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OBITUARY

William BULLERWELL
(1916 - 1977)

The sudden death of William BULLERWELL on 25th November 1977 not only deprived the Institute of Geological Sciences of an exceptionally able and loyal Deputy Director, but also robbed the geophysical community of one of its most dedicated practitioners.

Born in Newcastle-upon-Tyne in 1916, he graduated in 1937 in Physics at King's College, Newcastle (Durham University) and followed that in 1939 with a second degree in Geology, being awarded the Labour Prize for Field Geology. His doctorate, on mining geophysics, was completed in 1951 having been interrupted by war service from 1940 - 1946. During this period he was concerned with the development and operation of radar, serving in the Ministry of Supply, the RAOC and REME and being Mentioned in Despatches.

His professional career began in 1946 when he joined the field staff of the Geological Survey of Great Britain. Soon afterwards his geophysical talents were directed towards the introduction of geophysical methods as a component of the Survey's activities and subsequently to the establishment of a Geophysical Department. As well as organising many local geophysical investigations he initiated systematic gravity and aeromagnetic surveys over the UK mainland and surrounding waters. Publication of transparent overlays of the gravity measurements at a scale of a quarter inch to one mile took place under his supervision from 1954 and these were followed by interim aeromagnetic maps at the same scale, and in 1955 and 1972 by the "Ten-mile" coloured aeromagnetic maps. In addition to these official duties his energy enthusiasm led him, between 1953 and 1956, to undertake a reconnaissance gravity survey of Scotland jointly with his wife, Eileen, whom he married in 1942, and Dr. and Mrs J. PHEMISTER. His researches also led to the publication of a standard geophysical reference on the Tertiary volcanic centres of the Western Isles.

Appointed Chief Geophysicist in 1962, he was instrumental in broadening the scope of the Geophysical Division for which he was responsible within the Survey and its successor, the Institute of Geological Sciences formed in 1966 as a component body of the Natural Environment Research Council. To the systematic surveys and applied geophysical studies was added research work on geomagnetism and global seismology.
This broadly based Geophysical Division formed the foundation from which work extended into marine geophysics as the hydrocarbon search moved into the offshore domain. His contribution to the organisation and implementation of the offshore programme commissioned by the Department of Energy was considerable. He was also heavily involved in initiating the current Department of Energy and EEC assessment of the geothermal potential of the UK and, through his service on the EEC's Advisory Committee on Programme Management, of the EEC states as a whole. For many years he represented the Ministry of Overseas Development at various multi-national conferences on mineral exploration and offshore prospecting in the Far East.

He was awarded the Lyell Fund in 1955 by the Geological Society whom he served as Treasurer from 1963 to 1971. His extensive geophysical knowledge and contributions were recognised by his election to the Royal Society in 1972 and in the following year to the Royal Society of Edinburgh. He was Chairman of the Advisory Board on Geophysics of the University of London and was a member of the Bureau of the International Gravity Commission. He served on, and submitted evidence to, numerous Governmental, Parliamentary, institutional and professional committees.

William BULLERWELL - Bill to his many friends and colleagues - was a very positive personality whose generosity, loyalty and kindness were complemented by the dedication, integrity and professionalism shown in all his scientific activities.

D.A. GRAY
On April 13, 1978, Professor Dr. Ing. Alfred SCHLEUSENER, a pioneer of applied geophysics, died in Hannover, after a short severe illness.

Born on the 1st March 1898, SCHLEUSENER studied mining sciences at the Technical University of Berlin-Charlottenburg in the early twenties. Having received his Dipl.-Ing. degree, he turned immediately to the field of exploration geophysics, which was in rapid development at that time. From 1925 to 1933 he was actively engaged mainly in gravimetric investigations, in many regions of the world, including Africa, North America and Western Asia. Since 1928 he was with Seismos company, Hannover, where he became head of the department for gravimetric and other non-seismic methods. While until the beginning of the thirties, the torsion balance was nearly exclusively used at gravimetric prospecting, the development of gravity meters changed the situation completely. Here SCHLEUSENER made an important contribution by the development together with St. von THYSSEN-BORNEMISZA – of an astatized gravity meter suitable for practical field work. Numerous instruments of this type have been built by Seismos GmbH, and employed for instance at the regional gravimetric survey of Germany, carried out between 1934 and 1945 under the supervision of SCHLEUSENER. The gravity maps resulting from this extensive survey today still serve as a basis for regional gravimetric investigations. After the second world war, SCHLEUSENER was one of the persons who reestablished the Seismos Company and brought her to another worldwide activity in geophysical exploration.

The scientific work of Alfred SCHLEUSENER is characterized by numerous publications, following his thesis about deformations of level surfaces, produced by artificial mass shifts, which was the basis for obtaining the Dr.-Ing. degree at the University of Breslau in 1936, under Professor Ludger MINTROP. These publications deal practically with all fields of applied gravimetry, from instrumental construction and calibration problems, design of gravity networks and accuracy estimation, to the calculation, presentation and interpretation of local and regional gravity anomalies. But SCHLEUSENER was also interested in more general geophysical problems. So he took part in a German geodetic, geophysical and geological expedition to northern Iceland in 1938, and carried out a gravity survey along an east-west profile crossing the axial rift zone. The idea, to get detailed information about the regional and the time behaviour of gravity at this part of an active spreading zone, could be taken up by him again in 1964/1965. From this work, and from the evaluation of the gravity field in Germany, SCHLEUSENER came to a close cooperation with geodesy, especially with the geodetic department of the Technical University of Hannover. In collaboration with this department, he continued the Iceland gravity survey in 1967 and 1970, and could present the first indications of secular gravity variations at the IUGG-IAG General Assembly at Moscow 1971.
Because of SCHLEUSENER's scientific merits and practical experiences, the Technical University of Hannover invited him to teach applied geophysics, and awarded him a honorary professorship. During that activity period, which lasted from 1954 to 1968 he gave the students of geodesy a sound background especially of gravimetric techniques and methods, and fascinated some of them - including the author - so much that they later went to exploration geophysics or to gravimetric geodesy. The author personally feels happy to have had the chance of a close and fruitful cooperation with Alfred SCHLEUSENER at Seismos GmbH and, since 1968, at the Institute of Theoretical Geodesy, T.U. Hannover. The outstanding work of SCHLEUSENER in Iceland is continued by this Institute now.

Alfred SCHLEUSENER was one of the founder members of the European Association Exploration Geophysicists, and he was also member of the Society of Exploration Geophysicists, of the International Gravimetric Commission, and of the Deutsche Geophysikalische Gesellschaft, of which he was president from 1964 to 1966.

The gravimetric community will not forget Alfred SCHLEUSENER, who promoted gravimetry in theory and practice.

Wolfgang TORGES, Hannover.
INTERNATIONAL GRAVITY COMMISSION

As it was already announced in the Bulletin d’Information No 41, the eighth International Gravity Commission will be held in Paris:

from September 12th to 16th, 1976

Meetings will take place at the University Pierre et Marie Curie 4, Place Jussieu*, 75005 PARIS, in the amphitheatre 25, next to the Office of the I.G.B. (Tour 14).

Métro : Jussieu or Cardinal Lemoine

Entrances : 4, Place Jussieu, or
Rue des Fossés Saint-Bernard (in front of Tour 14), or
*11, Quai Saint-Bernard (same place).

We give, hereafter, the main scientific items included in the agenda with the title of the various papers already proposed to the I.G.B. and which will be presented at the meeting.

Item I - C. MORELLI : Report of the International Gravity Commission

Item II - International Gravity Bureau
U. UOTILA : " " Working Group II
Yu.D. BOULANGER : " " Working Group III

Item III - ABSOLUTE GRAVITY MEASUREMENTS
Chairman : A. SAKUMA

- A. SAKUMA (B.I.P.M., France) / Absolute gravity measurements
- J.E. FALLER (U.S.A.)* : Plans and progress in the development of a portable absolute gravimeter with a few parts in 10^9 accuracy.
  R.L. RINKER and M.A. ZUMBERGE.
- B. DUCARME (Belgium) : Precise tidal corrections for absolute gravity measurements.

Item IV - INTERNATIONAL GRAVITY STANDARDIZATION NETWORK
Chairman : C. MORELLI

- C. MORELLI (Italy) : General Report
- J.C. BHATTACHARJII (India) : Proposed absolute datum for Indian geodetic system.
Item V - GRAVITY MEASUREMENTS AT SEA

Chairman: J. WOODSIDE

- J. WOODSIDE (U.K.) : General view on the sea gravity measurements
- C. GOWIN (U.S.A.) : ...
- G.L. STRANG van HEES (Netherlands) : On recent gravity measurements on the Atlantic.

Item VI - NON-TIDAL VARIATION OF G

Special Study Group No 3.40

Chairman: Yu.D. BOULANGER

- Yu.D. BOULANGER (U.S.S.R.) : An international program of global studies of non-tidal gravity variations as indicator of mass center movement.
- G. BARTA (Hungary) : Mass distribution of the Earth on the surface and at depth and the global secular variation of the gravity field.
- R.S. MATHER (Australia) : On the recovery of geodynamic information from secular gravity changes.
- L. PETTERSON (Sweden) : High precision gravity measurements for studying the secular variation of gravity in Fennoscandia.
- C. GERSTENECKER (G.F.R.) : Investigation of non-tidal gravity changes.
- I. NAKAGAWA (Japan) : Gravity changes observed in the Kindi District, Japan.
- J.M. CALDERA & M. MENA (Mexico) : Secular variations of gravity in Latin America.
- Sh.K. SINGH (Mexico) : Secular variations of gravity in Mexico.
- W. TORGE (G.F.R.) : Local gravity variations in Northern Iceland connected with earthquake and volcanic activity.
- H. DREWES (Venezuela) : Regional subsidence of the Lake of Maracaibo as determined by repeated gravimetric measurements.

Item VII - HIGH PRECISION GRAVIMETRY

Special Study Group No 3.37

Chairman: C. GROTHE

- C. GROTHE (G.F.R.) : Report of Sp. St. Gr. 3.37 "Special techniques of gravity measurements".
- C. GROTHE (G.F.R.) : High precision gravity campaign in the Rhine graben net.
- DEICHL, GROTHE, KIVINIELI, WEICHEL. ...
- I. NAKAGAWA (Japan) : An accuracy of scale constant of LaCoste-Romberg gravimeters (model G) revealed by international and domestic gravimetric connections.
- Z. SZABO (Hungary) : Investigations of environmental effects on gravity measurements.

Item VIII - SECOND DERIVATIVES OF THE POTENTIAL (Vertical Gradient of Gravity)

...

Item IX - NEW GRAVIMETRIC INSTRUMENTATION

Chairman: D. WILLIAMS

...

Item X - GRAVITY FIELDS ON THE MOON AND PLANETS

...

Item XI - PREDICTION OF GRAVITY VALUES

Chairman: U. OOTILA

- A. MESSKO (Hungary) : Interpolation of gravity data with practical applications.
- C. TSCHEHRNING (Denmark) ...
Item XII - COMPARISON AND COMBINATION OF SATELLITES RESULTS WITH SURFACE DATA
Chairman: R. RAPP
- R. RAPP (U.S.A.): Ocean gravity data from Geos 3 altimeter data.
- G. DESVIGNES (France): Some numerical results on statistical behaviour of gravity anomalies and geoid undulations.

Item XIII - PHYSICAL INTERPRETATION OF GRAVITY ANOMALIES
Special Study Group No 5.48
Chairman: S. SAXOV
- S. SAXOV (Denmark): General Report
- S. SAXOV (Denmark): Gravity applied to geology.
- G. DESVIGNES (France): Geophysical interpretation of some large scale gravity anomalies and geoid undulations.
- H.G. KAHLE (Switzerland): Swiss Alps: gravity field and geodynamic implications.
- V. VYSKOČIL (Czechoslovakia): On the construction of the density models of the Lithosphere.
- S. RIAD (Egypt): On the downward continuation of the gravity field.

VARIOUS

- M.G. ARUR (India): National Report on the gravimetric work done in India.
- K.L. KHOSLA (India): Future program of survey of India.

- G. MARFÖLDI (Hungary): Physical interpretation of the relativistic variation of gravity constant.
I. NAKAGAWA, M. SATOMURA
Geophysical Institute, Kyoto University, Kyoto 606, Japan
and
T. SETO
Geographical Survey Institute, Tokyo 153, Japan

AN ACCURACY OF SCALE CONSTANT OF LA COSTE & ROMBERG GRAVIMETERS (MODEL G) REVEALED BY INTERNATIONAL AND DOMESTIC GRAVIMETRIC CONNECTIONS
Abstract

In gravity measurements, a discrepancy among the scale constants of gravimeters used is one of the most important but inevitable problems, especially when a difference of gravity values among the measuring stations is large. After the data that were obtained by two sets of international gravimetric connections amounting to about 1.8 gals and 2.1 gals, respectively, and one set of domestic gravimetric connection amounting to about 1.6 gals in gravity differences were adjusted by referring to the IGSN 71, the following values of correction factor for scale constants of LaCoste & Romberg gravimeters G-29, G-118 and G-196 were determined.

