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BUREAU GRAVIMETRIQUE INTERNATIONAL

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Informations for Contributors

Contributors should follow as closely as possible the rules below :

Manuscripts should be typed (double-spaced) in Prestige-Elite characters (IBM-type), on one side of plain paper 21 cm x 29.7 cm, with a 2 cm margin on the left and right hand sides as well as on the bottom, and with a 3 cm margin at the top (as indicated by the frame drawn on this page).

Title of paper. Titles should be carefully worded to include only key words.

Abstract. The abstract of a paper should be informative rather than descriptive. It is not a table of contents. The abstract should be suitable for separate publication and should include all words useful for indexing. Its length should be limited to one typescript page.

Table of contents. Long papers may include a table of contents following the abstract.

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Mathematics. For papers with complicated notation, a list of symbols and their definitions should be provided as an appendix. All characters that are available on standard typewriters should be typed in equations as well as test. Symbols that must be handwritten should be identified by notes in the margin. Ample space (1.9 cm above and below) should be allowed around equations so that type can be marked for the printer. Where an accent or underscore has been used to designate a special type face (e.g., boldface for vectors, script for transforms, sans serif for tensors), the type should be specified by a note in the margin. Bars cannot be set over superscripts or extended over more than one character. Therefore angle brackets are preferable to overbars to denote averages, and superscript symbols (such as *,', and ≠) are preferable to accents over characters. Care should be taken to distinguish between the letter O and zero, the letter l and the number one, kappa and k, mu and the letter u, nu and v, eta and n, also subscripts and superscripts should be clearly noted and easily distinguished. Unusual symbols should be avoided.

Acknowledgments. Only significant contributions by professional colleagues, financial support, or institutional sponsorship should be included in acknowledgments.

References. A complete and accurate list of references is of major importance in review papers. All listed references should be cited in text. A complete reference to a periodical gives author (s), title of article, name of journal, volume number, initial and final page numbers (or statement "in press"), and year published. A reference to an article in a book, pages cited, publisher, publisher's location, and year published. When a paper presented at a meeting is referenced, the location, dates, and sponsor of the meeting should be given. References to foreign works should indicate whether the original or a translation is cited. Unpublished communications can be referred to in text but should not be listed. Page numbers should be included in reference citations following direct quotations in text. If the same information has been published in more than one place, give the most accessible reference ; e.g. a textbook is preferable to a journal, a journal is preferable to a technical report.

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PART I

THE AFRICAN GRAVITY STANDARDIZATION NET

THE AFRICAN GRAVITY STANDARDIZATION NET

REPORT

ON THE EXTRAORDINARY MEETING OF THE GRAVITY COMMISSION

AND

THE COMMISSION FOR GEODESY IN AFRICA

PARIS, FRANCE

May 22-24, 1985

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BACKGROUND

This special meeting of the International Gravity Commission (IGC) arose from a request of the Gravity Network Committee (GNC) of the Commission for Geodesy in Africa (CGA) for assistance in putting together a proposal for an African Gravity Standardization Net (AGSN). The IGC obtained the agreement of Canada to provide the services of R.K. McConnell to assist with the network design, cost estimates and writing of the proposal. An ad hoc group from the IGC and the CGA met in Cairo in December, 1984 to discuss the draft proposal and the follow up to it. An agreement was reached to hold a meeting in Paris in May, 1985, to :

(a) discuss the plan among a broader European and African community,

(b) determine the technical and financial help required by the Africans in carrying out the project,

(c) define a training program in gravity field procedures for the development of the broader African geodetic and geophysical community,

(d) to seek indications of technical support from non-African countries in terms of instruments and expertise,

(e) to investigate avenues of financial assistance, and if possible, develop a plan for a systematic approach to the appropriate agencies,

(f) set a schedule for follow-up activities.

