

ASSOCIATION INTERNATIONALE DE GÉODÉSIE

11 B -

BUREAU GRAVIMETRIQUE INTERNATIONAL

BULLETIN D'INFORMATION

N° 45

Décembre 1979

**UNIVERSITÉ P.-et-M. CURIE
4, place Jussieu - Tour 14
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(FRANCE)**

BUREAU GRAVIMETRIQUE INTERNATIONAL

GENERAL INFORMATION

Mr J.J. LEVALLOIS, who was appointed Director of the Bureau at the XVith IUGG General Assembly in Grenoble (1975), has retired on the 2nd of December. He consequently sent his resignation to the President of the Union.

The problems which arose about his succession give the opportunity of reorganizing the activities of BGI in the context of a new host Agency which would provide better facilities and result in a better Service.

Therefore, the "Groupe de Recherches de Géodésie Spatiale" (GRGS) in Toulouse, and the "Bureau de Recherches Géologiques et Minières" (BRGM) in Orléans, the organization which has managed the data base for BGI for four years, proposed in Canberra (during the XVIIth IUGG General Assembly) to take over the activities of the Bureau. The proposal itself was presented by the French National Committee of Geodesy and Geophysics. It obtained the agreement of the International Association of Geodesy, of the International Gravimetric Commission, of the Federation of Astronomical and Geophysical Services, and finally of the Union.

Dr. Georges BALMINO, scientist at GRGS, has been appointed Director of BGI and is happy to undertake this new activity to the benefit of the International Community.

Our best wishes to his predecessor J.J. LEVALLOIS and our thanks to him for having kept the activities of BGI in Paris at a time when the means of the Bureau were insufficient.

December 18, 1978

BUREAU GRAVIMETRIQUE
INTERNATIONAL
Paris

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INTERNATIONAL GRAVIMETRIC BUREAU

PROPOSAL FROM THE G.R.G.S. IN TOULOUSE, IN COOPERATION WITH THE B.R.G.M., TO TAKE OVER THE INTERNATIONAL GRAVIMETRIC BUREAU (I.G.B.)

The Groupe de Recherches de Géodésie Spatiale (G.R.G.S.), with the help of the Bureau de Recherches Géologiques et Minières (B.R.G.M.), proposes that its team in Toulouse should take over the activities of I.G.B. presently located in Paris, from 1980 on. (Informations on these two organizations can be found in the appendix).

IGB is an executive office of the International Gravimetric Commission (I.G.C.) ; it is charged by this commission, according to the instructions of a Directing Board and in collaboration with three working groups, with collecting gravity measurements, with storing them in a data base at the international scientific community disposal, with the coordination of works done by some data supplying agencies, with the evaluation and comparison of observations of various origins, acquisition of any informations related to gravity, establishing and management of a specialized documentation, information of the community by means of bulletins.

1. PREAMBLE : ADVISIBILITY OF THIS PROPOSAL

During the XVIth I.U.G.G. General Assembly in Grenoble (1975), Mr. Levallois was appointed Director of the International Gravimetric Bureau. His resignation, sent in to the President of the Union, will become effective at the next assembly in Canberra, and sets the problem of his succession at a time when the international community wishes the evolution of some aspects of the IGB tasks, mainly because of the increasing contribution of satellite altimetry to the gravity science.

Besides the prominent part which they take in the geological interpretation of the subsoil structure, gravity measurements are of fundamental importance for interpreting various geophysical phenomena. This importance was recently emphasized due to the dramatic increase of the accuracy and of the oceanic coverage coming from satellite data (such as altimetry measurements). The very large number of new observations thus collected, places the activities of ICB in a totally new context. To the past duties which have always been well performed and which must be carried on, new tasks must be added and have to be undertaken by the Bureau for validating, comparing and analyzing very precisely all data of various origins. Principally, on pain of becoming unadapted to the present context, ICB must become capable of combining satellite altimetry data and has to be given the important means necessary for achieving such a work, including their transformation into gravity anomalies and the comparisons of these with existing gravimetric observations wherever it is possible.

The French organizations which are involved are fully conscious of the problems. More particularly, the Groupe de Recherches de Géodésie Spatiale in Toulouse, which has the experience both in satellite data and gravity measurements processing for the improvement of the geopotential, and the Bureau de Recherches Géologiques et Minières - specialist of subsoil data taking and processing, also in charge of the gravimetric map of France -, consider that they have the competence at the international level, and that it is their national duty (for the sake of continuity) to be in charge of the activities of a modern ICB, under conditions which will be explained below.

2. LONG TERM ORGANIZATION

2.1. ICB in France

The maintenance of ICB in France is desirable : as a matter of fact, all the basic resources and elements (gravity data bank at BRGM, satellite data and their processing in Toulouse, important documentation - station descriptions for the IGSN 71 network in Paris) exist and make easy on one hand to pursue a work which traditionnally has always been mastered in our country, on the other hand to develop new activities in taking

care of space techniques.