For the gravimeter G-29 : \( 1.000663 - 0.000042 \Delta g_{obs} \)

For the gravimeter G-118 : \( 1.000215 - 0.000061 \Delta g_{obs} \)

For the gravimeter G-196 : \( 1.000640 + 0.000121 \Delta g_{obs} \)

Using these correction factors, the gravity value at each measuring station was re-calculated. The discrepancy between the value thus obtained and that of the IGSN 71 was almost less than ± 0.03 mgals at all stations.
1. Introduction

A great many gravity measurements of high accuracy which investigate the time change of gravity are being carried out by many researchers at various regions in the world (Honkasalo, 1975). All possible efforts have been made to be sure that the accuracy of measuring is as high as possible.

One of the problems which hinder the advancement in the accuracy of measurement is an uncertainty in the scale constants of gravimeters which are used. In order to avoid this uncertainty, precise gravity measurements at stations of small gravity difference have recently been made in various regions (e.g., Kiviniemi, 1974 and Nakagawa and Satomura, 1975). However, their measuring areas were limited to special regions because of the small gravity difference. It is therefore necessary to carry out an accurate calibration on the scale constant of gravimeters used in gravity measurements not only for large gravity differences but also for small gravity differences.

An accuracy of scale constant of LaCoste & Romberg gravimeters (model G) was investigated by comparing the data of gravity connections for large gravity differences amounting to about 3.5 gals with gravity values of the International Gravity Standardization Net 1971.

2. Employed Data

An international connection of gravity was carried out by
means of three LaCoste & Romberg gravimeters G-29, G-118 and G-223 in 1974 at Tokyo, Moscow, Potsdam and Paris (Soto and Takima, 1975). Another international connection of gravity was undertaken by means of two LaCoste & Romberg gravimeters G-29 and G-196 in 1975 at Kyoto, Tokyo, Cahu-Honolulu, Los Angeles, Mexico City, Lima, Arequipa and Santiago (Nakagawa et al., 1977b). In addition, a domestic connection of gravity was carried out in Japan by using eight LaCoste & Romberg gravimeters involving the G-29, G-118 and G-196 in 1976 (Nakagawa et al., 1977a). The gravity differences were about 1.8 gals, 2.1 gals and 1.6 gals, respectively.

Data obtained by these three sets of gravimetric connections were employed in the present investigation. The results obtained by applying the scale constant of the gravimeters given by the manufacturer are shown in Table 1. As a reference, gravity values at measuring stations for the international gravimetric connections were referred to the International Gravity Standardization Net 1971 (IGSN 71) (Morelli et al., 1974) and those for the domestic gravimetric connection were referred to the IGSN 71 and the Japan Gravity Standardization Net 1975 (JGSN 75) (Geographical Survey Institute, 1976). The gravity values at the Japanese gravity stations based on the JGSN 75 are perfectly consistent with those based on the IGSN 71. The gravity values based on the IGSN 71 and the JGSN 75 are also shown in Table 1.
| Table I |

Gravity values referred to the IGSN 71/JGSN 75 and gravity differences obtained by applying the scale constant of the gravimeters given by the manufacturer.
<table>
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<th>Gravity value (IGSN 71/JGSN 75)</th>
<th>Gravity difference referring to the IGSN 71</th>
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* International Gravimetric Bureau Number.
** After Elstner, 1974.
* X Referred to the Japan Gravity Standardization Net 1975 (JGSN 75).
* X The surroundings around the measuring station were recently changed, and the gravity value was subject to have some change.
and gravity differences obtained by

by the present investigation

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<tr>
<td></td>
<td></td>
<td></td>
<td>Nat. Fund. St. of Grav., Kyoto Univ.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Faculty of Education, Kumamoto Univ.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Kagoshima Local Meteo. Obs.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Okinawa Meteo. Obs.</td>
</tr>
</tbody>
</table>
Tokyo C was adopted as the base station in the present investigation. The discrepancy between the gravity difference from the base station obtained and that referring to the IGSN 71 is shown in Figures 1, 2 and 3 for the gravimeters G-196, G-118 and G-29, respectively.

Table 1 - p. 13-14

<table>
<thead>
<tr>
<th>Figure 1 - p. 16</th>
</tr>
</thead>
<tbody>
<tr>
<td>Figure 2 - p. 17</td>
</tr>
<tr>
<td>Figure 3 - p. 18</td>
</tr>
</tbody>
</table>

3. Correction Factor for Scale Constant

Each gravimetric connection employed in the present investigation consists of a perfectly going and returning measurement. Generally speaking, if there were jumps in the readings of the gravimeter on any section within a single series of measurement, it is possible to make a correction for such jumps in calculation. However, when the reading jumps took place on the same section of both the going and returning measurements, it is impossible to correct the jumps in calculation.

The gravimeters were transported by commercial jet aircrafts and passenger cars, and were always kept on the observers' knees during transportation in order to avoid severe shock to the
The relation between gravity difference of each station from the base station (Tokyo C) and deviation of the obtained gravity value from the IGSN 71/JGSN 75, for the gravimetric G-196. The straight lines were obtained by least squares method for each gravimetric connection.
The relation between gravity difference of each station from the base station (Tokyo C) and deviation of the obtained gravity value from the IGSN 71/IGSN 75, for the gravimeter G-118. The straight lines were obtained by least squares method for each gravimetric connection.
The relation between gravity difference of each station from the base station (Tokyo C) and deviations of the obtained gravity value from the IGSN 71/JGSN 75, for the gravimeter G-29. The straight lines were obtained by least squares method for each gravimetric connection.
gravimeters. On the trip to South America, however, the gravimeters could not be carried into the plane cabin on the way from Los Angeles to Mexico City and back because the plane crew did not understand the problem. It is, therefore, doubtful that a jump in the readings of the gravimeter took place on both the going and returning measurements between Los Angeles and Mexico City.

As can easily be seen in Figures 1, 2 and 3, no step is found for the gravimeters G-196 and G-118, while there exist two steps for the gravimeter G-29. Taking these steps into consideration and under the assumption that the gravity value of the IGSN 71 and the JGSN 75 is correct, the scale constants of the gravimeters G-196, G-118 and G-29 seem to be slightly small.

Assuming that the discrepancy has a linear relation to gravity difference, correction factors for the scale constant were determined by applying the least squares method for each gravimetric connection, as shown in Table 2.

| Table 2 - p. 20. |

Since Tokyo C was adopted as the base station, the gravity values of the international gravimetric connection between Japan and Europe were found to range from 0 to + 1.8 gals, those of the international gravimetric connection between Japan and South America from - 2.0 gals to + 0.1 gals, and those of the domestic gravimetric connection from - 0.7 gals to + 0.9 gals. It may
Table 2
Correction factors for the scale constant

<table>
<thead>
<tr>
<th>Gravimeter</th>
<th>Gravimetric connection</th>
<th>Correction Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>G-29</td>
<td>International (Japan ~ Europe)</td>
<td>$1.000693 \pm 0.0000016$</td>
</tr>
<tr>
<td></td>
<td>International (Japan ~ South America)</td>
<td>$1.000893 \pm 0.000020$</td>
</tr>
<tr>
<td></td>
<td>Domestic (within Japan)</td>
<td>$1.000644 \pm 0.000022$</td>
</tr>
<tr>
<td>G-118</td>
<td>International (Japan ~ Europe)</td>
<td>$1.000157 \pm 0.000009$</td>
</tr>
<tr>
<td></td>
<td>Domestic (within Japan)</td>
<td>$1.000205 \pm 0.000017$</td>
</tr>
<tr>
<td>G-196</td>
<td>International (Japan ~ South America)</td>
<td>$1.000526 \pm 0.000012$</td>
</tr>
<tr>
<td></td>
<td>Domestic (within Japan)</td>
<td>$1.000668 \pm 0.000023$</td>
</tr>
</tbody>
</table>
therefore be thought that there exists a discrepancy of correction factor for the scale constant depending on its scale range.

As for the gravimeter G-196, the discrepancy between the gravity difference obtained and that referring to the IGSN 71 and the JGSN 75 seems to be expressed by a second order function in the gravity difference obtained. This can clearly be seen in Figure 1. The discrepancy \( \Delta g_{\text{IGSN}} - \Delta g_{\text{obs}} \) is expressed by the following formula, by applying the least squares method.

\[
\Delta g_{\text{IGSN}} - \Delta g_{\text{obs}} = (0.000060 \pm 0.000010) \times \Delta g_{\text{obs}}^2 \\
+ (0.000640 \pm 0.000015) \times \Delta g_{\text{obs}} + (0.000004 \pm 0.000010),
\]

where \( \Delta g_{\text{IGSN}} \) is the gravity difference from the base station (Tokyo C) referring to the IGSN 71 and the JGSN 75, and \( \Delta g_{\text{obs}} \) is the gravity difference from the base station obtained (unit in gals). This relationship is shown in Figure 4.

The correction factor \( C_{196} \) was finally determined for the whole scale range amounting to about 3.0 gals as follows:

\[
C_{196} = (1.000640 \pm 0.000015) + (0.000121 \pm 0.000020) \times \Delta g_{\text{obs}}
\]

As for the gravimeter G-118, the situation is similar to the gravimeter G-196. The discrepancy \( \Delta g_{\text{IGSN}} - \Delta g_{\text{obs}} \) is expressed by the following formula, by applying the least squares method.

\[
\Delta g_{\text{IGSN}} - \Delta g_{\text{obs}} = - (0.000031 \pm 0.000014) \times \Delta g_{\text{obs}}^2 \\
+ (0.000215 \pm 0.000019) \times \Delta g_{\text{obs}} - (0.000007 \pm 0.000009).
\]
Fig. 4.

(Upper). The relation between gravity difference of each station from the base station (Tokyo C) and deviation of the obtained gravity value from the IGSN 71/JGSN 75, for the gravimeter G-196. The curved line was obtained by fitting the second order function.

(Lower). Scale constant given by the manufacturer and revised scale constant.
This relationship is shown in Figure 5.

The correction factor \( (C_{118}) \) was determined for the whole scale range amounting to about 2.5 gals as follows:

\[
C_{118} = (1.000215 \pm 0.000019) - (0.000061 \pm 0.000028) \times \Delta g_{\text{obs}}.
\]

As for the gravimeter G-29, it was concluded from Figure 3 that the discrepancy between the gravity difference obtained and that referring to the IGSN 71 is expressed by a second order function in the gravity difference obtained, which is also the same as that for the gravimeter G-196, and that there exist two unquestionable steps; namely, one is between Tokyo and Moscow and the other is between Los Angeles and Mexico City.

The results obtained by applying the least squares method are expressed in the following formula and are also shown in Figure 6.

\[
\Delta g_{\text{IGSN}} - \Delta g_{\text{obs}} = - (0.000021 \pm 0.000015) \times \Delta g_{\text{obs}}^2
+ (0.000663 \pm 0.000016) \times \Delta g_{\text{obs}} - (0.000032 \pm 0.000010).
\]

The amount of the steps was determined to be \((0.129 \pm 0.032)\) mgals on the section between Tokyo and Moscow, and \((0.323 \pm 0.053)\) mgals on the section between Los Angeles and Mexico City.

The correction factor \((C_{29})\) was, therefore, determined for
(Upper). The relation between gravity difference of each station from the base station (Tokyo C) and deviation of the obtained gravity value from the IGSN 71/JGSN 75, for the gravimeter G-118. The curved line was obtained by fitting the second order function.

(Lower). Scale constant given by the manufacturer and revised scale constant.
Fig. 6.

(Upper). The relation between gravity difference of each station from the base station (Tokyo C) and deviation of the obtained gravity value from the IGSN 71/JGSN 75, for the gravimeter G-29. The curved line was obtained by fitting the second order function.

(Lower). Scale constant given by the manufacturer and revised scale constant.
the whole scale range amounting to about 3.6 gals as follows:
\[ G_{29} = (1.000663 \pm 0.000016) - (0.000042 \pm 0.000030) \times \Delta g_{obs} \]

Using the correction factors obtained above, the gravity value at each measuring station was re-calculated under the assumption that the mean value of gravity at twenty-two (for the G-29) or eighteen (for the both G-118 and G-196) stations involved in the IGSN 71 and the JGSN 75 is assumed to have undergone no change; its result is shown in Table 3. Except for Kyoto A and Kumamoto A, the discrepancy between the value thus obtained and that given in the IGSN 71 and the JGSN 75 is generally less than \( \pm 0.03 \) mgals.

Table 3 - p. - 27.