OPENING REMARKS

In opening the meeting the President of the IGC emphasized the vast nature of the undertaking. Africa is a continent of about 55 nations and if experience with activities in other areas is any guide, major logistical problems can be expected, particularly with the current proposal which envisages observing teams travelling throughout Africa in a concentrated two year field program. He suggested that alternatives to this approach should be seriously considered in the light of experience elsewhere in the world where international nets were built up by linking national nets through the co-operative efforts of various national agencies. While the latter model obviously requires more time to achieve the objectives, it has proved to be a practical and successful approach to the development of international reference systems.

REVIEW OF GRAVITY COVERAGE IN AFRICA

A review of the current status of gravity mapping by Africans attending the meeting indicated that national gravity mapping programs were underway in many parts of Africa. While the approach is not uniform in terms of density of stations or schedule for completion, significant progress has been realized in recent years. Indeed, it was evident during a discussion of the holdings of the Bureau Gravimétrique International (BGI) that much more gravity data exists in

Africa than has been incorporated into international data bases. Clearly a special effort is needed on the part of African national and regional agencies and the BGI to update holdings in computer based files and to make them available for use by African scientists and scientists from other regions engaged in global and regional geodetic and geophysical studies.

PRESENTATION OF THE PROPOSAL FOR THE AFRICAN GRAVITY STANDARDIZATION NET (AGSN)

Dr. Ajakaiye, the Chairwoman of the GNC reviewed the proposal that had been drafted by her with the aid and advice of McConnell. Briefly, the proposal calls for at least one gravity station (with excentres in each country tied to two or more other stations in the net). Absolute control would be provided by about ten absolute stations spread throughout the African continent. At least two absolute stations would observe each site. Gravimeter connections between stations in the net would be made with four LaCoste & Romberg instruments observed in an A-B-A sequence.

The project is proposed to commence with training programs, one in English and one in French. From the attendees of these training sessions one team of four African observers and back-up teams would be chosen to carry out the measurements. Led by an African project leader this small observing team would travel by chartered aircraft throughout Africa. Some twelve months would be spent making the observations. Upon their completion the observations would be sent to several African agencies for analysis and adjustment. A conference would then be held to compare results and decide the strategy for the final adjustment.

The style and form of the adjustment, description of stations, etc. would conform to international standards. The original and adjusted data would be available through various African centres and the BGI.

DISCUSSION OF PROPOSAL

The discussion on the first afternoon centred largely on the management of the project. The African delegates again confirmed that the GNC, chaired by Dr. Ajakaiye, would lead the project. Additional management support was offered by the Association Africaine de la Cartographie (AAC), an intergovernmental agency with established communications network throughout Africa, that played a major role in co-ordinating the activities of the ADOS project. Its contributions would also include assistance in raising financial support, facilitating communication among Africans and assistance in co-ordinating and managing the project. Given the success of ADOS the support of AAC was a most welcome contribution to the meeting and puts Africans in a much stronger position to realize the goals with respect to AGSN.

The first day concluded with the establishment of five discussion groups to review specific aspects of the proposal and report back during the following days. The areas designated for detailed review were management, training, absolute measurements, relative measurements and adjustment.

TECHNICAL DISCUSSIONS

The morning of the second day was devoted to scientific discussions illustrating the importance of a continent-wide network to applications in geophysics (geology), geodesy and geodynamics. Professor Louis described applications of gravity data to geological problems, choosing examples on a regional scale (hundreds of kilometres), a local scale (kilometres) and on the scale of prospecting for minerals. Professor Makris described studies of regional crustal structure in northeast Africa involving the application of gravity and deep seismic refraction with other geophysical and geological information. The combination of seismic and gravity data is a particularly powerful one which gives more insight into the processes controlling the development of crustal structure.

Both presentations emphasized that, properly used, gravity interpretation can be a powerful tool in understanding regional structure and the processes leading to its development - the same processes that provide the overall control in the location of mineral and petroleum resources. As Professor Louis showed, gravity investigations can be used directly to study small-scale geological structures and their associated mineral resources.

With respect to the AGSN, regional studies of structures which know no political boundaries clearly require a broad reference standard to control the relative gravimeter measurements. Local studies can be done on a local reference system but with good calibration or scale control. In practice the latter is most reliably achieved within the context of an absolute standard such as AGSN.