As we recall it in appendix 1, a large part of the GRGS activities in Toulouse has been devoted - with the support of CNES (the French Centre National d'Etudes Spatiales) and of the SFB 78 (Sonderforschungsbereich, Munich, RFA), to the development of methods for determining the geopotential and for solving many related problems : accurate computation of satellite orbits, filtering algorithms, surface gravity data reduction, processing of satellite altimetry measurements over the oceans, and recently extension of some of these techniques to the determination and interpretation of other planets' gravity fields. So it is legitimate that such a research group, which has won the regard of the international community, which possesses the competence and has all the necessary software, take over the worldwide gravity and altimetry data management and many tasks of compilation and evaluation. In particular, we recall that IGB is in charge of collecting any new set of data, of making comparisons which, in the new context, must take account of satellite altimetry observations. These can be converted into equivalent gravity anomalies, so as to evaluate the point measurements. Now satellite gravity observations are all in Toulouse and analyzed there, whether they come from direct measurements of the geopotential (altimetry data from GEOS 3 and SEASAT 1), or they are deduced from orbital perturbations. The combination of both sets of data should lead to better geophysical interpretation.

On the other hand, the experience of BRGM in organizing gravimetric campaigns, in data taking, in the computation of Bouguer anomalies, as well as the development of interpretation methods in geology and geophysics, puts this agency in the foreground for participating in the data collection and their management, more especially as it manages all geological and geophysical informations about the french subsoil.

2.2. Organization and resources

IGB will have its full moral independence and will act in complete freedom at the international level (in the scope of its duties), with respect to the proposing agencies, which warrant it.

As a general rule, IGB will continue to work as an executive agency of ICG. The relationships between the executive part of the Bureau, this commission, and the three working groups of IGB, as well as the frequent consultation of their members, will be strengthened due to the broadening of the problems to be solved.

2.2.1. Organization

- The Director of IGB will have the directorship of international relations for gravity and altimetry data collection ; the secretariat, production of catalogues, updated maps, the dissemination of the documentation and of informations (circulars, bulletins) will be his responsibility,
- In Orléans, at BRGM, tasks related to the gravimetric data base will be done : collection, updating (adding or withdrawing), selection of data subsets for the users,
- In Toulouse, GRGS will collect all satellite data and will process them in order to make them comparable with gravity values, if necessary with the help of other organizations (GRGS/CNES as a whole, OSU, DMA, ...). It will be the holder of softwares used for these transformations, to be made available to the users. Furthermore, GRGS will make all necessary comparisons between the satellite and surface gravity data wherever possible.

This working structure will be in operation after a decision has been taken in Canberra, during the next IUGG Assembly, and will have a care for non interrupting of the IGB services.

2.2.2. Resources

. Man power

In order to ensure an efficient operation of the Bureau and to produce results of high quality, our analysis of the working conditions has lead us to define the following staff, for which the funding is in each case

indicated.

In addition to the directorship which will be given to a member of GRGS in Toulouse, eight persons will constitute a minimum full time staff in the last stage :

. at GRGS :

One engineer from IGN (for all mapping works),

One engineer assigned by CNES to software development and maintenance,

Three persons hired on CNRS - type positions especially given to IGB by the french Ministry of Education in 1971 : two technicians for collecting and compiling data, one secretary,

GRGS will also allocate two persons half-time : one geoscientist specialized in gravity field problems, and one technician for altimetry data processing.

. at BRGM :

One engineer geophysicist, half-time, responsible for the gravimetric data and their collection,

One computer science engineer, half-time, for the data base maintenance.

. Office space

There is a new problem for the part of IGB in Toulouse. A solution is under study at the National Institute for Astronomy and Geophysics (INAG) in order to obtain adequate space for IGB within the offices which will be built for the Pic du Midi-Toulouse Observatory to be moved to a field located between the Toulouse Space Center (CST) and GRGS buildings, (this operation should take place in 1981).

For a first period (1980-1981), the Space Center has proposed a temporary solution in one of its buildings.

In Orleans, BRGM provides the necessary means for collecting and storing the gravity data, amidst the "Banque des Données du Sous-sol" department.

. Other facilities

IGB receives each year 3 000 \$ from FAGS.

Besides, the annual participation of BRGM in equipment and functioning covers the data base management expenses.

For a start, CNES will support the extra running cost coming from the settlement of IGB inside the Space Center. Finally, GRGS will obtain in 1980 from its constituting agencies the additional means, essential to IGB : magnetic tapes, microfilm for cataloguing and keeping some of the documentation, furniture, utilization of an interactive display console, cost of other facilities, computing time (on CDC 7600 and 6200 computers).

3. TEMPORARY ORGANIZATION (1980-1981)

The availability of some of the means quoted in the preceeding section, requires that the problem of transferring or assigning the people presently in Paris to another field, should be solved.