As for the station Kyoto A, the building in which the National Fundamental Station of Gravity in Japan (Kyoto A) was established was rebuilt in 1968, but the station was reconstructed at the same position and height as for the former one. The gravity value observed at the former station was used to the adjustment of the IGSN 71. According to the precise gravity measurements, the recent value of gravity at the Kyoto A is about 0.06 mgals smaller than the former one (Nakagawa et al., 1970), because of the difference of attractions between the former and the present buildings. Taking this difference into consideration, the difference between the mean value obtained and the gravity value for the Kyoto A given in the IGSN 71 and
### TABLE 3
Results of gravimetric connections

<table>
<thead>
<tr>
<th>Station</th>
<th>IGB N°</th>
<th>Gravity value (IGSN 71/ JGSN 75)</th>
<th>Gravity value corrected G-29</th>
<th>G-118</th>
<th>G-136</th>
<th>Mean</th>
<th>Dif.*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tokyo C</td>
<td>13159 C</td>
<td>mGal 978.763.19</td>
<td>763.16</td>
<td>763.18</td>
<td>763.18</td>
<td>763.16</td>
<td>-0.01</td>
</tr>
<tr>
<td>Moscow</td>
<td>21523 A</td>
<td>mGal 981.551.35</td>
<td>551.33</td>
<td>551.31</td>
<td>551.31</td>
<td>551.32</td>
<td>-0.03</td>
</tr>
<tr>
<td>Potsdam A</td>
<td>21523 A</td>
<td>mGal 981.260.19</td>
<td>260.20</td>
<td>260.20</td>
<td>260.20</td>
<td>260.20</td>
<td>+0.01</td>
</tr>
<tr>
<td>Potsdam B</td>
<td>21523 B</td>
<td>mGal 981.260.70</td>
<td>260.72</td>
<td>260.72</td>
<td>260.72</td>
<td>260.72</td>
<td>+0.02</td>
</tr>
<tr>
<td>Potsdam L</td>
<td>21523 L</td>
<td>mGal 981.257.09</td>
<td>257.09</td>
<td>257.11</td>
<td>257.11</td>
<td>257.10</td>
<td>+0.01</td>
</tr>
<tr>
<td>Paris A</td>
<td>16082 A</td>
<td>mGal 980.925.97</td>
<td>925.99</td>
<td>925.99</td>
<td>925.99</td>
<td>925.99</td>
<td>+0.02</td>
</tr>
<tr>
<td>Paris O</td>
<td>16082 O</td>
<td>mGal 980.898.44</td>
<td>898.42</td>
<td>898.43</td>
<td>898.43</td>
<td>898.43</td>
<td>-0.01</td>
</tr>
<tr>
<td>Kyoto C</td>
<td>13155 C</td>
<td>mGal 979.707.75</td>
<td>707.69</td>
<td>707.73</td>
<td>707.74</td>
<td>707.72</td>
<td>-0.03</td>
</tr>
<tr>
<td>Tokyo B</td>
<td>13159 B</td>
<td>mGal 979.788.72</td>
<td>788.73</td>
<td>788.70</td>
<td>788.70</td>
<td>788.71</td>
<td>-0.01</td>
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<tr>
<td>Tokyo N</td>
<td>13159 N</td>
<td>mGal 979.758.08</td>
<td>758.05</td>
<td>758.09</td>
<td>758.09</td>
<td>758.08</td>
<td>0.00</td>
</tr>
<tr>
<td>Oahu-Honolulu B</td>
<td>06817 B</td>
<td>mGal 978.680.76</td>
<td>680.84</td>
<td>683.64</td>
<td>683.62</td>
<td>683.63</td>
<td>0.00</td>
</tr>
<tr>
<td>Mexico City C</td>
<td>04699 C</td>
<td>mGal 977.926.71</td>
<td>926.89</td>
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<td>927.15</td>
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<tr>
<td>Lima O</td>
<td>36827 D</td>
<td>mGal 979.292.37</td>
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<tr>
<td>Araquide K</td>
<td>36611 K</td>
<td>mGal 977.701.73</td>
<td>701.74</td>
<td>701.74</td>
<td>701.74</td>
<td>701.74</td>
<td>+0.01</td>
</tr>
<tr>
<td>Santiago A</td>
<td>44030 A</td>
<td>mGal 979.814.11</td>
<td>814.13</td>
<td>814.13</td>
<td>814.13</td>
<td>814.13</td>
<td>+0.02</td>
</tr>
<tr>
<td>Nemuro</td>
<td>980</td>
<td>mGal 663.63</td>
<td>663.84</td>
<td>663.64</td>
<td>663.62</td>
<td>663.63</td>
<td>0.00</td>
</tr>
<tr>
<td>Kushiro</td>
<td>980</td>
<td>mGal 596.51</td>
<td>596.53</td>
<td>596.55</td>
<td>596.54</td>
<td>596.54</td>
<td>+0.03</td>
</tr>
<tr>
<td>Sapporo</td>
<td>980</td>
<td>mGal 475.57</td>
<td>475.76</td>
<td>477.54</td>
<td>477.52</td>
<td>477.55</td>
<td>-0.02</td>
</tr>
<tr>
<td>Sapporo K</td>
<td>16631 K</td>
<td>mGal 426.52</td>
<td>426.50</td>
<td>426.49</td>
<td>426.49</td>
<td>426.49</td>
<td>-0.03</td>
</tr>
<tr>
<td>Hachinohe</td>
<td>980</td>
<td>mGal 360.64</td>
<td>360.85</td>
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<td>360.85</td>
<td>360.85</td>
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</tr>
<tr>
<td>Kakoike</td>
<td>980</td>
<td>mGal 966.43</td>
<td>966.39</td>
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<tr>
<td>Kyoto A</td>
<td>13155 A</td>
<td>mGal 979.707.27</td>
<td>707.18</td>
<td>707.22</td>
<td>707.23</td>
<td>707.21</td>
<td>-0.06</td>
</tr>
<tr>
<td>Kumamoto A</td>
<td>13120 A</td>
<td>mGal 979.551.62</td>
<td>551.68</td>
<td>551.66</td>
<td>551.66</td>
<td>551.67</td>
<td>+0.05</td>
</tr>
<tr>
<td>Kagoshima A</td>
<td>13110 A</td>
<td>mGal 979.472.15</td>
<td>472.18</td>
<td>472.16</td>
<td>472.17</td>
<td>472.17</td>
<td>+0.02</td>
</tr>
<tr>
<td>Naha</td>
<td>979</td>
<td>mGal 099.42</td>
<td>099.41</td>
<td>099.42</td>
<td>099.37</td>
<td>099.40</td>
<td>-0.02</td>
</tr>
</tbody>
</table>

*Dif.*: Difference between the mean value obtained and the gravity value given in the IGSN 71 / JGSN 75.
the JGSN 75 should be changed from \(-0.06\) mgals to \(0.00\) mgal.

On the other hand, as can be seen in Table 3, there exists a large difference between the value obtained and the gravity value for the Kumamoto A given in the IGSN 71 and the JGSN 75. The building, in which the Kumamoto A was established, was recently demolished, and it is therefore conceivable that the recent value of gravity is slightly larger than the former one. Therefore, the difference of \(+0.05\) mgals can be reduced.

4. Conclusion

Using the data obtained by two sets of international gravimetric connection and one set of domestic gravimetric connection, correction factors for the scale constant of the LaCoste & Romberg gravimeters G-29, G-118 and G-196 given by the manufacturer could be determined.

The international gravimetric connection between Japan and Europe and the domestic one in Japan were carried out as a project. But the international gravimetric connection between Japan and South America was supplementarily carried out during of travel to Peru and Chile to undertake observations of crustal movement.

The discrepancy between the value obtained in the present investigation and that given in the IGSN 71 and the JGSN 75 is generally less than \(+0.03\) mgals. This may mean that the present result is accurate in spite of unfavorable conditions.
The present investigation was supported by a Grant in Aid for Fundamental Scientific Research from the Ministry of Education in Japan. The numerical calculations were carried out with a computer system at the Data Processing Center of Kyushu University.

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at stations of small gravity difference, paper presented at the XVI General Assembly of IUGG, Grenoble, 1975.

I. NAKAGAWA, M. SATOMURA, E. ABE, K. KATSURA and S. NISHIMURA:

I. NAKAGAWA et al.:

I. NAKAGAWA, Y. TANAKA, M. SATOMURA, M. KATO and K. OIKE:

T. SETO and M. TAZIMA:
AUXILIARY GRAVITY STATIONS

at the "BUREAU INTERNATIONAL DES POIDS ET MESURES" (B.I.P.M.)

The fundamental gravity station is Sèvres Point A, on a concrete pier about 0.20 m below the level of the floor, in the room of the absolute gravity apparatus.

This site is highly recommended for all connections and more specially for the international measurements.

However in order to facilitate the current connections, excenters have been established, i.e. :

excenter B and C inside the limits of B.I.P.M. in the main yard,
excenter E outside the B.I.P.M. close to the entrance gate. (See diagrams).

The connections of these sites to the A station have been observed by the International Gravity Bureau using the LaCoste-Romberg gravimeter G.225 kindly lent by the "Centre Géologique et Géophysique" of Montpellier (Mr. Louis).

Two circuits have been observed clockwise and anticlockwise with closure on the A point.

\[ g \ (A \ - \ C) = -0.25 \ \text{mGal} \]
\[ g \ (C \ - \ E) = -0.12 \ " \]
\[ g \ (E \ - \ A) = 0.09 " \]
\[ g \ (B \ - \ A) = 0.26 " \]

The gravity values referred to the absolute A point run then:

\[ g_A = 980.925.96 \ \text{mGal} \]
\[ g_B = 980.926.24 \}
\[ g_C = 980.926.21 \}
\[ g_E = 980.926.33 \}

\[ \pm 0.02 \]

It should be noted that the \( 
\Delta g_{AB} \) value referred to A, differs from the previous value (\( \Delta g = 0.33 \)) due likely to some changes in the site (rise of the pavement).

Furthermore, a new site A_3 has been chosen by Dr. SAKUMA for the absolute gravity measurements performed with transportable apparatus.
SEVRES - pt C
CREATION DE 2 BASES GRAVIMÉTRIQUES
A L'AÉROPORT CHARLES DE GAULLE (France)
ROISSY

L'Aéroport du Bourget étant sur le point d'être fermé au trafic international, le B.O.I. a créé 2 bases gravimétriques au nouvel aéroport "Charles de Gaulle" à Roissy en France.


On y accède par l'Autoroute du Nord A.1 de Paris à Lille et Bruxelles, et également par des trains, bus et des cars Air France.

Deux stations ont été choisies dans l'aérogare, l'une en zone internationale, située vers les boutiques hors-douane, facilement accessible par les observateurs venant de l'étranger (sans formalités de douane et de police) et l'autre en zone française, au pavillon de réception (cour anglaise).

DETERMINATION OF 2 GRAVITY BASE STATIONS
AT CHARLES DE GAULLE AIRPORT (France)
ROISSY

The Bourget Airport being about to be closed to the international traffic, the I.G.B. determined 2 new gravity bases at the new "Charles de Gaulle" airport at Roissy en France.

This airport is located in the Northeastern suburb of Paris at Roissy, at about 23 kilometers of Paris-Center.

Means of access : Northern speedway A.1, from Paris to Lille and Brussels, and also trains, busses and Air France coaches.

Two stations have been chosen in the air-terminal, one in the international zone, in the duty free-shops area, easily accessible by any Observers coming from abroad (without authorization of Customs and Police Offices), and the other in French zone, at the welcome house (Pavillon de réception, "cour anglaise").
STATION R

Aérogaré N° 1. Oratoire catholique en zone internationale, étage transfert, dans la zone des boutiques hors-douane.
La station se situe à 70 cm devant le pilier de l'autel, et à 165 cm du mur gauche de l'oratoire.
Pour tous renseignements, demander l'Aumonier de l'aérogaré ou téléphoner au Service des Relations Extérieures de l'Aéroport : 862.17.91 ou 862.10.31

R STATION

Air terminal N° 1. Catholic oratory located in international zone, at transfer level, in the duty free-shops area.
The gravity point is situated at 70 cm in front of the altar pillar, at 165 cm of the wall of the oratory.
For all information, ask the Chaplain of the Air Terminal or call to "Service des Relations Extérieures de l'Aéroport" : 862.17.91 or 862.10.31.

Altitude of the station : 104,80 m
Latitude : 49°00'82
Longitude : 2°32'50 E.G.
g observed : 980 915,49 mGal

STATION S

Pavillon de réception, situé dans la zone technique de l'aéroport (zone française).
La station est située à l'extérieur, dans la cour anglaise, sous l'escalier conduisant au sous-sol du bâtiment.
Pour tous renseignements, téléphoner au Service des Relations Extérieures : 862.10.31 ou 862.10.33

S STATION

"Pavillon de réception" (welcome house), located in the technical zone of the airport (French zone).
The gravity point is situated outside, in the "cour anglaise", under the staircase, leading to the basement of the building.
For all information, call to:"Service des Relations Extérieures" 862.10.31 or 862.10.33

Altitude of the station : 99,60 m
Latitude : 49°00'76
Longitude : 2°32'09 E.G.
g observed : 980 917, 93 mGal
Gravimetry connections between
ROISSY Stations and 2 IGSN 71 Stations

The 2 ROISSY stations have been connected on one hand, to the absolute
gravity station SEVRES, on the other hand, to the IGSN 71 station : LE BOURGET
airport. (Hall, code 180 82 K).

The gravity connections have been carried out into two steps.

- SEVRES (Point B) + LE BOURGET (point K) and Roissy (point S) :

These measurements have been made on 21.03.1977 by "Le Bureau de
Recherches Géologiques et Minières" (B.R.G.M., Mr. Ogier) with a LaCoste-
Romberg gravimeter, model G, calibrated on american bases of the IGSN 71,
in February 1976.