Professor Boedecker examined the spectrum of geodetic and geodynamic applications. On the broadest scale geoidal studies require world-wide gravity data on a uniform absolute reference standard. Recent advances in technology have increased the requirements for accuracy of geoidal determinations to the order of decimetres. The importance of a project like AGSN to the realization of such a lofty goal cannot be overemphasized. On a regional and local scale Prof. Boedecker's geodynamic studies are perhaps the most interesting from the standpoint of AGSN. Such applications place a high demand on accuracy (microgals) and if carried out on a regional scale require a regional absolute reference standard such as AGSN.

Prof. Torge presented a state-of-the-art review of modern relative gravimeter observations using LaCoste & Romberg instruments. In his error budget he showed that a single gravity difference measured with one gravimeter had a precision of about 25 μgal without special precautions. By taking account of non-linearities in the mechanical system, using electrical read-outs, taking special precautions during transport, etc. the precision could be increased to about 18 μgal. As the accuracy proposed for AGSN is 20 μgal special techniques will be required during the field program.

Finally Dr. Ducarme described a joint program between the International Centre for Earth Tides (ICEF) at Brussels and various African nations to make earth tide measurements. New standards for gravity measurements have led to great improvements in our understanding of earth tides and our ability to measure them accurately. ICET has gained much operational experience in African and could be of great help to those in African responsible for AGSN.

REPORTS OF DISCUSSION GROUPS

(a) Management Group

Africans wish to have the project carried out under the tight control of the GNC with Dr. Ajakaiye as its chairwoman. An African project manager familiar with field logistics in various parts of Africa would organize and supervise field operations. Outside contributions to the project would be co-ordinated with this management structure through the IGC or its operating agency the BGI. Discussion stressed the need for good communications among the African contributions with the AAC viewed as the organization with the best developed network.

(b) Training Group

The training program is perhaps the most important product of the project. If done correctly a cadre of fully trained gravity specialists would be available which in turn could pass on these skills to other African colleagues. Emphasis was therefore placed on the need for well written technical manuals, stand-alone software for microcomputers and other documents on instruments logistics, etc. which would constitute in effect a complete operational system that could be taken away and used directly by the trainees either in the field or to train others. A number of countries outside Africa have expressed a willingness to contribute to this activity. The proposal of the GNC recommended training courses in English and French, but discussion from the floor suggested that one course with translation facilities would be practical alternative.

(c) Absolute Measurements

The discussion on the absolute measurements naturally centred on the number of sites with most Africans wishing to see the number increased. In the end the group recommended an increase in the number from ten to twenty with each site observed by two different apparatuses (e.g., rise and fall and free fall) preferably at the same time. To achieve this goal would require a closely co-ordinated campaign lasting in excess of six months in elapsed time. Dr. Marson of Italy was suggested as the person best qualified to provide this co-ordination. During the discussion the importance of local organizations to locate suitable sites for the absolute measurements and the attendant excentres and to make available technical support systems needed to operate absolute gravity apparatuses. At each location one or two Africans should be assigned to the measurement team to undergo basic training in the techniques of absolute gravimetry. Several countries in Europe as well as the USSR have indicated their willingness to take part in the project.

(d) Relative Measurement Group

A lengthy discussin was held on the question of relative measurements. Most or all of the gravimeters could be found in Africa, although a special effort would be needed to calibrate them against the best world standards. The operations were recognized as complex, possibly requiring the involvement of more than one observing team. At each site local committees would be needed ot organize local transportation, arrange clearance through customs, minimal but essential technical support (minor repairs, battery chargers, etc.) and generally smooth the passage of the observers in and out of the country. The need for special procedures in the case, calibration and operation of the gravimeters was stressed several times.

(e) **Adjustment Group**

The adjustment discussion group recommended that W.G. 2 of the BGI (Prof. Uotila, Chairman) be asked to draw up a list of organizations inside and outside Africa that would participate in the adjustment, provide software recommend mechanisms for publication of results and take part in the on-going maintenance of the network.
The meeting generally supported this approach although some Africans suggested the plan was unnecessary as the required skills and techniques exist in their countries. The recommendations of this group will be examined further by the GNC.

