemble de constantes astronomiques et ensuite la résolution de l'Union Géodésique et Géophysique Internationale de l'année 1967 sur l'établissement du nouvel ensemble de constantes conventionnelles définissant le Système de Référence Géodésique 1967 (SRG, 1967) avaient pour but l'introduction dans les travaux de recherche de nouveaux paramètres plus précis.

Comme essai d'une interprétation du Système de Référence Géodésique 1967, les auteurs de ce communiqué présentent les valeurs des paramètres pour l'Ellipsoïde de Référence 1967 et pour le répartition de la pesanteur, c'est-à-dire pour la formule de pesanteur 1967 calculées d'après les constantes citées ci-contre".

b) ADAMCZEWSKI Z. - "Méthode de la dépendance maximum et son application".
p.95-102.

"L'auteur présente une méthode de compensation d'observations toute différente de la méthode des moindres carrés.

La grandeur observée z_j, j = 1, 2,..., n, est liée linéairement avec grandeurs x_{1j}, x_{2j}, ... x_{mj}, tout en considérant les coefficients a_1, a_2, ..., a_m de ces grandeurs étant non négatifs, de façon que l'on ait :

$$a_1 x_{1j} + a_2 x_{2j} + \dots + a_m x_{mj} = zj \qquad j = 1,2, \dots n,$$

où $a_i \geqslant 0$, i = 1, 2, ..., m. Il faut trouver des paramètres a_i tels que cette dépendance soit réalisée dans un certain sens optimum.

Ayant recours aux idées de géométrie et de l'analyse multidimensionnaire, l'auteur présente un procédé vraiment effectif de détermination des paramètres a_i. Des épreuves numériques de la méthode y sont aussi citées. Ces épreuves démontrent que la dite méthode est pratiquement équivalente à la méthode des moindres carrés, laquelle, on le sait, n'est pas basée sur la condition $a_i \geqslant 0$.

On a donné aussi quelques exemples d'application géodésique de la nouvelle méthode, nommée "de la dépendance maximum" par son auteur".

161 - CHOJNICKI T. - "Calculs des marées terrestres théoriques et leur exactitude".
Geod. i Kart., t. XIX, Z.3, p.171-201, Warszawa, 1970.

"Pour éviter la propagation des erreurs systématiques à l'élaboration des observations propres aux différentes méthodes de détermination des marées théoriques, cet article présente une nouvelle méthode de calcul de ces marées visant à l'unification des méthodes employées jusqu'alors. Ce problème constitue, en outre, une partie d'une nouvelle méthode de détermination des paramètres marémétriques au moyen d'observations basées sur le principe des moindres carrés, qui vient d'être élaborée dernièrement par la Section de Géodésie Planétaire d'Institut de Géophysique de l'Académie Polonaise des Sciences..."

162 - SCHUSTER O. - "Strenge Zweigruppen-Erdgezeitenanalyse nach der Methode der kleinsten Quadrate".
D.G.K., Reihe C : Dissert., H.n°146, 126 S, München, 1970.

163 - SIMONSEN O. - "Why introduce the revised local references in the international collaboration between oceanographers and geodesists ?".
Submitted to the Symposium on Coastal Geodesy, July 20-24, München.
Danish Geod. Inst., 90 p, Copenhagen, 1970.

CENTRE NATIONAL pour l'EXPLOITATION des OCEANS (C.N.E.X.O.), Paris.

164 - Bull. Inf. n°13 & 14, 14 p, Janv.-Fev. 1970.
165 - " " n°15, 17 p, Mars 1970.
166 - " " n°16, 14 p, Avril 1970.
167 - " " n°17, 9 p, Mai 1970.
168 - " " n°18, 13 p, Juin 1970.
169 - " " n°19 & 20, 20 p, Juil.-Août 1970.
170 - " " n°21, 9 p, Sept. 1970.
171 - Rapport annuel 1969, 52 p, Paris, 1970.

172 - Society of Exploration Geophysicists. - Cumulative index of Geophysics.
Supplement to June Geophysics, 1970 Edition, also includes Geophysical prospecting and early geophysical papers.
290 p, Tulsa (Oklahoma), 1970.

173 - Geophysics, v.35, n°4, 1970.

a) SHARMA B. & M.P. VYAS. - "Gravity anomalies of a fault cutting a series of beds".
p.708-712.

b) THYSSEN BORNEMISZA S. - "Instrumental arrangement to measure gravity with gradients".
p.713-715.

178 - GIESE P. & G. de VISINTINI. - "Ergebnisse des Lago Lagorai-E-Profils".
from : Proc. 8th Ass. Europ. Seismol. Commiss., p.95-101, Budapest.
Osser. Geof. Sper., Contr. n°193bis, Trieste, 1970.