The details of the measurements and the results are published in :
"Base gravimétrique fondamentale française : Paris - Toulouse - Pic du Midi
de Bigorre - liaison 1977", Mr. Ogier, B.R.G.M., Département Géophysique ;
77 SGM 431 GPH.

The results $\Delta g$ are as follows :

<table>
<thead>
<tr>
<th></th>
<th>Adopted value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Roissy (S) - Le Bourget (K) = -17,410</td>
<td>-17,395 - 17,397 - 17,40 mGal</td>
</tr>
<tr>
<td></td>
<td>- 17,385</td>
</tr>
<tr>
<td>Le Bourget (K) - SEVRES (B) = 9,105</td>
<td>9,085 9,090 9,09 mGal</td>
</tr>
<tr>
<td></td>
<td>9,085</td>
</tr>
<tr>
<td>SEVRES (B) - Roissy (S) = 8,310</td>
<td>8,305 8,31 mGal</td>
</tr>
<tr>
<td></td>
<td>8,300</td>
</tr>
</tbody>
</table>

Referring to SEVRES (point A), with $g = 0,28$ mGal + for the difference
SEVRES (B-A), it is obtained :

ROISSY (S) = 980 925,36 (SAKUMA value) \(0,28, -6,31\) 980 917,93 mGal

Referring to Le Bourget (K), it is obtained :

ROISSY (S) = 980 935,33 (IGSN 71 value) \(-17,40\) 980 917,93 mGal

- SEVRES (point A) with Roissy (S) and (R) :

These measurements have been carried out on 15.11.1977 by the
B.G.I. with the LaCoste-Romberg, model G-225, already used for the
relative gravity measurements at the B.I.P.M. The calibration factor
was the one given by the manufacturer.

Two there and return have been made between the 2 Roissy sites. The $\Delta g$ results are:

- Sèvres (A) - Roissy (S) = 8.06 mGal
- Roissy (S) - Roissy (R) = 2.445 ± 0.02

This first difference was neglected, the difference previously measured by the B.R.C.M. (8.03) was adopted.

**Gravity value at ROISSY**

Referring to Sèvres (point A) : 980 925 96 mGal (Sakuma's value), it is obtained:

- ROISSY (S, Pavilion, staircase) : 980 917.93 mGal
- ROISSY (R, catholic oratory) : 980 915.49 mGal

S. CORON
N.F. ESNOLI
Determination of the Absolute Value of Gravity in Singapore

One of the most important problems of modern gravimetry is a study of non-tidal gravity variations in time. At present there are various estimations of possible variations based on these or those assumptions on geodynamic processes occurring in the Earth. The values of annual gravity variations are thought to be of from several to many hundred mc gal per year. Therefore it is of a great scientific interest to carry out special high-precision repeated gravity determinations in those regions of the globe where the maximal variations of its value could be anticipated. The equatorial zone is the first such region.

Bearing in mind the abovesaid, the Institute of Physics of the Earth, USSR Acad. of Sci., jointly with the Institute of Automatics and Electrical Telemetry, Siberian Branch, USSR Acad. of Sci. made a determination of the absolute gravity value in Singapore in December, 1976. Measurements were performed with a laser gravimeter developed at the Institute of Automatics and Electrical Telemetry. The instrument and methods of its operations are described in /1/ /2/. These measurements were different from the earlier ones due to vibroprotection used in the instrument against the effect of vertical disturbing accelerations caused by micro- and vibroseisms.

In Singapore measurements were carried out on the territory of Singapore University in a separate pavilion where earlier radioactive substances were kept. The pavilion is on a bank of
a rather large swamp. The device was installed on a concrete floor. The installation site is shown on Fig. 1.

Before the departure to Singapore and after the return to Moscow control measurements of the absolute value of gravity in Ledovo (Moscow) were carried out at the International Gravimetric Point to control stability of the instrument operation. The device was installed on a concrete pillar directly above the mark N 5035/3.

Measurements with the absolute gravimeter were carried out as before in the following order. Each result of measurement introduced into processing was deduced as an arithmetical mean from 140–150 observations of free fall angular reflector. The drops followed one another each 15–20 seconds. These observations are completely automatized and at the end of each measurement we recorded the value of $g$ measured, its mean quadratic error and the number of performed drops. Such a measurement lasts about 40 minutes. After each measurement the control of the instrument adjustment is made. Then the instrument was switched on again and the subsequent measurement began. Two independent series of observations were made at each point. Each series consisted depending on observational conditions of 7–15 measurements.

To the measured $g$ values corrections were introduced for the $\Delta g_i$ time interval, $\Delta g_t$ Doppler effect, residual air resistance $\Delta g_r$, laser beam deviation from the vertical $\Delta g_\phi$, laser wave length $\Delta g_\lambda$, tidal gravity variations $\Delta g_\tau$ and the vertical gravity gradient to adjust the measured $g$ value to the surface of the pillar where the instrument was installed $\Delta g_H$. In Ledovo this correction was obtained from direct measurements made by a group of gravimetres. Its value appeared
to be equal to \( \pm 489 \pm 5 \) mcgal. In Singapore the correction for
the gradient was calculated assuming the vertical gradient equal
to the normal value of 308.6 mcgal per metre. Since the effective
height of the gravimeter \( H = 153 \) cm, the correction was assumed
to be equal to \( \Delta g_H = \pm 472 \) mcgal. Corrections \( \Delta g_i \), \( \Delta g_t \)
and \( \Delta g_q \) remained unchanged during all observations both in
Singapore and in Ledovo. The correction for tidal gravity vari-
ations was introduced according to specially calculated tables.

The arithmetical mean was calculated for each series of mea-
surements and by their convergency within the series – mean
quadratic errors of the arithmetic mean for this series.

Table I gives a summary of the results of all measurements
accomplished in Singapore and Ledovo. From these data it follows
that in Singapore a random error of measurements increased essen-
tially as compared with that in Ledovo. Its mean value for
Singapore appeared to be equal to \( \pm 38 \) mcgal whereas in Ledovo
it was \( \pm 14 \) mcgal. This was the result of large microseisms
generated by the Pacific ocean which could not be eliminated
entirely by seismic vibrational protection. As a result of this
a random error of \( g \) determination in Singapore appeared to
equal \( \pm 7.0 \) mcgal, and in Ledovo \( \pm 3.0 \) mcgal inspite of the fact
that in Ledovo the number of drops was by 454 less than in Sin-
gapore.

A total error of the absolute \( g \) value on definite points
is as follows:

\[
\begin{array}{c|c|c}
\text{Singapore} & \text{Ledovo} \\
\hline
\text{random error of } g \text{ measurements} & \pm 7 \text{ mcgal} & \pm 3 \text{ mcgal} \\
\text{laser wave length determination} & 8 & 8 \\
\text{error of the vertical} & 10 & 10 \\
\end{array}
\]
- error of correction determination due to air resistance 8 8
- error introduced by electron-computer block 3 3
- error of tide correction determination 2 2
- error of measured value reduction to the pillar surface 5 (?) 5

Hence the total error of determination of the $g$ absolute value as the quadratized sum of all mentioned errors for Singapore will be $\pm 17.7$ mcgal and $\pm 16.6$ mcgal for Ledovo.

An excellent convergence of the results of measurements in Ledovo before and after measurements in Singapore indicates a high stability of parameters of the absolute gravimeter. This allows to hope that the error of measurement of gravity value difference by this gravimeter can be reduced to the value of a random error of $g$ determination i.e. to the error on the order of $\pm 5$ mcgal.

So we have for

Singapore $g = 978.069.792 \pm 0.017.6$ mcgal
Ledovo $g = 981.551.337 \pm 0.016.5$ mcgal

Unfortunately due to technical reasons independent of executors of these measurements it was not possible to make this gravimetric connection of the new point with the IGSN-71 point. It is intended to be done during repeated determinations which are planned for the end of 1978 or beginning of 1979.

In conclusion I should like to express my deep gratitude to Prof. Radjaratnam, professor of the Singapore university for great assistance rendered to us during measurements and exceptionally cordial hospitality which made the stay of the participants of the expedition pleasant and interesting.

Moscow, October 22, 1977.

Yu. D. BOULANGER
Results of Measurements in Singapore (series I)

<table>
<thead>
<tr>
<th>NN</th>
<th>Date</th>
<th>Time of measurements</th>
<th>number of measurements</th>
<th>measured value</th>
<th>corrections</th>
<th>CORRECTED value</th>
<th>error of determination</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1976.12.18</td>
<td>16 20 - 16 50</td>
<td>110</td>
<td>978 069.410</td>
<td>+53</td>
<td>-11</td>
<td>-72</td>
</tr>
<tr>
<td>2</td>
<td></td>
<td>17 10 - 17 45</td>
<td>120</td>
<td>.422</td>
<td>+53</td>
<td>-11</td>
<td>-68</td>
</tr>
<tr>
<td>3</td>
<td></td>
<td>20 45 - 21 45</td>
<td>100</td>
<td>.262</td>
<td>+42</td>
<td>-6</td>
<td>+117</td>
</tr>
<tr>
<td>4</td>
<td></td>
<td>21 30 - 22 00</td>
<td>102</td>
<td>.172</td>
<td>+43</td>
<td>-6</td>
<td>+147</td>
</tr>
<tr>
<td>5</td>
<td></td>
<td>22 20 - 22 50</td>
<td>102</td>
<td>.172</td>
<td>+42</td>
<td>-6</td>
<td>+162</td>
</tr>
<tr>
<td>6</td>
<td></td>
<td>23 25 - 24 10</td>
<td>128</td>
<td>.225</td>
<td>+40</td>
<td>-26</td>
<td>+147</td>
</tr>
<tr>
<td>7</td>
<td>1976.12.19</td>
<td>0 20 - 0 55</td>
<td>123</td>
<td>.295</td>
<td>+41</td>
<td>-26</td>
<td>+110</td>
</tr>
<tr>
<td>8</td>
<td></td>
<td>1 10 - 1 50</td>
<td>145</td>
<td>.255</td>
<td>+40</td>
<td>-20</td>
<td>+62</td>
</tr>
<tr>
<td>9</td>
<td></td>
<td>2 10 - 2 50</td>
<td>130</td>
<td>.333</td>
<td>+42</td>
<td>-11</td>
<td>-2</td>
</tr>
<tr>
<td>10</td>
<td></td>
<td>3 10 - 3 50</td>
<td>137</td>
<td>.421</td>
<td>+42</td>
<td>-20</td>
<td>-56</td>
</tr>
<tr>
<td>11</td>
<td></td>
<td>4 10 - 4 50</td>
<td>142</td>
<td>.463</td>
<td>+41</td>
<td>-26</td>
<td>-87</td>
</tr>
<tr>
<td>12</td>
<td></td>
<td>5 10 - 5 50</td>
<td>141</td>
<td>.429</td>
<td>+41</td>
<td>-26</td>
<td>-88</td>
</tr>
<tr>
<td>13</td>
<td></td>
<td>6 10 - 7 20</td>
<td>234</td>
<td>.427</td>
<td>+41</td>
<td>-26</td>
<td>-45</td>
</tr>
<tr>
<td>14</td>
<td></td>
<td>7 40 - 8 20</td>
<td>136</td>
<td>.261</td>
<td>+40</td>
<td>-6</td>
<td>+31</td>
</tr>
<tr>
<td>15</td>
<td></td>
<td>8 40 - 9 20</td>
<td>145</td>
<td>.282</td>
<td>+40</td>
<td>-11</td>
<td>+95</td>
</tr>
</tbody>
</table>

Mean: 978 069.798 ± 7.2 mcgal

Corrections: for time interval \( \Delta q_t = -17 \) mcgal; for the Doppler effect \( \Delta q_t = 26 \) mcgal; for the deviation from the vertical \( \Delta q_{v} = -10 \) mcgal; for the vertical gradient \( \Delta q_{g} = +472 \) mcgal.
Results of measurements in Singapore (Series II)

<table>
<thead>
<tr>
<th>NN</th>
<th>Date</th>
<th>Time of measurements</th>
<th>number of drops</th>
<th>measured value</th>
<th>Corrections</th>
<th>Corrected value</th>
<th>Error of determination</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1976.12.19</td>
<td>11 30 - 12 10</td>
<td>136</td>
<td>978 069.191</td>
<td>+ 43</td>
<td>978 069.760</td>
<td>± 36</td>
</tr>
<tr>
<td>2</td>
<td></td>
<td>14 30 - 15 00</td>
<td>135</td>
<td>*384</td>
<td>43</td>
<td>*830</td>
<td>40</td>
</tr>
<tr>
<td>3</td>
<td></td>
<td>15 30 - 16 10</td>
<td>137</td>
<td>*361</td>
<td>43</td>
<td>*747</td>
<td>43</td>
</tr>
<tr>
<td>4</td>
<td></td>
<td>17 35 - 18 15</td>
<td>141</td>
<td>*446</td>
<td>40</td>
<td>*787</td>
<td>36</td>
</tr>
<tr>
<td>5</td>
<td></td>
<td>18 30 - 19 10</td>
<td>130</td>
<td>*388</td>
<td>40</td>
<td>*765</td>
<td>43</td>
</tr>
<tr>
<td>6</td>
<td></td>
<td>19 30 - 20 10</td>
<td>123</td>
<td>*341</td>
<td>40</td>
<td>*789</td>
<td>41</td>
</tr>
<tr>
<td>7</td>
<td></td>
<td>20 30 - 21 10</td>
<td>110</td>
<td>*316</td>
<td>40</td>
<td>*830</td>
<td>42</td>
</tr>
</tbody>
</table>