CONCLUDING DISCUSSIONS

The final day of discussions was largely devoted to a review of the progress of the meetings, a summary of the actions to be undertaken and a discussion of the resolutions. Several Africans who arrived the last day expressed disappointment at the lack of financial commitments from non-African countries. Despite the strenuous efforts of several delegates no formal commitments were obtained. Many funding and/or aid agencies indicated interest, but stressed that a formal request should come from Africa. Clearly one of the major tasks of the GNC and the AAC will be the organization of the various approaches to funding agencies, both African and non-African.

With respect to future actions the GNC will :

(a) revise the proposal in line with discussion at the meeting - by October, 1985,

(b) make formal presentations, in conjunction with the AAC, to Economic Council for Africa (ECA) in February, 1986 and the Organization of African States (OAS) in April, 1986.

(c) conduct a full scale technical review at the 3rd Symposium on Geodesy in Africa in April, 1986,

(d) jointly, with AAC, make submissions for financial support to such non-African agencies as the European Economic Commission, UNESCO, etc.,

(e) communicate their progress through the IGC (BGI) so that the international community can support their efforts as appropriate.

The International Gravity Commission will :

(a) circulate (and publish) a brief summary of the meeting,

(b) direct the BGI to cooperate with African institutions in the acquisition of regional gravity data not currently residing in data centres in Africa or the BGI - the data produced by this search will be available through the African centres and the BGI.

(c) will circulate the revised proposal of the GNC to its membership seeking commitments of support for the project and forward the results to the GNC and AAC.

(d) collaborate with GNC and AAC in the development of a plan for the absolute measurements and the training programs.

(e) review progress at its annual meeting in September, 1986 at Toulouse.

RESOLUTIONS

Four resolutions were passed by the meeting. These will be submitted by the IGC to the Executive of the International Association of Geodesy for approval at its meeting in December, 1986. Copies of the resolutions are attached.

SUMMARY OF COMMITMENTS FOR SUPPORT RECEIVED TO DATE

1. No financial commitments have been made by any African or non-African agencies.

2. Technical commitments have been received as follows :

   (a) Training
      (i) Canada - software and documentation
      (ii) India - training staff
      (iii) Italy - training centre facility
      (iiii) West Germany - training staff, manuals, co-ordination.

   (b) Absolute Gravity Apparatuses
      (i) Finland
      (ii) Germany
      (iii) Italy
      (iiii) USSR

   All offers are contingent upon some form of partial support from the host country or an international fund. The offer from Russia is specifically directed to Mozambique, Angola, Madagascar, Algeria, Ethiopia and Senegal.

3. Relative Measurements

   Although the Africans believed they would be self-sufficient, many countries offered to make available fully calibrated instruments under the condition that the measurements be made on a co-operative basis.

RESOLUTIONS

Des résolutions ont été présentées Vendredi 24 Mai et discutées en détail. Les textes ci-après ont été finalement adoptés mais ne sont pas encore considérés comme définitifs.

Veuillez nous faire parvenir vos suggestions de modification avant le 30 Juin 1985, dernier délai.

RESOLUTIONS

Resolutions were presented on Friday, May 24, and were discussed in detail. The texts below were adopted but are not yet final.

Would you please send us your suggestions for modification before June 30, 1985 at the latest.

RECOMMENDATION PRESENTEE PAR LES PAYS AFRICAINS

Compte tenu de l'importance scientifique et économique de l'implantation d'un Réseau Gravimétrique Normalisé Africain (R.G.N.A.),

Considérant la nécessité de la participation active des organismes nationaux africains de Géodésie et Géophysique ainsi que la participation active des organisations africaines spécialisées pour le succès de ce projet continental,

Les pays africains présents à la Réunion tenue à Paris du 22 au 24 Mai 1985, à l'invitation de la Commission Gravimétrie Internationale et du Comité Africain de Gravimétrique de la Commission de Géodésie pour l'Afrique,

Recommandent

1. la constitution de commissions Gravimétriques nationales, regroupant tous les organismes officiels intervenant dans le domaine de la gravimétrie et de la géodésie aux fins de mieux coordonner cette action sur le plan national et d'assurer le succès de la mise en place du réseau continental.