180 - DAY G.A. - "Marine Geophysics Unit : Trials of the LaCoste and Romberg gravitymeter, S-40, August - September 1969".
Inst. Geol. Sci., Rep. n°2, 15 p, London, 1970.

"The LaCoste and Romberg sea gravity meter n°S-40 was operated in R.R.S. Discovery simultaneously with the Askania Sea gravimeter GSS-2, n°11 for seven weeks in 1969, during which time 24 hours was spent on a gravity evaluation range. Profiles for both meters over the range are compared with the sea-bottom stations. A great deal of instrumental trouble was experienced with the meter. The main conclusions are that the accuracy of this meter is marginally better than that of the Askania GSS-2 n°11, but that it is closely output and is more limited by weather than the Askania because of its faster response, but is simpler to install and operate. Its automatic cross-coupling correction is an advantage".

181 - WEIGEL W., J. HJELME & M. SELLEVOLL. - "A refraction profile through the Skagerrak from Northern Jutland to Southern Norway".
Geod. Inst., Med. n°45, Paper n°7, 27 p, Copenhagen, 1970.

"Seismic reflection profiles were measured in the sea on a nearly north-south going line in the Skagerrak. Some of the explosions were also recorded at stations on land near the coasts.

The basement was found at a depth of 5 km with a velocity of 5.7 km/s. Above the basement velocities of 2.8, 3.8, and 5.0 km/s were found. The velocities are determined in reversed profiles at the southern end. Towards the north only unreversed profiles are available. But another source claims horizontal layering here. An observed velocity of 6.3 km/s found in an unreversed profile cannot be explained by a simple model.

A geological interpretation associates the 2.8 km/s with the Upper Cretaceous chalk. The 3.8 km/s may correspond to the Lower Jurassic or to the top of the Triassic.

The observations are not sufficient to determine a continuous model of the structure below the basement. An intermediate velocity of 7.2 km/s was located at a depth of 20 km. The depth to Moho was 29 km. Some distinct arrivals interpreted as wide-angle reflections from the Moho in the area below the Norwegian Channel fitted best in with a depth of 31 km".

184 - Geophysical Bulletin n°20, Soviet Geophys. Comm., Acad. Sci. USSR, Moscow, 1969.

a) KOSMINSKAYA I.P., N.A. BELYAEVSKY & I.S. VOLVOSKY. - "Explosion seismology in the U.S.S.R.".
p.7-14.

"The paper discusses the results of studies of the Earth's crust by the method of deep seismic sounding on the territory of the USSR the methods of conducting work and the methods of interpretation of the data obtained by the DSS. The paper emphasizes that further researches in the field of explosion seismology should cover the major problems of applied and theoretical value : the study of relations between the deep structure and the crustal structure and the determination of the physical parameters of matter of the interior. Both these problems are in close connection with the development of the physical foundations and the improvement of methods of seismic observations".

b) GAINANOV A.G., E.N. ISAEV, P.A. STROEV & S.A. USHAKOV. - "Isostasy of the Bering Sea".
p.15-19.

"The paper presents the description of the topographic-isostatic corrections and analysis of the isostatic anomalies of the Bering sea.

It has been determined that the deviation from the isostasy exists towards the under-compensation of the Commandors and the south-eastern parts of the Aleutian basin. The isostatic anomalies allowed to follow the continuation of the coastal structures to the foot of the continental slope. The greatest deviation from the isostasy is observed in the Aleutian arc, which is an area of modern tensions in the crust and mantle. The marginal oceanic swell is characterized by the positive isostatic anomalies".

c) RODNIKOV A.G., R.D. RODNIKOVA, K.M. SEVOSTIANOV & A. Y. TABOYAKOV. "Basic structural elements of the Japanese-Sakhalin island arc". p.27-32.

"Within the Japanese-Sakhalin island arc a number of structural zones are distinguished which differ in history of geological development, tectonic structure, volcanism, the peculiarities of which in the geological past and at present are caused by the effect of the processes going on in the upper mantle of the Earth".

d) UDINTSEV G.B. & I.P. KOSMINSKAYA. - "The study of the crust and the upper mantle of the Earth (by the materials of the XI Pacific Congress in Tokyo, 1966)". p.33-47

185 - GRUSHINSKY N.P. - "Gravity determinations in Antarctica". Soviet Geophys. Comm., Acad. Sci. USSR, Geophys. Bull. n°21, p.18-39, Moscow, 1970.