Mean: 978 069.787 ± 12.4 mcgal

Constant corrections: for time interval $\Delta g_t = -17$ mcgal; for the Doppler effect $\Delta g_d = -26$ mcgal; for the deviation from the vertical $\Delta g_\varphi = 10$ mcgal; for the vertical gradient $\Delta g_\eta = +472$ mcgal.
<table>
<thead>
<tr>
<th>Point</th>
<th>No. of Series</th>
<th>Date</th>
<th>N of Measurements</th>
<th>Number of Drops</th>
<th>Number of mgal</th>
<th>Number of mgal</th>
<th>Number of mgal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ledovo I</td>
<td>1</td>
<td>1976.12.08</td>
<td>7</td>
<td>990 ± 14</td>
<td>981 551.334</td>
<td>± 4.3</td>
<td></td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>1976.12.08</td>
<td>4</td>
<td>558 ± 14</td>
<td>0.338</td>
<td>± 4.5</td>
<td></td>
</tr>
<tr>
<td>Ledovo I</td>
<td></td>
<td>1976.12.08</td>
<td>11</td>
<td>1548 ± 14</td>
<td>981 551.336</td>
<td>± 3.1</td>
<td></td>
</tr>
<tr>
<td>Singapore</td>
<td>1</td>
<td>1976.12.18/19</td>
<td>15</td>
<td>1995 ± 36</td>
<td>978 069.798</td>
<td>± 7.2</td>
<td></td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>1976.12.19</td>
<td>7</td>
<td>912 ± 40</td>
<td>978 069.787</td>
<td>± 12.4</td>
<td></td>
</tr>
<tr>
<td>Singapore (mean)</td>
<td></td>
<td></td>
<td>22</td>
<td>2907 ± 38</td>
<td>978 069.793</td>
<td>± 7.0</td>
<td></td>
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<tr>
<td>Ledovo 2</td>
<td>1</td>
<td>1976.12.27</td>
<td>8</td>
<td>905 ± 26</td>
<td>981 551.339</td>
<td>± 5.1</td>
<td></td>
</tr>
<tr>
<td>Ledovo (mean)</td>
<td></td>
<td></td>
<td>19</td>
<td>2453 ± 20</td>
<td>981 551.337</td>
<td>± 3.0</td>
<td></td>
</tr>
</tbody>
</table>
SINGAPORE University

The point of absolute determinations of gravity is located in the pavilion 250 m to south-west of the building of the Geographical Faculty of the University, where the gravimetrical point Singapore A is situated. Previously the pavilion was used for storage of radioactive substances.
References


Yu. Boulanger, G. Armanov, R. Klish, Yu. Stus,
V. Tarasiuk, S. Stcheglov

THE ABSOLUTE VALUE OF GRAVITY ACCELERATION ON THE A_3 POINT AT SÈVRES

To compare the Soviet absolute ballistic gravimeter developed at the Institute of Automatics and Electrometry, Siberian Branch, USSR Academy of Sciences with the stationary absolute gravimeter of Prof. A. Sakuma a determination of the absolute value of gravity acceleration was made by a Soviet instrument on the A_3 point at Sèvres in September, 1977.

Before going to Paris and upon the return to Moscow with controlling purposes in view absolute gravity determinations were made on the International Gravimetric Point in Ledovo. The instrument was installed on a concrete pillar above the mark 5055 (2).

Measurements were accomplished by the same program as before /3/, /4/. Each measurement received to the processing, was obtained as the arithmetical mean out of 120-150 observations of the free incidence of angular reflector in vacuum. Drops followed one another each 15-20 seconds. Observations with gravimeter are completely automatized and at the end of each measurement the value of measured \( g \), its mean quadratic error and the number of drops performed were recorded.

Such a measurement lasts for about 30 minutes. Upon the end a control of the adjustment of the instrument is being made for about 20 minutes. Then the instrument is switched on again and a new measurement begins. At Sèvres 3 series of such measurements were performed. In tables 1, 2 and 3 the results of all measurements done in Sèvres are given. Table 4 gives a summary of measurements made in Sèvres and Ledovo.
To measured \( g \) values corrections were introduced for:

- \( \Delta g_t \): time interval,
- \( \Delta g_D \): Doppler effect,
- \( \Delta g_p \): residual air resistance,
- \( \Delta g_\phi \): deviation of the laser beam from the vertical,
- \( \Delta g_\lambda \): laser wave length variation,
- \( \Delta g_g \): tidal gravity variation,
- vertical gravity gradient for the adjustment of the measured \( g \) value to the pillar surface where the instrument is installed \( \Delta g_h \) and \( \Delta g_H \): Honkasalo correction.

When calculating the correction for the vertical gradient in Sèvres its value according to Prof. A. Salama's data was assumed to be equal to 273 mcgals/m. The vertical gradient in Ledovo was measured in 1975 by a group of gravimeters /3/ and /5/ and appeared to be equal to 320 ± 4 mcgals/m. The effective height of the instrument is both in Sèvres and in Ledovo equal to 132 cm.

The arithmetical mean was calculated then for each series of measurements. Within each series according to their convergence the mean quadratic error of the arithmetical mean of the given series was computed. A random error of the result was deduced by the convergence of series.

The total error of the absolute value of gravity on the points in Sèvres and Ledovo was deduced by summing up the following:

<table>
<thead>
<tr>
<th></th>
<th>Sèvres</th>
<th>Ledovo</th>
</tr>
</thead>
<tbody>
<tr>
<td>a random ( m_{g_0} ) error of ( g_0 ) determination</td>
<td>±2.4 mcgals</td>
<td>±4.2 mcgals</td>
</tr>
<tr>
<td>an ( m_\lambda ) error of the laser wave length determination</td>
<td>± 3</td>
<td>± 8</td>
</tr>
<tr>
<td>an ( m_\phi ) error of the vertical representation</td>
<td>± 10</td>
<td>± 10</td>
</tr>
<tr>
<td>an ( m_p ) error in determination of the correction for air resistance</td>
<td>± 8</td>
<td>± 8</td>
</tr>
<tr>
<td>an ( m_\delta ) error introduced by electron-computing blocks</td>
<td>± 3</td>
<td>± 3</td>
</tr>
</tbody>
</table>
- an \( \pm \) error of determination of the correction for the tide
- an \( \pm \) error of determination of the correction gradient

<table>
<thead>
<tr>
<th></th>
<th>Sèvres</th>
<th>Ledovo</th>
</tr>
</thead>
<tbody>
<tr>
<td>± 2</td>
<td>± 2</td>
<td></td>
</tr>
<tr>
<td>± 2</td>
<td>± 4</td>
<td></td>
</tr>
</tbody>
</table>

Hence the \( \pm \) total error of determination of absolute value obtained as quadrated sum of all the mentioned errors will be \( ± 15.8 \) mcgal for Sèvres and \( ± 16.5 \) mcgal for Ledovo.

A good convergence of the results of measurements in Ledovo after and before measurements in Sèvres and also with measurements performed earlier /3/, /4/ point to a rather high stability of parameters of the Soviet absolute gravimeter. This allows to assume the value of the total error of gravity determination by this instrument to be somewhat exaggerated and in reality it must be evidently close to its random part.

Thus we have obtained the following values of the absolute value of gravity for the points:

Sèvres A3 \( g = 980925938 \pm 16 \) mcgal
Ledovo 5035 \( g = 981551380 \pm 16 \) mcgal.

Let us compare the measured \( g \) value with similar \( g \) values obtained by Prof. Sakuma and by an italian instrument, the data on which were given to us by Prof. A. Sakuma (Table 5).

**Table 5**

<table>
<thead>
<tr>
<th>NN</th>
<th>Instruments</th>
<th>( g )</th>
<th>( M_g )</th>
<th>( P )</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>A.Sakuma 1976-1977</td>
<td>980925926 ( \pm 7 )</td>
<td>20</td>
<td></td>
</tr>
<tr>
<td>2.</td>
<td>Italian 1976-1977</td>
<td>980925925 ( \pm 10 )</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>3.</td>
<td>Soviet 1977</td>
<td>980925938 ( \pm 16 )</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td></td>
<td>the weight mean</td>
<td>980925927 ( \pm 5.4 )</td>
<td>34</td>
<td></td>
</tr>
<tr>
<td></td>
<td>the arithmetical mean</td>
<td>980925930 ( \pm 4.2 )</td>
<td>-</td>
<td></td>
</tr>
</tbody>
</table>
The convergence of all three determinations appeared to be a very good one. Discrepancies between the instruments appeared to be less than the total errors ascribed to them.

In conclusion let us compare the mean \( g \) obtained by three instruments with the \( g \) value given in the catalogue IGSN-71 for Sèvres.\(^1\) We have:

\[
\begin{align*}
\text{Determinations 1976-1977} & \quad 930925930 \pm 4 \text{ mgal} \\
\text{IGSN-71} & \quad 930925230 \pm 14 \text{ mgal}
\end{align*}
\]

\[
\text{Difference} \quad + 50 \pm 15 \text{ mgal}
\]

The obtained result: is of a very high scientific interest. A question arises: what is it – a systematic error which penetrated to earlier determinations or a result of gravity variation in Sèvres caused by deep tectonic reasons or reasons of local character?

The authors express their most sincere gratitude to Prof. A. Sakuma and Prof. J. Terrien, Director, Bureau International des Poids et Mesures for the opportunity they have given us to carry out the described measurements in Sèvres and for a great assistance in their organization.

\(^1\) Reduced to the A3 point, new site chosen for the absolute measurements made with transportable apparatus.
**Table 1**

Point: Sèvres A3  
Series: 1  
Date: September 12-13, 1977  
h = 132 cm  
Gradient: 273 mgal/m  
g = 980925934 mgal

<table>
<thead>
<tr>
<th>NN</th>
<th>Time of observations</th>
<th>g_i (m)</th>
<th>m</th>
<th>n</th>
<th>(\Delta g )</th>
<th>(\Delta g _f )</th>
<th>(\Delta g _p )</th>
<th>(\Delta g _q )</th>
<th>(\Delta g _r )</th>
<th>(\Delta g _h )</th>
<th>(\Delta g _y )</th>
<th>(\Delta g _u )</th>
<th>(g )</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>19 30 - 20 00</td>
<td>629</td>
<td>±25</td>
<td>129</td>
<td>-18</td>
<td>-24</td>
<td>+38</td>
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<td>938</td>
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\[ \bar{m} = \pm 20 \quad 1432 \]

\[ g = 980 \quad 925 \quad 934 \text{ mgal} \]

\[ m_g = \pm 17.7 \text{ mgal} \]

\[ M_g = \pm 5.4 \text{ mgal} \]

\[ n = \text{number of drops} \]
### Table 2

**Point: Sœvres A₂**

Series: 2  Date: September 13-14, 1977  h=132 cm  Gradient = 273 mogal/m

$$\text{= 980 925 941} \text{ mogal}$$

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<th>$m$</th>
<th>Number of drops</th>
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<th>$\Delta g_P$</th>
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$$\bar{m} = \pm 18 \text{ 1489}$$

$$\bar{g}_{m,g} = \pm 9 \text{8 mogal}$$

$$\bar{g}_{m,g} = \pm 2 \text{8 mogal}$$
Table 3

Points: Sèvres A

Series: 3; Date: September 19-20, 1977; $h = 132$ cm; Gradient = 273 megal/m

\[ g = 980 \, 925 \, 939 \text{ megal} \]

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<tr>
<th>NN</th>
<th>Time of observations</th>
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<th>$m$</th>
<th>Number of drops</th>
<th>$\Delta G_i$</th>
<th>$\Delta G_l$</th>
<th>$\Delta G_p$</th>
<th>$\Delta G_q$</th>
<th>$\Delta G_r$</th>
<th>$\Delta G_h$</th>
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<th>$\Delta G_h''$</th>
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<td>360</td>
<td>-6</td>
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\[ m = \pm 20 \, 1328 \]

\[ g = 980 \, 925 \, 939 \text{ megal} \]

\[ m_g = \pm 11.6 \text{ megal} \]

\[ M_g = \pm 3.7 \text{ megal} \]
### Table 4

A summary of absolute measurements in Ledovo and in Sèvres

<table>
<thead>
<tr>
<th>Point</th>
<th>NN of the series</th>
<th>Date of measurements</th>
<th>Number of measurements</th>
<th>Mean error of one determination</th>
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<td>$980.925.938 \pm 2.2$</td>
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</table>

References


LISTE des PUBLICATIONS
reçues au
BUREAU GRAVIMETRIQUE INTERNATIONAL
(Juin à Décembre 1977)

CONERNANT LES QUESTIONS DE PESANTEUR

A set of 38406 1° x 1° anomalies were compiled starting from a smaller set supplied by the Defense Mapping Agency Aerospace Center. These anomalies using least squares prediction techniques and a direct mean approach. Several different covariance functions were used to examine their effect on the resultant prediction and accuracy. On the average the estimation is insensitive to the covariances used with the largest differences occurring when there was only a few known 1° blocks within the 5° block. The direct mean estimation process was not considered as good as the least squares estimation because the estimated anomaly field was too rough when compared through anomaly degree variance data derived from satellite data. A complete 1654 5° anomaly set was formed by estimating the 157 remaining blocks using the 10 closest previously predicted values.