2. que le Comité Gravimétrique Africain finalise l'étude du projet de R.G.N.A. compte tenu des suggestions et recommandations faites devant la réunion de Paris au plus tôt possible et en concertation avec l'Association Africaine de Cartographie (A.A.C.) et le Centre Régional de Cartographie et Géodésie de Nairobi (R.C.S.S.M.).

RESOLUTION PRESENTED BY AFRICAN COUNTRIES

Recognizing the scientific and economic importance of the establishment of an African Gravity Standardization Net (A.G.S.N.),

Considering the need for an active participation of African national Geodetic and Geophysical organizations as well as the active participation of other specialized African organizations for the success of this continental scale project,

The African countries attending the May 22-24 1985, Paris workshop, at the invitation of the International Gravivimetric Commission and of the African Committee for Gravimetry of the Commission for Geodesy in Africa,

Recommend

1. the establishment of national commissions for gravimetry, including all official bodies involved in gravimetric and geodetic activities, in order to better coordinate activities at the national level and ensure the successful establishment of the continental network.

2. that the African Gravity Network Committee finalizes, as soon as possible, and jointly with the Association Africaine de Cartographie (A.A.C.) and the Regional Center for Services in Surveying and Mapping (R.C.S.S.M.) of Nairobi, the project proposal for the African Gravity Standardization Net, taking into account the suggestions and recommendations expressed at the Paris meeting.

3. la présentation de ce dossier finalisé auprès de l'O.U.A. et de la C.E.A. pour l'adoption de résolutions appropriées visant l'implantation dès que possible de ce R.G.N.A. Cette présentation doit être faite en étroite collaboration entre l'A.A.C., le R.C.S.S.M. et la Commission pour la Gravimétrie en Afrique (C.G.A.) aussi tôt que possible.

4. q'une action commune à l'initiative du Comité Africain de Gravimétrie soit entreprise par les organisations africaines auprès des organisations internationales, des organismes de financement et tout autre organisme susceptible d'appuyer la réalisation urgente de ce réseau continental.

5. la poursuite de la coordination du Projet continental par le Comité Africain de Gravimétrie, en étroite relation avec l'A.A.C. et le centre de Nairobi, ainsi que la prise en charge du traitement des données par des centres africains à l'instar du réseau géodésique.

3. that the finalized project be presented to O.U.A. and C.E.A. for the adoption of appropriate resolutions for the immediate establishment of the A.G.S.N. This presentation must be made jointly by A.A.C., the R.C.S.S.M. and the African Gravity Network Committee as soon as possible.

4. that a common action, initiated by the African Gravity Network Committee, be made by African agencies to international organization and financing agencies and any other pertinent body capable of helping in the immediate establishment of the continental net.

5. that the Africa Gravity Network Committee continues to coordinate the continental project in close collaboration with A.A.C. and the R.C.S.S.M., and that African centers take over the data processing, as was done for the geodetic network.

L'ATELIER DE TRAVAIL DE LA C.G.I. SUR LA GRAVIMÉTRIE EN AFRIQUE

Reconnaissant l'importance de programmes de formation pour la diffusion d'expertise en gravimétrie et

Considérant le large éventail des bénéfices qu'une telle formation peut amener au futur Réseau Gravimétrique Normalisé Africain et aux programmes nationaux de cartographie gravimétrique pour satisfaire les besoins économiques et de recherche,

Recommande que des séminaires de formation sur l'acquisition, les calculs, l'évaluation et l'utilisation des données gravimétriques aient lieu en Afrique dès que possible.

THE I.G.C. AFRICAN GRAVITY WORKSHOP

Recognizing the importance of training programs for the dissemination of expertise in gravimetry and

Considering the wide spectrum of benefits of such training for a future African Gravity Standardization Net and for national gravity mapping programs to meet economic and research needs,

Recommends that training seminars on the acquisition, reduction, evaluation and use of gravity data be held in Africa at the earliest possible opportunity.