Miss Coron, assistant to the present Director in Paris, will pursue her activities during this temporary phase.

The people having the positions given to IGB in 1971 will be asked to work in Toulouse, and the best will be done to assure a continuous career to them. Here and now, one position is vacant since one of these persons retired, and it can be transferred to Toulouse at the beginning of 1980.

Finally, the person who presently works under a contract from the Institut de Physique du Globe in Paris, and participates to the gravity data analysis, has accepted to come to Toulouse. His contract will be maintained until mid-1980 ; he will then have a position in CNES.

All these actions should be spread over two years.

4. THE MISSION OF I.G.B.

The main duties of IGB have been recalled in the introduction to this proposal. Its activities are those described by the International Gravimetric Commission (IGC) in September 1974, redefined during the last IUGG general assembly in Grenoble (1975), and published in the Bulletin Géodésique n. 115 (1975, p. 87-92). Some of these activities must be extended considering the new satellite context : collection of gravity and altimetry measurements, compilation and updating of a catalogue of $5^{\circ} \times 5^{\circ}$ mean values to be provided to everyone. We summarize the present situation at IGB to this effect.

Presently, 740 000 data points are in the data base, which is almost the whole of what has been collected since the founding of IGB. 1 500 000 measurements recently received at the Bureau will be added in the near future after transformation in the base format (Cf. IGB Information Bulletin n° 33), and other data are being incorporated. Consequently, although some of these sets consist of old observations, the present data base, from the point of view of the gravity measurements only, is in a good shape, the management being the responsibility of BRGM since 1975. But the space side of it (altimetry data collected from 1975 to 1979 by Geos 3, and in 1978 by Seasat 1) is non existent (although a first file of compiled geoid heights have been sent by DMA) ; the reason is that there is no appropriate means at IGB (for example, there is no software for processing these data and converting them into gravity anomaly values, and conversely) since no measures were taken beforehand for this different type of observation. Therefore the Bureau must find the way, through research institutes like GRGS or OSU, to incorporate easily and update these new data to be finally validated. The concerned international community will be informed of these updates by the IGB Bulletin.

5. WORKING SCHEDULE

The relationships between IGB, its working groups and the International Gravimetric Commission have already been mentioned. We shall limit ourselves below to describing the tasks to be done in France, in Toulouse and Orléans.

A transfer of some data files will be made from BRGM to GRGS (in Toulouse), so as to be evaluated (statistical analysis, correlations with long wavelength satellite information, correlations with altimetry observations - for marine gravity data, etc...) and a summary of this work will be sent to the scientific community. At the same time, we shall start to combine surface gravity measurements with gravity anomalies computed from the most recent file of satellite altimetry derived geoid heights (including the Seasat I data in some areas, as soon as possible).

The data collection will continue without interruption, and will even increase due to the large number of satellite measurements. As far as the surface gravity observations are concerned, the Director in Toulouse will come and keep in touch with the various data suppliers (a task partly fulfilled by Miss Coron during the temporary period). All data will be sent to BRGM where they will be added to the data bank. As for the satellite data, the preferential position of GRGS (one of its members is Principal Investigator in the Geos 3 program) results in a fast increase of the altimetry data set - within a few months, all measurements acquired since 1975, which means around 20 000 oceanic profiles, will be obtained from NOAA. These measurements will be processed, and after taking into account precise Geos 3 orbital arcs, will be converted into geoid heights and gradually compared with the gravity anomalies.

Other types of activity, such as : comparing algorithms for deriving gravity from satellite observations and for computing $1^{\circ} \times 1^{\circ}$ and $5^{\circ} \times 5^{\circ}$ mean values, could be done by IGB, as well as the book-keeping of absolute measurements of g and possibly the correction of some networks. Such works, or the participation to projects like a satellite to satellite tracking experiment (another technique from which a fantastic resolution of gravity could be obtained everywhere), will of course be submitted to the Directing Board and will require the agreement of its members.

Finally an effort will be devoted to making micro-fiches of the important documentation (such as the IGSN 71 station descriptions), automatic contoured maps of anomalies will be produced, and the international community will be informed as often as possible.

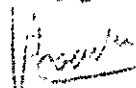
8. APPOINTMENT OF THE DIRECTOR OF IGB

GRGS and BRGM agreed to propose Dr. G. Balmino as the Director of IGB, to be in charge of the duties defined above.


B. LAGO

Executive Director
G.R.G.S.

*Le Directeur du Service
Géologique National*



J. BODELLE

APPENDIX I

The Groupe de Recherches de Géodésie Spatiale (G.R.G.S.)