The determination of potential coefficients from this data was made considering a smoothing operator as well as the effects of the atmosphere, a spherical approximation, and the effect of the terrain. The smoothing operator is important in these studies above degree 10. The terrain correction effects amount to 10 to 25% of the low degree coefficients; however, the actual corrections can only be approximated with such approximations not yielding improved solutions at this time. Potential coefficients and their accuracy were computed and listed to degree 52. Tests indicate that it is imperative to use integrated kernel expressions in these computations above degree 5. Anomalies were computed from the potential coefficients for comparison to the original anomalies. Tests showed that the agreement improved considerably as the degree increased to the maximum considered. These tests shed some doubt on the rule of thumb that a block of size theta can be represented by a spherical harmonic expansion to 180/theta.


Astronomical data compiled during the last 70 years by the international organizations (ILS-IPMS, BIH) providing the coordinates of the instantaneous pole, clearly shows a persistent drift of the "mean pole" (= barycenter of the wobble).

This study was undertaken with a specific objective in mind: to investigate the possibility of a true secular motion of the barycenter; that is, an actual movement of the Earth pole of figure resulting from differential mass displacement due to lithospheric plate rotations.

The method developed assumes the Earth modeled as a mosaic of 1° x 1° crustal blocks, each one moving independently in accordance with their corresponding absolute plate velocities.

The differential contributions to the Earth's second-order tensor of inertia were obtained and applied, resulting in no significant displacement of the Earth's principal axis.

In view of the above, the effect that theoretical geophysical models for absolute plate velocities may have on an apparent displacement of the "mean pole" as a consequence of station drifting was analyzed.

The investigation also reports new values for the crustal tensor of inertia (assuming an ellipsoidal Earth) and the orientation of its axis of figure, reopening the old speculation of a possible sliding of the whole crust over the upper mantle, including the supporting geophysical and astronomical evidence.

ACADEMIE des SCIENCES de l'U.R.S.S. - Références bibliographiques :
Géodésie et Astronomie, Série 52.

440 - N° 12, 45 p, Moscou, 1976.
441 - N° 1, 39 p, " 1977.
442 - N° 2, 32 p, " 1977.
446 - N° 6, 38 p, " 1977.
448 - N° 8, 52 p, " 1977.


CENTRE NATIONAL pour l'EXPLOITATION des OCEANS - Bulletin d'Information.

Mémoires de l'Inst. Géod. Danemark, 3ème sér., 43ème tome, 73 p + maps :
I - Navigation tracks
II - Free-air anomaly contours $E = 10$ mGal
III - Bouguer anomaly contours $E = 5$ mGal
Copenhagen, 1977.
List of about 7000 points with geographical coordinates, depth and the free-air and the Bouguer anomalies.
In the period 1970-75 sea gravity measurements were carried out by the Danish Geodetic Institute with the purpose of procuring a uniform gravity survey of the waters around Denmark. This project was carried out in continuation of the early Skagerrak Survey of 1955-56.
The results of the project are presented in this paper.

This compilation is one of the end products of a research programme which began at Leicester University in 1965. It supersedes previous catalogues by SEARLE and DARRACOTT (1971) and KHAN, MANSFIELD and SWAIN (1972), although, for reasons to be discussed later, not all the data listed in those catalogues are included here.
A pre-print of the gravity map on the scale 1/2 000 000 and based on the 8709 stations listed is included here.
The data are catalogued in one degree squares in order of source and station number. The datum used in reducing the gravity observations is defined by the IGSN 71 together with the 1967 gravity formula (IAG 1967). Terrain corrections have been made for 8447 stations, that is for all except the oil company data. Gravity units (g.u.) have been used throughout. (1 g.u. = 0.1 mGal = 10^-5 ms^-2).

466 - ROTSTEIN Y., J. COMBS & S. BIEHLER - "Gravity investigation in the southeastern Mojave Desert, California".
A gravity investigation consisting of some 900 stations was conducted over an area of approximately 3 500 km^2 between the Eagle Mountains and the Colorado River in the southeastern Mojave Desert to define the major anomalies. The data were reduced to the complete Bouguer anomaly and presented on a contour map. The density contrasts that exist between the basin sedimentary rocks and the underlying basement rock produce gravity anomalies that can be readily delineated by gravity surveys. Several gravity anomalies are associated with regional structural trends particularly faults. Two-dimensional model analyses along profiles across five major anomalies are presented to show the distribution and depth of sedimentary deposits.
Subsurface geology in the area is poorly known. Analysis of the gravity anomalies, however, indicates that the basement beneath the sedimentary basins is highly faulted, consisting of complex structures and rapidly varying rock types similar to those in the mountain ranges of the area. In the center of the several subdivisions of the Chuckwalla Valley, depths to basement range from less than 200 m to more than 2 km. The Pah Leap Valley is shallow in the northern section yet reaches a probable depth of over 1.5 km in its southern portion. The Palo Verde Valley east of the Chuckwalla Valley is divided into two separate structural styles. A northwest trending sedimentary basin in the north has a maximum depth of at least 2 km, while basement to the south is generally more flat and less deep. The structural and geological information inferred from the gravity data and resultant anomalies provides important input toward a better understanding of the geology in the area.

467 - BUCKLEY J.S. & R.J. BAILEY - "A free-air gravity anomaly contour map of the Irish Continental margin".

Compilation of currently available gravity data permits the construction of a free-air anomaly contour map of the continental margin west of Iceland (51° - 54°N). Major elements in the structure of the margin, previously delineated on the basis of seismic reflection and magnetic surveys are clearly seen on the FAA contour map, notably the Porcupine Seabight Trough, and Porcupine Ridge. However, contrary to earlier ideas, the gravity data imply that the Seabight Trough extends northwards onto the Slyne Ridge, and the Slyne Trough, formerly regarded as northeasterly prolongation of the Seabight Trough, appears to be a discrete, fault-bounded, feature separated from the latter by a basement ridge. East-west gravity profiles are modelled in terms of thinned crust with the Moho at a minimum depth of 15 km beneath the axis of the Seabight Trough. The models tend to support hypotheses invoking formation of the Seabight Trough by simple westward translation of Porcupine Ridge with respect to the Irish Mainland.

468 - SABET M.A. - "Gravity and magnetic investigation, Eastern shore area, Virginia".

A simple Bouguer gravity map and a total magnetic intensity map were made for the Eastern Shore area of Virginia. Both maps exhibit a great similarity, thus suggesting that the density contrast between the crystalline basement and the overlying sediments is the main source of the gravity anomalies. The maps show two major anomaly trends, north, and N. 30°W. The northwest end of a trough that trends N. 30°W. appears to occupy the northern half of the area and extends southeastward toward the Atlantic Ocean. It also appears to be separated from the adjacent Solisbury embayment, on the subaerial coastal plain, by a large basement uplift centered over the town of Circletree, Maryland.

Quantitative interpretations of the gravity map were made along three profiles.

.../...
The thicknesses of the sedimentary rocks in the vicinity of the town of Cheriton, between the towns of Exmore and Melfa, and near Wallops Island are estimated to be 7,200; 2,200; and 6,300 ft (2,195; 670 and 1,920 m), respectively. A fault trending N. 30°W. through Exmore is also suggested; if present, its structural throw would be about 1,300 ft (400 m).

469 - INSTITUTO GEOGRÁFICO MILITAR, Departamento Geofísico -
"Mediciones gravimétricas en Bolivia".
185 p. + mapas de anomalías de Bouguer y Air Libre, La Paz, 1974.

La presente publicación, preparada por el IGM e IGB de Bolivia, incluye la relación de objetivos que nos proponemos con ella, un breve bosquejo histórico, la relación de datos de las estaciones fundamentales de Bolivia y de la Red Nacional (La Paz - Santa Cruz), trabajos ejecutados en prospección petrolera, enlaces internacionales, los gravímetros empleados, y la relación de los datos observados y calculados para las estaciones ocupadas en 18 años de trabajo. Asimismo, se adjunta a escala reducida los mapas de Bolivia de Anomalías de Bouguer y Air Libre (mas o menos de 7300 estaciones).

470 - LODEO M. - "The gravitational attraction of a right polygonal prism".

Closed formulae are presented for calculating the vertical component of the gravitational attraction of a right polygonal prism. They offer large possibilities of approximating a buried body and need short calculation times on an electronic computer.

478 - COCHRAN J.R. & M. TALWANI - "Free-air gravity anomalies in the world's oceans and their relationship to residual elevation".

Surface-ship gravity measurements were used to obtain 5° x 5° average free-air gravity anomalies over much of the world's oceans. Comparison of the surface data with the recent GEM 6 "combination" field shows the combination solution to be in reasonable agreement with the surface data in most areas in the general location and amplitude of major features of the Earth's gravity field. There is, however, significant disagreement on the location of extrema and on the exact values at specific points. It is thus necessary to use surface data to make detailed studies of the relationship of the gravity field to surface features at wavelengths of less than 4000 km. Mid-ocean ridges are consistently characterized by a gravity maximum. The gravity anomaly across mid-ocean ridges can be described by an empirical 1° x 1° average gravity-age relationship which shows a positive gravity anomaly of about 25 mGal falling off to zero by about 40 my. The observed gravity-age relationship is generally compatible with current thermal models of the lithosphere. The empirical gravity-age curve was removed from the free-air anomalies to produce residual gravity anomalies which can be compared to similarly obtained residual depth anomalies.
A correlation between the two is found over some features. The most prominent of these are intermediate wavelength positive features associated with areas of extensive off-ridge volcanism. This applies not only to recently active areas but also to inactive areas such as Bermuda and assimic ridges. On the other hand, areas of unusual elevation and volcanic activity located at a mid-ocean ridge crest such as Iceland and the Azores do not have a corresponding gravity anomaly at intermediate wavelengths. The long-wavelength component of the Earth's gravity field is characterized by large areas in which significant anomalies of constant sign are found. There is no apparent relationship between the long-wavelength gravity anomalies and oceanic depths. If the gravity anomalies have their origin within the asthenosphere, the lithosphere must in effect be decoupled from the main body of the asthenosphere. This could result from the effects of a strongly depth-dependent viscosity on the convection pattern under the elastic plates.


The paper presents a unified least-squares method (collocation) which encompasses least-squares adjustment and least-squares prediction. This method is being applied to the determination of the terrestrial gravitational field and of geodetic position by combining data of different kind. The relationship between this method and geophysical inverse problems is discussed.


The deviation of the vertical and geoid undulation components of the disturbing potential are estimated using a combination of geopotential coefficients and surface gravity data. Least squares collocation is used in the inner-zone and Vening Meinesz's and Stokes' integral formulae in the outer-zone. The radius of the inner-zone depends upon the density of the gravity data in this zone and the capabilities of the computer available. The radius of the outer-zone is a function of the set of geopotential coefficients used to calculate the global effects of the disturbing potential on the two components of the deviation of the vertical and the geoid undulation at the computation point.

.../...
The method is tested by estimating components of the deviation of the vertical and geoidal undulations at several points located in Canada. The corresponding estrogeodetic deviations of the vertical and Doppler derived geoidal undulations provide external comparison standards to obtain realistic accuracy estimates. Goddard Earth Model 8 is used to calculate the global effects of the disturbing potential. A radius of 8° for the outer-zone is found to be appropriate; the radius of the inner-zone varies between 0°7 and 1°5 depending on the density of the gravity data in the inner-zone.


It has been suggested (MATHER 1973) that the changes in absolute gravity measured at a global network of stations, could be used to monitor the motion of the geocentre in relation to this network. Such information is of value in high precision geodesy as dynamic satellite techniques are always referred to the instantaneous geocentre. Gravity changes are simulated at such a network of stations over epochs up to 10^2 yr.

These changes in gravity, in addition to contributions from the seasonal, Chandler period and secular motion of the pole, together with those due to models of Earth expansion and changes in the flattening of both the meridian and equatorial ellipses concomitant with current estimates of plate motion, also take into account variable amounts of random noise as well as the effects of seasonal phenomena.

The simulated data banks were analysed to study the effect of the following factors on the resolution with which the above quantities of geodynamic interest are determined:

- The interval of time over which the changes are measured.
- The extent of random noise in the data.
- The distribution of the absolute gravity measuring sites at the surface of the Earth.