L'ATELIER DE TRAVAIL DE LA C.G.I.
SUR LA GRAVIMÉTRIE EN AFRIQUE

Reconnaissant l'intérêt des mesures absolues à la fois pour l'établissement d'un futur Réseau Gravimétrique Normalisé Africain, et pour un Réseau International Absolu,

Recommande d'effectuer ces observations par coopération entre les divers pays d'Afrique et les instituts possédant les gravimétres absolus, dans le cadre du projet de Réseau Gravimétrique Normalisé Africain.

THE I.G.C. AFRICAN GRAVITY WORKSHOP

Recognizing the benefits of absolute gravity measurements both for a future African Gravity Standardization Network and for the International Absolute Gravity Network,

Recommends to carry out these observations in cooperation between the individual African countries and groups owning absolute gravimeters, within the framework of the African Gravity Standardization Network project.

L'ATELIER DE TRAVAIL DE LA C.G.I. SUR LA GRAVIMÉTIE EN AFRIQUE

Reconnaissant la valeur des données de pesanteur pour les études en géophysique et géodésie, pour la prospection minière et l'exploration des ressources naturelles, et

Considérant que des mesures gravimétriques existent à la fois dans les bases de données du B.G.I. et de pays africains,

Recommande que le B.G.I., en collaboration avec les organisations africaines concernées, entreprenne une nouvelle compilation de ces données en vue de mettre à jour notre connaissance du champ gravitationnel en Afrique, et les mette à la disposition de tous les pays Africains.

THE IGC AFRICAN GRAVITY WORKSHOP

Recognizing the value of gravity data for geophysical and geodetic investigations, and for mining and resource exploration, and

Considering that gravity measurements exist in both the BGI file and in African data bases,

Recommends that BGI, in cooperation with African agencies, undertakes a new compilation of these data with a view of updating our understanding of the gravity field in Africa, and make it accessible to all African countries.

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PART II

CONTRIBUTING PAPERS

ONCE MORE ABOUT COMPARISON OF ABSOLUTE GRAVIMETERS IN SEVRES IN 1981

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In 1981 the first international comparison of absolute ballistic gravimeters was carried out in Sèvres. The results were published in several papers /1,2,3/.

Since all compared instruments could not be simultaneously placed on one pillar, they were mounted at 5 different points located in the main building of the Bureau International des Poids et Mesures. In order to make their records comparable, a gravimetric micronet was set up by six La Coste-Romberg gravimeters and at each point of the micronet the same group of gravimeters determined the vertical gradients. This provided the possibility for measurements made by absolute gravimeters at the effective height to be adjusted to the surface of the pillar on which they were mounted.

The mean square errors of Δg determination at the links of the micronet are within the range from ± 1.6 to 3.0 mcgal, whereas the determination errors of vertical gradients vary from ± 1.0 to ± 1.6 mcgal/m /3/.

Due to various reasons, the micronet was set up by simultaneous measurements with absolute and relative gravimeters. This circumstance necessitated the placing of La Coste-Romberg gravimeters not at the points of absolute gravimeters, but at excentric points situated on the same pillars at distances of not more than 80 cm from the basic point.

Due to the fact that the basic point and the excentric were always at the same height, in observation data processing the gravity values at the basic point and the excentric were assumed to be equal. Proceeding from this assumption and using the established micronet and the measured values of the vertical gradients, all absolute determinations were adjusted to pillar A3. This procedure made it posssible to compare the results of all absolute determinations carried out in Sèvres in the period from 1976 to 1982 practically without loss of precision. The absolute value of gravity was simultaneously obtained for A3 point /3/ :

$$g = 980\ 925\ 914 \pm 3.6 \text{ mcgal} \qquad (1)$$

However, the analysis of results of relative gravimeters revealed the fact that the difference value between A and A3 pillars and the vertical gradients value at A3 point, which were obtained previous to the establishment of the network by the La Coste-Romberg gravimeter belonging to Prof. A.Sakuma, differ from Δg and $\Delta g/\Delta h$ values obtained in the process of micronet establishment by 12 mcgal and 10 mcgal/m, respectively.