GRGS was founded in 1971 by the Paris Observatory, the Centre National d'Etudes Spatiales, the Bureau des Longitudes and the Institut Géographique National. Consequently, these organizations have pooled their resources, leading to the completion of a coherent space geodesy program. The originality of this group lies in the fact that the different teams it consists of, remain under management of their original organizations, which bring them the basic support. These teams present jointly to various national research organizations a program which, after approval, is undertaken by the whole group. The corresponding budgets are managed by the four administrations above mentioned. The overall coordination is ensured by an Executive Director, who presently is Mr. B. LAGO for the GRGS in Toulouse (team depending of the Centre National d'Etudes Spatiales - CNES), assisted by a Scientific Director, Mr. B. GUINOT (from Paris Observatory ; he is also the Director of the Bureau International de l'Heure).

This proposal is presented by the team in Toulouse, located in buildings close to the Space Center (CST). This sub-group is also a Research Team of the Centre National de la Recherche Scientifique (CNRS).

Since its establishment, GRGS has carried on works in satellite geodesy, geodynamics and planetology. We simply recall the main fields in which important scientific results were obtained or for which big projects are under study :

- . determination and study of the Earth's gravity field (GRIM 1 and GRIM 2 models, computation of gravimetric geoids - over the North Atlantic Ocean, for instance, utilization of satellite altimetry),

- . solid and ocean tides : computation of Earth tide parameters, and of some coefficients of selected ocean tides by satellite methods,
- . physical oceanography : oceanic tide studies based on satellite altimetry, determination of the sea surface state using the same technique,
- . very precise time synchronisation (LASSO project),
- . precise station positioning (EDOC 1 & 2 experiments, LESAGE Campaign),
- . planetology : GRGS has begun to study terrestrial bodies by naturally extending the techniques, methods of analysis and interpretation developed in the Earth and Earth-Moon system cases, to other planets (dramatic improvement of the Mars gravitational field model in 1978, model of evolution of Venus rotation).

APPENDIX 2

The Bureau de Recherches Géologiques et Minières

(B.R.G.M.)

BRGM is a French State, public utility agency, of industrial and trading character. It is acting as national geological service, and as a mining company.

As a public service, it is in charge of collecting, storing all data related to the french subsoil, including geophysical measurements, and of placing them at the disposal of anyone. Besides, it does the survey and publication of the geological map of France, and of other maps of geophysical interest.

The small scale and complete gravimetric coverage of France was undertaken by BRGM back in 1941 ; it is now being concluded and consists in about one million measurements. The basic scale of the published maps is 1/80 000. Several methods and computer programs have been developed for the interpretation of Bouguer anomalies, in particular an original inversion algorithm by the SIGMA frequency technique.

BRGM recently undertook a cooperative program with BNM (Bureau National de Métrologie) and should be recognized as Federate Laboratory in the Measurement of Gravity.

In 1975, during the IUGG General Assembly in Grenoble, BRGM proposed to help IGB, due to its own experience in gravimetry and also its competence in the management of large data bases. The general system developed for the subsoil data bank (BSS), manageable on an IBM 360-135 computer, made possible the storage of all data collected so far by IGB. About four hundred thousand data points were available in 1975. Since the utilization of the BSS system, the number of consultations of the bank increased extensively, mainly in the form of magnetic tape exchanges with important foreign agencies.

Item III - ABSOLUTE GRAVITY MEASUREMENTS

Addendum - See Bull. Inf. N° 44, p. I-B-2.

Precise tidal corrections for high precision gravity measurements

by B. DUCARME, C. POITEVIN & J. LOODTS

After the presentation of this communication Dr. C. TSCHERNING makes a remark reported p. I-B-3 and Dr. B. DUCARME adds the following answer :

"The large variations of the tidal signal are due to the indirect effect of the oceanic tides. For gravity tides the local geological structures have no influence. But of course we cannot extrapolate the DTM over oceanic areas where large tidal signal arise. As the tides in the Baltic sea are quite small we can use the same DTM over Denmark and Sweden. More questionable is the crossing of the Channel to include British Islands in the model.

Concerning the behaviour of the DTM in areas where large gradients of the tidal factors occur further studies are necessary. It is a reason why some coastal stations had to be eliminated to increase the stability of the model".

The complete text on "Precise tidal corrections for high precision gravity measurements" will be published in the next Bulletin d'Information.

INTERNATIONAL GRAVITY WORKSHOP

NAIROBI, 20th November - 1st December 1978

A - PROGRAMMEMONDAY, 20TH NOVEMBEROPENING SESSION:11:00 - 12:30INTRODUCTION:

Mr. R. Omondi, Chairman National Committee for Geodesy and Geophysics.

OFFICIAL
OPENING:

Hon. Mbiyu Koinange, C.G.H., MP,
Minister for Natural Resources.

OPENING
ADDRESSES:

Prof. H. Moritz, First
Vice-President, International
Association of Geodesy

Dr. S. Coron, Vice-Director,
International Gravity Bureau

Dr. A. M. Wassef, Secretary-General,
Committee for Developing Countries,
International Union of Geodesy and
Geophysics

SESSION 1

(CHAIRMAN: DR. A. M. WASSEF)

2:15 p.m. - 3:15 p.m.