It is concluded that information of adequate accuracy for maintaining geodetic systems of reference for secular geodynamics could be obtained from a network of 25 well distributed stations using data collected over at least 10 years in the presence of noise at the 10 μGal level even if the representation in polar and oceanic regions were non-existent. The resolution drops by a factor of two if the noise level were increased to 20 μGal. Even such results could be helpful in modelling secular geodynamic phenomena of relevance in maintaining geodetic reference systems in four dimensions.


A relatively simple double pass method is used to

a) reduce longitudinal spread of satellite navigation fixes and,
b) obtain antenna height or sea level height on board a ship in a fixed harbor or fixed open-sea position (over an acoustic beacon).
Required are the satellite navigator output of latitude, longitude, elevation angle, and path geometry for two consecutive passes (one E and one W of the site) of the same satellite.

Sea level height thus determined on board the R.V. Kana Kaoki in harbors around the Pacific and on board the Glomar Challenger in position over Deep Sea Drilling Project sites in the Atlantic show good agreement with geoidal height models.

Determining sea level (with respect to the Navigation Satellite Reference) using the double pass method thus provides an important independent alternative to Sky Lab Radar Altimetry for the measurement of geoidal height over the open oceans.


a) SCHWARZ K.P. & J. KRYNSKI - "Improvement of the geoid in local areas by satellite gradiometry".
  p. 163-176.

Satellite gradiometry is studied as a means to improve the geoid in local areas from a limited data coverage. Least-squares collocation is used for this purpose because it allows to combine heterogeneous data in a consistent way and to estimate the integrated effect of the attenuated spectrum. In this way accuracy studies can be performed in a general and reliable manner.

It is shown that only three second-order gradients contribute significantly to the estimation of the geoidal undulations and that it is sufficient to have gradiometer data in a $5^\circ \times 5^\circ$ area around the estimation point. The accuracy of the geoid determination is strongly dependent on the degree and order of the reference field used. An accuracy of about $\pm 1 \text{ m}$ can be achieved with a reference field of (12,12). There is an optimal satellite altitude for each reference field and this altitude may be higher than 300 km for a field of low degree and order. The influence of measuring errors is discussed and it is shown that only gradiometer data with accuracies better than $\pm 0.05 \text{ m}$ will give a significant improvement of the geoid. Finally, some results on the combination of satellite gradiometry and terrestrial gravity measurements are given.

The proposed method seems to be well suited for local geoid determinations down to the meter range. It is especially interesting for unsurveyed and difficult areas because no terrestrial measurements are necessary. Furthermore, it has the practical advantage that only a local data coverage is needed.

b) NAKAGAWA I. & M. SATOMURA - "Gravity change observed near Lake Biwa, Japan"
  p. 213-218.

Precise gravity measurements have repeatedly been carried out in the area around Lake Biwa in Japan since 1950 in order to detect the secular change of gravity. The results obtained so far show that gravity change observed on the west line of the first order levelling route around the lake during the period of 1971 - 1975 was consistent with the results of levelling surveys. This evidence shows that precise gravity measurement is one of the powerful methods for detecting vertical crustal movement.
c) DUFOUR H.M. - "Fonctions orthogonales dans la sphère - Résolution théorique du problème du potentiel terrestre".
   p. 227-236.

   Il est possible de définir des fonctions orthogonales dans la sphère, capables d'approximer en norme euclidienne toute fonction à variation bornée (potentiel, densité).

   La représentation de la densité étant supposée donnée, on trouve le potentiel intérieur et extérieur, et l'on montre notamment que seul le sous-ensemble harmonique de la densité interne produit un potentiel externe non nul.

   Cet article a été présenté à Oberwolfach (République Fédérale Allemande) au cours des journées d'études sur les problèmes mathématiques en géodésie (Mars 1976), organisées par E. GRAFarend et R. Leis (Tagung über Mathematische Probleme der Geodäsie, Mathematisches Forschungsinstitut, Oberwolfach).


a) JOD I. - International Symposium on Satellite Geodesy in Budapest,
   June 28 - July 1, 1977.
   p. 249-252.

b) RAPP R.H. - "Determination of potential coefficients to degree 52 from 5° mean gravity anomalies".
   p. 301-323.

   A set of 38406 1° x 1° mean free-air anomalies were used to derive a set of 1507 5° equal area anomalies that were supplemented by 147 predicted anomalies to form a global coverage of 1654 anomalies. These anomalies were used to derive potential coefficients to degree 52 using the summation formulae. In these computations, a smoothing operator was introduced and found to significantly effect the results at higher degrees. In addition, the effects of the atmosphere, spherical approximation and terrain were studied. It was found that the atmospheric effects and spherical approximation effects were about 0.3 % of the actual coefficients. The terrain correction effects amounted to 10 to 25 % of the low degree coefficients depending on a specific terrain correction model chosen; however, the correction terms found from the models did not yield solutions that agreed better with current satellite derived potential coefficient determinations.

   Anomalies were computed from the derived potential coefficients for comparison to the original anomalies. These comparisons showed that the agreement between the two anomalies became significantly better as the degree of expansion increased to the maximum considered. These comparisons shed some doubt on the rule of thumb that a block of size 8° can be represented by a spherical harmonic expansion to 180° / 8°

487 - ISAEV E.N. & M.A. MITWALLI - "Gravity studies in the Sudan, Part I : Gravity Bases".
   Ministry of Ind. & Mining, Geol. & Mineral Res. Dept., Bull. n° 26,

.../...
This bulletin is mainly a reference to gravity base stations in Sudan. Establishment of these base stations was an effort of several observers including the authors who tried to collect these base stations in a bulletin and analyze them so that they can readily available in a better form to anyone who is interested in them. In such a collection, these bases can also be a start point for further development of more base stations in the country.


Interpretation of the results of aero magnetic, total-gamma radioactivity, and gravity surveys, combined with geologic data for western Liberia and other geologic information, allows the construction of a tectonic map of Liberia. ...

A regional gravity survey was made of the country along the coast using available roads and along tidewater rivers in western Liberia and showed a 50 to 60 mGal (milligal) positive Bouguer anomalous area extending along the coast from Sierra Leone to Ivory Coast. This anomaly correlates with mafic granulites in the Monrovia region, where the gradient is too steep to be entirely due to crustal thickening at the continental margin. The only major break in this positive anomaly above basement rocks along the entire coast of Liberia is above granitic gneiss adjacent to (and presumably underlying) the only onshore basins of the coast. Local negative Bouguer anomalies exist over two Cretaceous basins in the coastal area. The high mean free-air anomaly of ~22 mGal (exclusive of the coastal anomaly) suggests that the approximately 200 m mean elevation of Liberia is not compensated, at least over the Liberia region. A linear regression, showing a significant correlation of elevation with Bouguer anomaly, has a zero elevation intercept of ~18 mGal, again indicative of an isostatic anomaly. The standard deviation of ~14 mGal from the Bouguer anomaly elevation regression line is indicative of the amplitude range of local geologic anomalies. These include a 30 mGal anomaly above an ultramafic intrusion near Juuzohn and an approximate 30 mGal anomaly associated with a mafic intrusion at Cape Mount. A suggested crustal model computed to fit observed marine and land Bouguer anomalies shows an abrupt thickening at the continental margin, several kilometers of sedimentary rock on the continental slope, uplifted dense lower crustal rocks at shallow depths beneath the continental shelf southeast of Greenville, and a high mean crustal density.

A suggested sequence of events indicates particularly uplift of Liberia to a mean elevation of about 200 m without apparent isostatic compensation.

This report contains the invited papers which were presented at the International Symposium "The Changing World of Geodetic Science" which was held October 6-8, 1976, at the Fawcett Center for Tomorrow, The Ohio State University, Columbus, Ohio.

The Symposium was arranged as the culmination to the 25th year celebration of the teaching of geodetic science at The Ohio State University. The theme of the Symposium was developments in geodetic science during the past 25 years and those to be expected in the next 25 years with emphases on current and future developments.

Among the papers presented, it can be mentioned:

Session II

CORDOVA W.R. - "New concepts in Geodetic Instrumentation". p. 73-97.


KAULA W.M. - "Geophysical inferences from statistical analyses of the gravity field". p. 119-141.

Session III

MORITZ H. - "Changing techniques of gravimetric geodesy". p. 142-149.


WILLIAMS O.W. - "Does geodesy have a future?". p. 230-234.


A simulated field of gravity anomalies and second-order gradients is used to study the recovery of gravity anomalies at ground level from measurements at flight level.

The spectral properties of gravimetric quantities simulated by an array of mass points are discussed for first and second order gradients and some rules are derived for generating such fields. To study the effect of observational errors, uncorrelated normally distributed errors and correlated errors from a stationary Markov sequence are used. Results agree well with estimates obtained in a previous accuracy study.

Computations show that a fast operational program can be obtained by using a least-squares collocation procedure. The programs and a sample computation are part of the report.
492 - RAPP R.H. - "The use of gravity anomalies on a bounding sphere to improve potential coefficient determinations".

The precise determination of potential coefficients from terrestrial gravity data requires that, among other things, the topography of the Earth's surface must be considered. This paper first formulates a procedure where the potential coefficients can be determined using anomalies determined on a sphere that encloses the mass of the Earth. The resultant equations can also be formulated to compute correction terms to potential coefficients derived from uncorrected surface free-air anomalies. In order to obtain the anomalies on the bounding sphere the method of least squares collocation was investigated. The computation of anomaly correction terms for 1854 5° equal area blocks was carried out with the largest correction being 5.1 mGal with the root mean square value being + 0.9 mGal. Using these correction terms and previously derived potential coefficients from terrestrial gravity data, an improved set was derived. From degree 5 to degree 20, the improved set showed slightly better agreement with the GEM 3 (satellite derived) potential coefficients than the original coefficients. The correction of the original coefficients was small, however, being 1.8% of the original coefficients at degree 2, rising to 7.5% at degree 40.

Finally, the anomaly correction terms were used to obtain an improved comparison of satellite derived 5° anomalies and terrestrial data. This was done by using the satellite determined potential coefficients to derive anomalies on a bounding sphere which were then downward continued to the surface. These anomalies showed a better agreement with the observed anomalies than did anomalies computed directly on the surface (mean square difference: 108 mGal² vs. 91 mGal²).

493 - MORITZ H. - "On the computation of a global covariance model".

The report treats the problem of determining a global covariance function if the following data are given: the variances of the gravity anomalies, the variance of second-order gradients, the correlation length, and the lower degree variances. The proposed covariance model is a linear combination of the reciprocal distance covariance function and a covariance function of logarithmic type.

It is found that the correlation length is already fixed, within rather narrow limits, by the remaining data.

494 - AMES C.B., R.B. CLARK, P.M. LAHUE & R.W. PETERSON - "Rotating gravity gradiometer development".

The purpose of this contract was to further the development of the Hughes Rotating Gravity Gradiometer (RGG); this effort is a direct continuation of two prior Air Force contracts. The stated performance objective for these contracts was the design, construction and demonstration of the Rotating Gravity Gradiometer capable of operating in an airborne environment and producing no more than one (1) E/√h² unit (EU) of noise, at an equivalent ten-second integration time, in the determination of the components of a gravity gradient tensor.

.../...
The scope of effort in this contract was limited to studies and performance tests and demonstrations in the laboratory environment. Two RGG sensors were involved. The first, RGG-1, was built in 1974 and 1975 under the prior contracts. The second, RGG-2, was designed and built during the course of this contract. The initial scope of work included various tasks to test and modify RGG-1, with the goal of determining configuration changes to be incorporated in RGG-2.

The design for RGG-2 was frozen in April 1976; however, RGG-1 testing continued through November 1975. RGG-2 was assembled and ready for grooming and initial performance evaluation by December 1975. Since this contract was completed on 31 January 1977, the period of RGG-2 performance evaluation was limited to a brief span of a few weeks. However, during that short time, it was conclusively demonstrated that significant progress had been made toward achieving the ultimate performance goals.

Specifically, the performance results obtained with RGG-2 demonstrate that:
1) The design goals have been met for thermal and electronics noise,
2) The sensor output noise goals have nearly been met for the vertical spin axis orientation,
3) Considerable optimism is warranted that the sensor output noise goals can be met for the horizontal spin axis orientation,
4) Continued development is both necessary and warranted.

A second purpose of this contract was to study the requirements of a platform needed to stabilize up to three RGG sensors in an airborne mapping environment. The results of this study, conducted under subcontract by Incosym, Inc., is reported in Volume II of this Final Report. The study results are encouraging, particularly because an existing DoD platform has been identified as being suitable to support a triad of RGG sensors.

In summary, the availability of a platform and the performance success of RGG-2 permit immediate consideration of a follow-on program which would test and demonstrate all the components of a gravity gradiometer system. It is the recommendation of this report that the Hughes RGG sensor be integrated with a platform at the earliest possible time, and tested in the laboratory environment. It is also the recommendation of this report that the RGG-1 sensor be retrofitted up to the RGG-2 configuration to permit simultaneous development and test efforts.


A lunar laser ranging facility was established at Orrroral Valley, Australia by the Australian Division of National Mapping with the assistance of the Smithsonian Astrophysical Observatory with equipment obtained from the Air Force Geophysics Laboratory. Range measurements to lunar reflectors are made from this facility regularly. Some equipment problems must still be overcome before this observatory becomes fully operational.