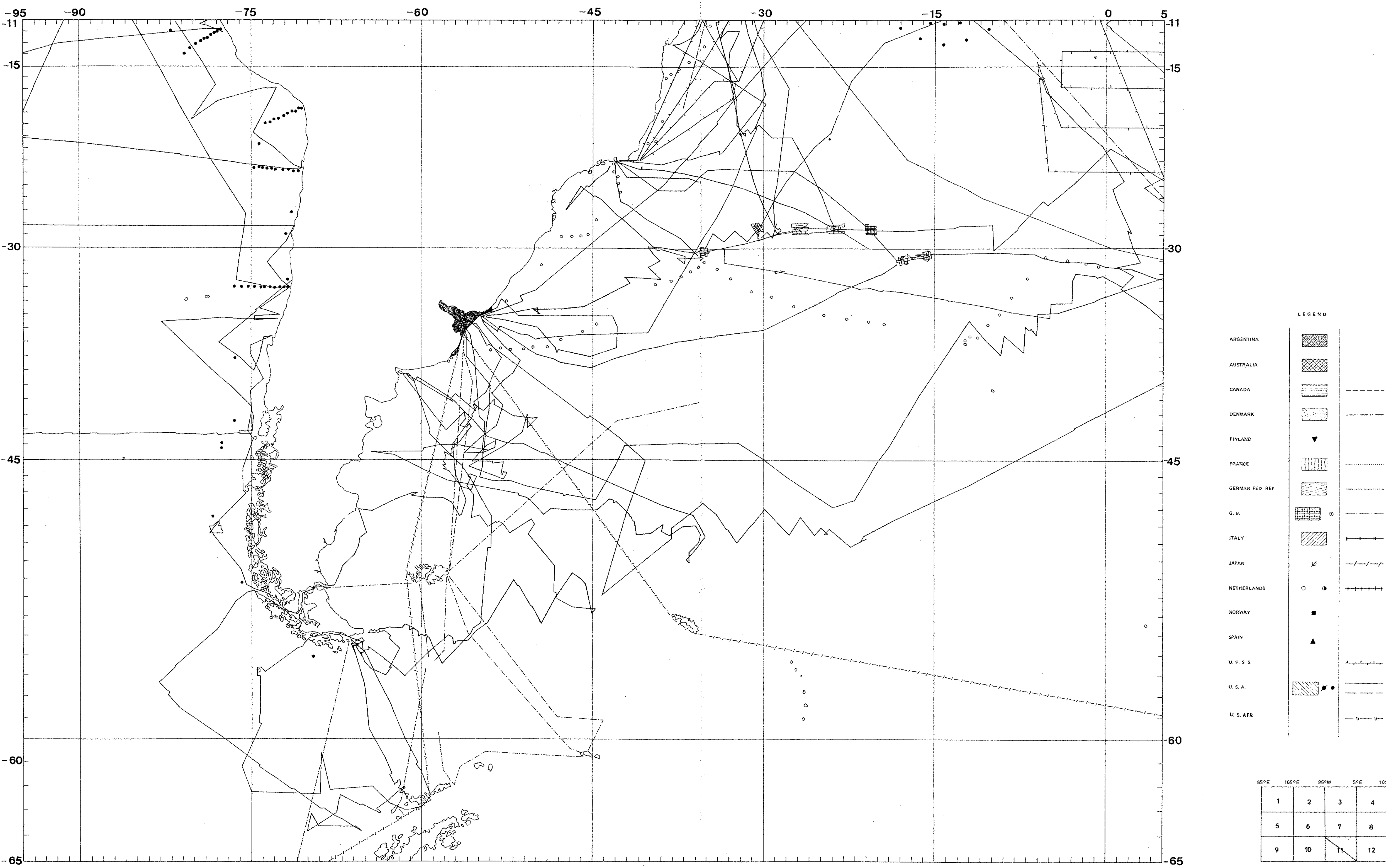
"The paper presents a catalogue of gravimetrical points obtained by the gravimetrical party of the Sternberg State Astronomical Institute during the nine Antarctic expeditions of the USSR Academy of Sciences. The points are located mainly in the Antarctic seas and on the Antarctic continent. Part of them is determined in the Ocean en route of the ship. The paper gives a brief description of the expeditions, as well as the evaluations of gravity values included in the catalogue".

186 - Union Géodésique et Géophysique Internationale - Chronique n°79, 64 p, Mars 1970.

187 - Union Géodésique et Géophysique Internationale - Chronique n°80, p.65-128, Juillet 1970.

GRAVITY MEASUREMENTS AT SEA

B.G.I. 1970



GRAVITY MEASUREMENTS AT SEA

B.G.I. 1970

GRAVITY MEASUREMENTS AT SEA

B.G.I. 1970