Dr. S. Coron

1. Purpose and activity of the International Gravity Bureau.
2. The unification of the gravity nets of Africa.

3:45 - 5:00 p.m.

Prof. H. Moritz

Mathematical aspects of
filling gaps in the gravity
coverage, especially in view
of geoid determinations.

TUESDAY, 21ST NOVEMBERSESSION 1

(CHAIRMAN: PROF. C. E. GERSTENECKER)

9:00 a.m. - 10:30 a.m.

Dr. J. Njombi

Gravity studies of Olkaria
geothermal region, Kenya.

SESSION 2

11:00 - 12:30 p.m.

Prof. E. Groten

Chairman: Chief R. O. Coker

Uses of gravity measurements in applied geodesy and surveying.

SESSION 3

2:15 - 3:15 p.m.

Dr. L. Zboril

Chairman: Prof. H. J. Skinner

Gravity, electrical and magnetic surveys for hydrogeology of the African Platform.

Demonstration: Wall Poster of Geophysical and Hydrogeological investigations in Africa.

SESSION 4

3:45 - 5:00 p.m.

Dr. M. Blizkovsky

Chairman: Mr. P. P. Anyumba

Compilation of a gravity data bank on the computer and its further use.

WEDNESDAY, 22ND NOVEMBER

SESSION 1

9:00 - 10:30 a.m.

Prof. C. E. Gerstenacker

Chairman: Dr. G. E. Sherurah

Metrological aspects of gravity Measurements.

SESSION 2

11:00 - 12:30 p.m.

Prof. S. Saxon

Chairman: Mr. P. M. Leretholi

Some examples of the applicability of gravity measurements in economical geological problems.

SESSION 3

2:15 - 3:15 p.m.

Dr. S. Coran

Chairman: Prof. H. Moritz

Gravity nets and gravity anomalies: Various examples.

THURSDAY, 23RD NOVEMBER

Whole day tour of Olkaria Geothermal Project, Naivasha, Departure at 9:00 from K.C.C. (Kenya Conference Centre). Lunch at Lake Naivasha Hotel.

FRIDAY, 24TH NOVEMBER

SESSION 1

9:00 - 10:30 a.m.

Dr. A. Kivimäki

Chairman: Prof. R. Green

The land uplift and the precise gravity measurements in Fennoscandia.

SESSION 2

(CHAIRMAN: MR. C.J. SWAIN)

11:00 - 12:30 p.m.

Dr. A. M. Wassef

A preliminary note on the inventory of geo-physical and other basic surveys in Africa carried out at UNECA.

SATURDAY, 25TH NOVEMBER

9:00 - 12:30 a.m.

Tour of Nairobi National Park and Animal Orphanage.

12:30 - 2:00 p.m.

Lunch at Masai Lodge.

2:00 - 4:30 p.m.

Visit to Bomas of Kenya for traditional dances and back to hotels.

MONDAY, 27TH NOVEMBER

SESSION 1

(CHAIRMAN: M. MIDASSY MOHAMED)

9:00 - 10:30

Dr. M. Blinkovsky

Micro gravity and application in Engineering.

SESSION 2

(CHAIRMAN: DR. S. CORON)

11:00 - 12:30

Prof. I. Mareson

Instruments, methods and results of absolute gravity measurements.

2:00 - 4:00 p.m.

Visit to Mines and Geological Department, Nairobi (Madini House)

TUESDAY, 28TH NOVEMBER

SESSION 1

(CHAIRMAN: PROF. S. SAEED)

9:00 - 10:30

Mr. S. Matvey

IGSN degree gravity anomalies for Africa and their related geoid, by Prof. G. Obensou and M. Ayaraina.

SESSION 2

(CHAIRMAN DR. L. ZBORIL)

11:00 - 12:30

Prof. R. Green

1. An example of successful transfer of science and technology - The Indonesian Regional Gravity Map.

2. The Completion of Regional Gravity
Map of Indonesia.

SESSION 3

2:15 - 3:15 p.m.

M. Midaszi Mohamed

(CHAIRMAN: MR. R. OMONDI)

The establishment of the Gravity
Map of Tunisia.

SESSION 4

2:45 - 5:00 p.m.

Mr. P. S. Bhogal

(CHAIRMAN: DR. I. MARSON)

Electrical resistivity surveys at
Olkaria Geothermal field, Kenya.

WEDNESDAY 29TH

SESSION 1

9:00 - 10:30 a.m.

Prof. N. J. Skinner

(CHAIRMAN: DR. A. M. WASSEF)

Review of recent geophysical work in
Kenya.

SESSION 2

11:00 - 12:30

Mr. C. J. Swain

(CHAIRMAN: DR. A. KIVUNIGI)

Some techniques for regional gravity
surveys.