One of the most important objectives accomplished during the present analysis has been the upgrading of the AFGL computer program SAGG (Satellite Altimetry and Ground Gravity). This program serves in the determination of the global geoid and the Earth's gravity field, based on the combination of satellite altimetry observations and gravity anomalies. A typical feature of SAGG is the simultaneous recovery of both the orbital parameters and the spherical harmonic potential coefficients. The short arc adjustment mode makes these determinations possible without the requirement of highly precise reference orbits. Perhaps the most important refinement in SAGG has been the differentiation of the radial distance to a sub-satellite geoidal point with respect to the state vector parameters. A practical benefit of this feature is faster convergence in the adjustment, which as removed the need for iterated solutions.

The new version of SAGG has been used in a combined adjustment of real data, in conjunction with a (14, 14) geopotential model. A comparison of internal precision has demonstrated the beneficial effect of adding altimetry data to the existing body of gravity anomaly data. However, adding this relatively new and completely independent source to a more traditional type of data in a combined adjustment is benefi-
cial also for other reasons, such as increasing the external reliability of the results. The recovered geoid over most of the globe shows good agreement with gravimetric geoids obtained from independent sources. This is especially true of the areas covered by the GEOS-3 satellite when compared with the earlier reported results of the AFGL computer program SAGRA (Short Arc Reduction of Radar Altimetry).

As a separate task, a theoretical study has been performed in comparing the spherical harmonic representation of the potential with the spheroidal harmonic representation. The outcome of this study has indicated that truncated expressions in any coordinate system other than the spherical (e.g., in a spheroidal coordinate system) would be essentially equivalent to using spherical harmonics, and they would be far less convenient.

The last independent part of the present effort has been devoted to an analysis of the point mass technique. The purpose of introducing the point mass parameters into the adjustment is to add the structure to a geopotential model that is based on spherical harmonic coefficients. The main attractive attributes of such an approach are its economy and its flexibility. In particular, in areas where an accurate geoid determination is not required or cannot be accomplished due to the lack of data, no point masses would be introduced; the geoid in such areas would accordingly be described by potential coefficients alone. This means that on the whole, the number of parameters could be kept relatively small. The point masses would be employed in areas where, for various reasons, a more detailed knowledge of geoid features may be required. The point mass technique has an immediate appeal not only for its relative simplicity and its practical applicability, but also because it is founded on a plausible physical concept.

This report investigates the impact that the assumptions of homogeneity and isotropy, when applied to potential related fields, have upon the stochastic processes which are applied to these fields. After seeing how these assumptions are incorporated into the statistical model to produce the familiar covariance function, the investigation centers on techniques which can be used to detect the presence of anisotropy in the field. The method found most useful in the two-dimensional covariance function, and some methods of representing this function are also investigated.

Numerical studies are then carried out to see the effect the use of the 2-D covariance function has upon the results of prediction and collocation computations. It is found that, under certain circumstances, the 2-D function produces a result superior to that given by the general function. Recommendations are then given as to when the 2-D covariance function should be used in practical solutions, and suggestions made as to the possible areas of further research.


The spherical harmonic expansion of the external gravity field of the Earth is divergent at the surface of the Earth. From the practical point of view a truncated series can be used if the errors are small. The errors are of two types: the truncation error and the downward continuation error. In this report we investigate the latter, which is caused by the disturbing topography above the point where the series is developed. This error is studied for potentials, gravity anomalies and for the vertical gradient of gravity. It is shown that the usual relation between the spherical harmonics of \( T \) and \( \Delta g \) is also valid for their errors, while the relation between \( T_n \) and \( S_n \) does not hold for the downward continuation errors. The relative errors of \( \Delta g \) are found to be more serious than those for \( T \).

Some global RMS errors are estimated based on the degree variances of TSCHERNING and RAPP (1974). Furthermore, formulae are developed for a numerical integration of the errors over an approximately known topography. Finally, these formulae are tested for 1854 5° x 5° mean elevations. In the Earth model "a level ellipsoid with topography of constant density" these computations gave the RMS error 0.13 m for global undulations in an expansion to degree 16. The gravity anomaly errors were generally within \( \pm 5 \) mGal except at the edges of the continents and for rough areas inside the continents, where larger errors might be expected.

The gravimetric results obtained crossing Sierra de Córdoba by the middle (roughly parallel 31°30'S) are tentatively explained imputing a lesser part of the negative anomaly to the granitic intrusion of betholithics dimensions of Achala, and the rest (large negative anomaly) to a cortical thickening. Several possibilities are analyzed such as: density changes and cortical thickness changes, rise of materials from the upper mantle related to the elevation of the set of blocks constituting Sierra de Córdoba, etc.; together with the difficulties of the gravimetric method in order to obtain a more accurate interpretation.


The motion of a satellite with negligible mass in the Schwarzschild metric is treated as a problem in Newtonian physics. ...


A spherical harmonic equation for the gravitational potential energy of the Earth is derived for an arbitrary density distribution by conceptually bringing in mass-elements from infinity and building up the Earth shell upon spherical shell. The zeroth degree term in the spherical harmonic equation agrees with the usual expression for the energy of a radial density distribution. The second degree terms give a maximum nonhydrostatic energy in the mantle and crust of $-2.77 \times 10^{29}$ ergs, an order of magnitude below McKean's (1966) estimate. This figure is almost identical with Kaula's (1983) estimate of the minimum shear strain energy in the mantle, a not unexpected result on the basis of the virial theorem. If the Earth is assumed to be a homogeneous viscous oblate spheroid relaxing to an equilibrium shape, then a lower limit to the mantle viscosity of $1.3 \times 10^{20}$ poises is found by assuming the total geothermal flux is due to viscous dissipation. This number is almost six orders of magnitude below MacDonald's (1986) estimate of the viscosity and removes his objection to convection. If the nonequilibrium figure is dynamically maintained by the Earth acting as a heat engine at one percent efficiency, then the viscosity is $10^{22}$ poises, a number preferred by some (e.g. Cathles [1975]) as the viscosity of the mantle.


A computer software system is described which computes global numerical solutions of the integro-differential Laplace Tidal Equations, including dissipation terms and ocean loading and self-gravitation effects, for arbitrary diurnal and semi-diurnal tidal constituents. ...

A variety of sources of detailed information has been analyzed to arrive at a geoid power spectrum from global altimeter data. Using the equivalent of only two revolutions of data (mostly from GEOS-3) from all the major oceans, the high frequency geoid power (rms) is estimated (most simply) to be

\[ 80.7n - 1.47 \text{ meters}, \]

where \( n \) is in cycles/global revolutions. This law is valid for all frequencies above 19 cycles but includes sea state. The (simple) law has more power than predicted by Kaula's rule for the geopotential. However, the data shows significantly less power for frequencies below 100 cycles. A closer approximation to the altimetry accumulates 2.18 m (rms) for all frequencies higher than 19 cycles/rev. (including sea state), somewhat less power than predicted by the rule. The data permits up to 

1 1/4 (rms) non-gravitational departures from the high frequency marine geoid.


A technique has been developed for pre-processing GEOS-3 altimetry data to establish a model of the regional sea surface. The algorithms, as presently used, develop models for a \( 35 \times 10^6 \) km\(^2\) area with an internal precision of \( \pm 1 \) m. This figure is substantially influenced by the data acquisition period and the sea state. There are discrepancies between the sea surface model so obtained and GEM 5 based geoid profiles with wavelengths of approximately 2500 km and amplitudes of up to 5 m in this region. The amplitudes are smaller when compared with GEM 10-based geoid determinations. However, the comparison of 14 pairs of overlapping passes in the region indicates altimeter resolution at the \( \pm 25 \) cm level if the wavelength corresponding to the Nyquist frequency were 30 km. In most cases, the spectral analysis of such comparisons indicates the existence of significant signal strength in the discrepancies after least squares fitting, with wavelengths in excess of 200 km. Regional studies of time varying features of the sea surface in the data analysis area are not currently possible due to inadequate tracking support and the limited time span over which a dense data coverage was available.


The Starlett satellite, launched in February 1975 by the French Centre National d'Etudes Spatiales, was designed to minimize the effects of non-gravitational forces and to obtain the highest possible accuracy for laser range measurements. Analyses of the first four months of global laser tracking data have confirmed the stability of the orbit and the precision to which the satellite's position can be established.

.../...
Initial orbit computations using the GSFC GEM-7 gravity model produced rms fits of about 8 to 10 meters for arc lengths of 5 days. Through a series of gravity model improvements these rms fits have been reduced to 1 to 2 meters for the 5 day arcs. An rms fit of 4.3 meters was obtained for a 90 day arc. Five day arcs overlapped by 2.5 days showed rms satellite position differences generally less than 2 meters. Prediction errors at the end of two months were less than 30 milliseconds.


The orbit of the 1967-92A satellite has been studied to ascertain the extent to which tidal forces contribute to orbital perturbations. This study has permitted an estimation of parameters describing the ocean tide potential - in particular for the $M_2$ and $S_2$ constituents.

510 - VONBUN F.A., W.D. KAHN, P.D. ARGENTIERO & D.W. KOCH - "Spaceborne Earth applications ranging system (SPEAR)".

A technique is discussed for the accurate (i.e., to within fractions of centimeters per year) detection of Earth surface motions utilizing the latest space technology. It is shown that, over a six-day period and assuming a 50% cloud cover (i.e., as experienced over the past few years of laser operation) utilizing spaceborne precision ranging systems, inter-station distances on the order of 5 to 15 km (dependent mostly on the beam width of the laser) can be determined in the vertical and horizontal components, with errors in the 0.5 to 1.5 cm range. These errors are almost independent of ground survey errors up to 0.25 m and orbit errors up to 200 m. A spaceborne laser ranging system is assumed to range to two or more ground-emplaced retroreflectors. This can be done either in a simultaneous or non-simultaneous mode. Hardware is under development for the latter technique.

511 - TORGE W. & H. DREWES - "Gravity variations with time in Northern Iceland 1965-1975".

Since 1936 repeated gravity measurements along a west-east profile in northern Iceland ($\phi = 65^\circ 40'$) have been carried out in order to detect eventual changes of gravity in the young volcanic zones. The latest survey took place in 1975, when 176 stations of the main profile with more than 150 km length have been occupied. Four gravity meters of type LaCoste and Romberg have been used, measuring 1169 gravity differences at the main profile, yielding root mean square errors of the gravity values from \( \pm 3 \) to \( \pm 14 \mu \text{Gal} \), the average being \( \pm 7 \mu \text{Gal} \).
The comparison of the 1975 survey with the results of 1970/71 and 1969 indicates a lasting increase of gravity in the young volcanic zone relative to the adjacent tertiary basalt zones. Different mathematical methods are applied to represent the behaviour of gravity variations with time along the profile. The maximum gradient of gravity changes occurs in the Nyow-Nanayjall region with a total difference of nearly 0.01 mgal/year between the adjacent parts of the profile.


Ce texte présente une méthode de calcul du potentiel de gravité créé par un corps cylindrique d'extension limitée. La méthode permet l'interprétation quantitative du géode obtenu à partir des données des satellites artificiels. Il est en particulier montré que ces données ainsi que les mesures gravimétriques sont compatibles avec l'hypothèse de subduction de la plaque Arabique vers le Nord-Est.


From 4.1.1973 until 20.1.1974 gravimetric earthtime observations were performed at Kerguelen Island (southern Indian Ocean). Results of total analysis of data after Chojnicki's and Venedikov's method are listed. Monthly analysis show variations of tidal parameters of partly non-stochastic character, the determination of the reason for these variations will be the aim of further investigations.


The gravimetric levelling reduces the determination of relative geoid undulations by the formula of Stokes to some simple procedures of least squares prediction and the summation of the predicted values. Absolute undulations are obtained by transformation with at least three identical points. The accuracy of differences of geoid undulations is in good agreement with practical determinations of several authors (HEIKKASALO 1974, KLEEMAN 1974).
b) TÖRGE W., G. BOEDECKER & H.F. WENZEL - "Astrageodetic geoid determination in the Western Harz".
  p. 107-122.

In the geodetic test network Western Harz (Federal Republic of Germany), relative geoid determinations have been carried out, using different terrestrial methods. The aim of this research work is, to investigate the possibilities of solving the height problem in three-dimensional terrestrial networks of regional extension ... The accuracy level obtained by the different methods for the ellipsoidal heights and the relative geoid, is at the order of a few cm.


For the transformation between the German Gravity Net 1982 (Deutsches Schwereamt 1982, DSN 62) and the International Gravity Standardization Net 1971 (IGSN 71) parameters (differences in reference level and scale) are determined by least squares adjustment. For the comparison gravity measurements have been made at 111 referring stations. An Appendix comprises 79 sketches of IGSN 71-stations in the Federal Republic of Germany, updated in 1976 and recommended for use.


  Liste d'environ 5,000 points gravimétriques.


521 - WENZEL H.G. - "Zur Optimierung von Schwerenetzten".

The method of sequential optimization for the optimal design of geodetic networks is described and applied to the planned German gravity basic network 1976 and to the planned gravity network of Lower Saxony. The practical aspects of the optimal design with different target functions are discussed.