During the discussion of results of comparison at the Symposium in Tokyo (May, 1982) and then at the meeting of the International Gravimetric Commission in Hamburg (August, 1983) this fact was not given its due. Consequently, the result presented above was adopted as the final value for A3 point. Moreover, it was tacitly assumed that Prof. A.Sakuma's measurements, due to certain causes, have an unaccounted for systematic error.

But this difference, exceeding 6-8 times the accuracy of measurements, needed explanation. An attempt was made to theoretically calculate the pattern of the gravity field on the surface of the pillar, which by its size is similar to the pillar of A3 point.

These calculations were made by Prof. M.Sagitov /4/. The results showed that in actual fact the gravity field is not stable on the surface of the pillar. Gravity should decrease from its central part to the periphery by about 8-10 mcgal, which accounts for a considerable part of the obtained difference.

Special measurements were conducted under the guidance of R.Rukavishnikov at the Gravimetrical Laboratory, Institute of Physics of the Earth, USSR Academy of Sciences, to confirm this supposition. These measurements were made with the purpose of revealing the non-linearity of the gravity field on the surface of the pillar and at various heights above it /5/.

This experiment established that the gravity value on the surface of the pillar is unstable and it really decreases to the periphery. This decrease on the surface of the studied pillar, whose dimensions are close to those of the A3 point pillar, reaches 18 mcgal (Fig.1.).

The measurements of **g** value over the pillar at the height of 1 m,i.e., at the height approximately corresponding to the effective heights of absolute gravimeters, have shown that when moving in space over the pillar the field changes, but according to another law. This fact results in the change of the vertical gradient value while the gravimeter moves on the surface of the pillar.

Therefore, R.Rukavishnikov's measurements have established the indisputable fact of the changes of gravity values and its vertical gradient in the process of moving from one point of the pillar's surface to the other.

It was later found that when the micro-net was being established the excentric of A3 point was situated 0.6 m from the edge of the pillar. According to the data of R.Rukavishnikov, this fact may have caused the reduction by 12-14 mcgal of gravity value and by 10 mcgal/m in the determination of the vertical gradient. These values are very close to the differences mentioned earlier.

All stated circumstances induced us to once again revise the results of the comparison made in 1981 taking into account the new conception about the non-linearity of the gravity field caused by the mass of the pillar itself.

Column 2 of Table 1 presents the values obtained at the links of the micronet and column 3 shows the values after the introduction of correction for gravity change caused by the non-linearity of the gravity field. The value of this correction was assumed equal to the difference of 11.3 mcgal shown above. The value of the vertical gradient at A3 point was assumed to be equal to :

$$\frac{\Delta g}{\Delta h} = 273 \text{ mcgal/m}$$

in accordance with Prof. A.Sakuma's measurements made previously.

Using the corrected values of **Δg** at the links of the micronet and the adopted vertical gradient value at A3 point, all measurements were again adjusted to A3 pillar. Their summary is given in Table 2.

The insignificant variations of **g** values obtained in the six-year interval (1976-1982) allow to conclude about small gravity variations in time in Sèvres during these years. Even if the variations did occur, they would have been small and comparable with the value of accuracy of **g** measurements proper. This suggestion allowed to consider the results of comparison in three variants :

TABLE 1

Values of Δg at micronet links

Link	Δg, Assumed	
	earlier. mcgal	after correction. mcgal
A - A3	- 78.8 ± 2.0	- 90.1 ± 3.0
A - A4	- 579.1 2.2	- 579.1 2.2
A - A5	- 581.0 2.3	- 581.0 2.3
A - A6	- 609.4 2.0	- 609.4 2.0
A4 - A5	+ 1.8 1.6	+ 1.8 1.6
A3 - A6	- 688.3 2.2	- 699.6 3.7
A3 - A5	- 659.8 3.0	- 671.1 3.8
A3 - A4	- 657.9 3.0	- 669.2 3.7

- assuming as independent all measurements conducted in Sèvres (n = 12) ;
- assuming as independent only the observations averaged by instruments (n = 5)
- using gravity values measurec only in 1981 and 1982 (n = 3).