SESSION 3

2:15 - 3:15 p.m.

Panel discussion on First order gravity network in Africa.

(CHAIRMAN: PROF. R. GREEN)

SESSION 4

3:45 - 5:00 p.m.

Mr. C. J. Swain

(CHAIRMAN: PROF. N. J. SKINNER)

Isostasy and the interpretation of
Kenya's gravity field.

THURSDAY 30TH

SESSION 1

(CHAIRMAN: PROF. R. GREEN)

9:00 - 10:30

Panel discussion

First order gravity networks in Africa
(cont.).

SESSION 2

(CHAIRMAN: PROF. S. SAZIV)

11:00 - 12:30

Panel discussion on specifications for gravity surveys.

SESSION 3

(CHAIRMAN: CHIEF O. R. COKEE)

2:15 - 3:15 p.m.

Discussion of proposed resolutions.

SESSION 4

(CHAIRMAN: MR. P. P. ANYUMBA)

Mr. R. Omondi: Chairman, Organizing Committee

Dr. A. M. Wassef: Convener of the Workshop

POST WORKSHOP TOUR

FRIDAY 1ST DECEMBER

Either Express or 1½ day tour of Amboseli National Park

B - R E S O L U T I O N S

RESOLUTION N° 1

Indonesian Gravity Network

The International Gravity Workshop of the International Union of Geodesy and Geophysics meeting in Nairobi from November 20th to December 1st, 1978, noting the completion, by the Geological Survey of Indonesia in cooperation with the University of New England, Australia, of a regional Bouguer gravity map of Indonesia. (Scale 1 : 5 000 000 ; 20 mGal contour interval) and a regional Bouguer gravity map of Eastern Indonesia (Scale 1 : 2 000 000 ; 10 mGal contour interval),

records its appreciation of this accomplishment. Furthermore, commends the Indonesian Ministry of Mines and Energy for their action in developing a Centre of excellence within the Department of Mines and Energy for the measurement, processing, interpretation and presentation of gravity data whose work represents a major contribution to the Scientific understanding of the Geotectonics of the region and the Science in general.

RESOLUTION N° 2

Documentation and Dissemination of Gravity Data

The International Gravity Workshop of the International Union of Geodesy and Geophysics meeting in Nairobi from November 20th to December 1st, 1978, considering the efforts and cost involved in geophysical work in general and gravity measurements in particular,

realizing the need to refer back to earlier data when any exploration programme is undertaken,

considers it prudent that all data should be properly documented at the national service concerned in a retrievable form and that, with due regard to national interests, the information should be made available to the international scientific community after the lapse of a prescribed period of time.

RESOLUTION N° 3

Release of Gravity Data by Non-Governmental Organizations

The International Gravity Workshop of the International Union of Geodesy and Geophysics meeting in Nairobi from November 20th to December 1st, 1978, expresses its appreciation to all non-governmental companies who, at the request of national and international services, have already communicated their results in the form of gravity anomaly map and listed data, furthermore, in view of the rapid increase of geophysical work carried out in Africa by new national services and to avoid repetition of Surveys, invites the concerned non-governmental organisations to assist these services in establishing general and regional gravity maps by releasing their gravity anomaly maps and gravity data with details of reference bases to the national services.

RESOLUTION N° 4

UNECA Cartographic Inventory of Basic Survey Data in Africa

The International Gravity Workshop of the International Union of Geodesy and Geophysics meeting in Nairobi from November 20th to December 1st, 1978, recognizing the significance to the planning of National and Regional development of natural resources and the need for the preparation of a cartographic inventory of basic survey data, appreciating the programme initiated and being implemented by the UNECA in this respect for Africa,

recommends

- (1) that all African Governments continue to contribute to this programme to facilitate its early completion,
- (2) that UNECA take the necessary action to ensure the continuous up-dating of the inventory,
- (3) that other developing regions consider adopting similar programme.

RESOLUTION N° 5

Gravity Map of Tunisia

The International Gravity Workshop of the International Union of Geodesy and Geophysics meeting in Nairobi from November 20th to December 1st, 1978,

noting the completion of the gravity map of Tunisia,

commends the authorities concerned for the foresight in initiating the programme and,

recommends that the relevant data should be communicated to the I.G.B.

RESOLUTION N° 6

Bouguer Gravity Map of Kenya

The International Gravity Workshop of the International Union of Geodesy and Geophysics meeting in Nairobi from November 20th to December 1st, 1978,

noting the completion of a Bouguer gravity map of Kenya,

commends the authorities concerned for the foresight in initiating the programme and for communicating some data to I.G.B.,

recommends that all other relevant data should be communicated to the I.G.B.

RESOLUTION N° 7

Establishment of Absolute Gravity
Stations for Gravity Calibration Lines

The International Gravity Workshop of the International Union of Geodesy and Geophysics meeting in Nairobi from November 20th to December 1st, 1978,

aware of the Resolution 5 of the Inaugural Meeting of the Commission for Geodesy in Africa held in Lagos, Nigeria in March 1977,

realising the importance to African countries of establishing gravity calibration lines in Africa,

recommends

- (1) The establishment of absolute gravity stations located so as to form two calibration lines, one through East Africa and the other through West Africa ;
- (2) That the calibration lines should include stations selected from the list of first order gravity stations proposed in Lagos ;
- (3) That, so far as practicable, the stations on both lines in Africa should be in pairs of equal gravity values to facilitate the establishment of isogal lines ; and
- (4) That the absolute gravity stations on the calibration lines should be at intervals of 200 ~ 250 milligals.

RESOLUTION N° 8

Technical Assistance for the Establishment of the
Absolute Gravity Stations in Africa

The International Gravity Workshop of the International Union of Geodesy and Geophysics meeting in Nairobi from November 20 th to December 1st, 1978, referring to the Resolution N° 7 regarding the establishment of absolute gravity stations for gravity calibration lines in Africa, realising the importance of coordinated effort to accomplish this task, aware of the offer by the Italian delegation to the Lagos meeting to support this project, recalls the interest of Professor Marussi and Professor Morelli in assisting the African countries in the field of geodetic and geophysical activities, requests Professor Marussi and Professor Morelli to continue to make the necessary representations to the Italian Government to reactivate the offer of the Italian Government to support the project, recommends that the U.N. Economic Commission for Africa approach the Italian Government for the necessary financial assistance that would enable the Istituto di Metrologia "G. Colonetti" of Torino to undertake the project.

RESOLUTION N° 9

Specifications of Gravity Surveys

The International Gravity Workshop of the International Union of Geodesy and Geophysics meeting in Nairobi from November 20 th to December 1st, 1978, realising The importance of adequate specifications for gravity surveys recommends

- (1) That gravity operations should aim at establishing gravity stations with a density of one stations per twenty five square kilometres ;
- (2) That, as far as practicable, the stations should be located at places not likely to be disturbed,
- (3) That base stations should be suitably marked indicating name and number,
- (4) That base stations should be connected by spirit levelling to the national levelling network ; and
- (5) That satellite stations should be established around some of the base stations.

RESOLUTION N° 10

Collaboration with the International Gravity Bureau

The International Gravity Workshop of the International Union of Geodesy and Geophysics meeting in Nairobi from November 20th to December 1st, 1978,
considering

the task of the International Gravity Bureau in connection with the documentation of gravity data and its work to unify the different gravity nets in Africa already observed with support from UNESCO,

recommends

that the collaboration between the International Gravity Bureau and the national services of geodesy and geophysics in the African countries continue and be strengthened with a view to have all new gravity nets adjusted within the International Gravity Network.

RESOLUTION N° 11

Offer of Computing Facilities from Canada

The International Gravity Workshop of the International Union of Geodesy and Geophysics meeting in Nairobi from November 20th to December 1st, 1978,

noting the offer communicated to the Workshop by the Department of Energy Mines and Resources, Earth Physics Branch, Gravity Division, Observatory Crescent, Ottawa, Canada, to make available under certain conditions, computing facilities and overall direction to assist African Nations in adjusting national gravity nets,

invites African countries to consider taking advantage of the offer.

RESOLUTION N° 12

Appreciation

The International Gravity Workshop of the International Union of Geodes and Geophysics meeting in Nairobi from November 20th to December 1st, 1978, considering the scientific and technical benefits derived from the Workshop, realizing its contribution to the advancement of technology in the field of gravity and related topics, conscious of the interest this workshop has stimulated in fostering gravity activities in developing countries, conveys its thanks and appreciation to the IUGG Committee for Developing Countries for convening the Workshop and to the IUGG for its financial support

RESOLUTION N° 13

Publication of the Proceedings of the Workshop

The International Gravity Workshop of the International Union of Geodes and Geophysics meeting in Nairobi from November 20th to December 1st, 1978, considering the value and importance of the papers and other documents presented in the course of the Workshop, realizing the advantage of having a permanent record of the proceeding, request the Survey of Kenya to make the necessary arrangements to publish the complete record of the proceedings of the Workshop.

RESOLUTION N° 14

Appreciation

The International Gravity Workshop of the International Union of Geodesy and Geophysics meeting in Nairobi from November 20th to December 1st, 1978,

appreciating the tremendous effort and amount of work involved in the organization of the Workshop in Nairobi,

noting that the Workshop has been a great success,

conveys its thanks and appreciation to the Government of Kenya for providing the facilities for the Workshop and for its hospitality and

thanks the National Committee for Geodesy and Geophysics for the excellent arrangements made for the Workshop and for the welfare of the participants.