All three variants of processing produced one result : the mean square error of determination of the absolute gravity value by one instrument was about ± 6 mcgal. Taking into account the fact, that instruments of different construction were used for comparison, the obtained result clearly shows the real accuracy of measurements of the absolute gravity value by modern portable ballistic gravimeters.

The measurements allowed to determine the gravity value at A3 point in Sèvres with great accuracy and reliability for the epoch 1982,0

$$g = 980\ 925\ 903 \pm 2 \text{ mcgal}$$

Naturally, this value was by 11 mcgal less than the one obtained without allowance for the non-linearity of the gravity field on A3 pillar.

It seems interesting to compare the obtained result with the **g** value assumed for this point in the IGSN-71 system, which is :

g = 980 925 867 ± 14 mcgal

i.e. by 36 ± 14 mcgal less.

Analogous results were obtained for other IGSN-71 points too, after measurement of the absolute gravity value at these points by the GABL gravimeter. Thus for Potsdam S-13 this difference was + 48 ± 18 mcgal, for Ledovo 5036 it was + 49 ± 21 mcgal, and for Helsinki + 72 ± 20 mcgal /6/. On the average for the European continent it was + 52 ± 7.5 mcgal.

This systematic difference could have appeared only as the result of the deviation of the zero of IGSN-71 system, or the change of gravity of global nature. The most probable cause is the first, produced by large local changes of gravity in Sèvres during the period of establishment of IGSN-71 system.

The cause of that change is yet unknown, but inspite of that the fact remains that the change of gravity in Sèvres from 1969 to 1977 reached about 40 mcgal.

CONCLUSIONS

1. As the result of the first international comparison of absolute gravimeters made in Sèvres in 1981, it was established that modern portable ballistic gravimeters have an accuracy with a mean square error of about ± 6 mcgal.

2. One gravimeter showed a systematic error + 48 ± 12 mcgal implying the necessity of systematic international comparisons, not less than once in 3-4 years, of all absolute gravimeters which are used for international basic gravimetric networks of high order.

3. Incidental errors of **g** determination, obtained by internal compliance, are at the level of ± 2 - ± 3 mcgal, which allows to measure **Δg** or gravity changes in time with that accuracy.

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TABLE 2

Results of absolute determinations in Sèvres (1981)

Instrument	Date	Point	Measured value	Reduction to A3 point	g at A3 point	complete error
			mcgal	mcgal	mcgal	mcgal
Colonetti	1976, May	A3	980 925 892	-	980 925 892	± 10
	1976, June	A3	902	-	902	10
	1977, January	A3	896	-	896	10
	1977, March	A3	906	-	906	10
	1982, April	A3	900	-	900	10
				Average :	980 925 899	± 10
GABL	1977, September	A3	980 925 906	-	980 925 906	± 8
	1981, October	A6	980 926 609	- 700 ± 3.7	909	8
	1981, November	A3	980 925 907	-	907	8
				Average :	980 925 907	± 8
Sakuma	1976	A	980 925 990	- 90 ± 3.0	980 925 900	± 7
China	1980	A3	980 925 914	-	980 925 914	± 14
Hummond	1981, October	A4	980 926 620	- 669 ± 3.7	(980 925 951)	± 12
Faller	1981, October	A5	980 926 563	- 671 ± 3.8	980 925 892	± 5
	1982, March	A	980 925 997	- 90 ± 3.0	980 925 907	± 8

n = 12; m = ± 6,8 mcgal g = 980 925 903 ± 2,0 mcgal
n = 5; m = ± 6,4 mcgal 904 ± 2,9 mcgal
n = 3; m = ± 4,6 mcgal 903 ± 2,7 mcgal

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Fig. 1. Gravity variations around the A3 pillar (in mcgal)