Item XIII - GEOPHYSICAL INTERPRETATION OF GRAVITY DATA

Chairman : Prof. S. SAXOV

One session held on Friday 15 September 1978, 11.15 am - 1.15 pm.

Five papers were presented. G. Desvignes (France) discussed geophysical interpretation of some large scale gravity anomalies and geoid undulations, while H.G. Kahle (Switzerland) presented a paper dealing with the Swiss Alps : Gravity Field and Geodynamic Implications. V. Vyskočil (Czechoslovakia) talked on the construction of the density models in the lithosphere, and A. Vogel (German Federal Republic) dealt with the problem of geophysical interpretation of standard Earth gravity anomalies. S. Saxov (Denmark) presented various examples showing how gravity can be applied to geology.

REPORT of the SPECIAL STUDY GROUP N° 5:46

At the end of the session a report on the activity of the study group was given, the main emphasis being put on the recent symposium on the Role of Density (Aarhus, May 9-11, 1978). The proceedings of the symposium is published in GEO-SKRIFTER 10 issued jointly by the Laboratory of Physical Geography and the Laboratory of Geophysics, Aarhus University.

At the symposium the SSG-members present adopted the following resolution :

Following the Symposium on the Role of Density, Special Study Group N° 5:46 held a meeting on Thursday, May 11, 1978, in order to discuss the symposium and the consequences which could be drawn from it. SSG 5:46 also dealt with the question of a continuation of its theme : Physical Interpretation of Gravity anomalies, and will in this respect put forward the following utterance : SSG 5:46 feel that the proper utility of gravimetric measurements in the physical interpretation with regard to geodetic (geoidal) studies requests an application of additional information. In this respect the density function is an important parameter. Therefore, SSG 5:46 feel that studies should be orga-

nized by a new study group established at the IAG Assembly in Australia 1979 in the following way:

New SSG 5:--

Determination of density distribution within the Earth: static and geodynamic models.

Topics

1. Density reference models (global and regional) by use of gravity, geoid, and all available physical information of the Earth together with relevant contributions from the planets and the moon.
2. Incorporation of geodynamics knowledge by realistic utilization of geotectonics, age determination and so on.
3. Application of mathematical and computational techniques.

SSG 5:46 is furthermore of the opinion that during the coming 4 year period (1979-1983) an interdisciplinary Union Symposium with the title: Determination of Density Distribution within the Earth: static and geodynamic models - should be arranged by IAG (through the new SSG) and with participation from IASPEI, IAVCEI, and IAGA.

SSG 5:46 will therefore recommend that IAG informs IASPEI, IAVCEI, and IAGA at the earliest convenience of the proposed symposium.

The SSG 5:46 Subcommittee on Gravity Prediction was formed in 1976. The members of this Subcommittee included:

Dr. Luman E. Wilcox, Chairman (USA)
 Dr. Kenneth I. Daugherty (USA)
 Professor, Dr. E. Groten (Germany)
 Dr. Gerard Lachapelle (Canada)
 Dr. Richard H. Rapp (USA)
 Mr. William E. Strange (USA)
 Dr. C.C. Tscherning (Denmark)
 Professor George P. Woollard (USA)

The chairman has proposed the following initial program for the Subcommittee:

- a. Development and improvement of gravity prediction methods (conventional, statistical, geophysical) for application in surveyed or unsurveyed areas, both continental and oceanic.
- b. Development of more rigorous formulations to enable expression of the accuracy of completed gravity predictions.
- c. Applications of gravity predictions to produce gravity anomaly values, deflection of the vertical, etc.
- d. Development of combined statistical-geophysical approaches to the gravity prediction problem.
- e. Development of global surface gravity models using surface measurements and prediction methods.

Work on geophysical gravity prediction for continental areas continues at DMAAC although progress has been slowed considerably because of the necessity of completing other non-related work. Since the IAG session at Grenoble in 1975 we have published new gravity anomaly maps for Greenland, and a completely revised and updated set of gravity maps for South America. Both sets of maps are based on $1^{\circ} \times 1^{\circ}$ mean gravity anomaly predictions. Work now underway or planned for the future includes new mean anomaly predictions for the Antarctic continent and revised and updated predictions for Africa.

Work on development of geophysical prediction methods for oceanic areas has been terminated, at least for the time being. It now appears that mean gravity anomalies recovered from the geoid heights measured by satellite radar altimetry will satisfy all areas for mean gravity anomalies in the oceanic areas.

Other work completed since 1975 includes a comprehensive review of graphical and analytical methods for gravitational modelling of earth structure and a review of Airy isostasy as interpreted by G.P. Woollard.

At the Institute of Theoretical Geodesy, Technical University of Hannover the activities have been as follows:

1. Density determinations

For the construction of a regional Bouguer anomaly map of northeastern Iceland, density determinations have been carried out by sample rock weighing and by Nettleton-profiles. The gravity observations were reduced with average densities of 2.7 g/cm^3 (tertiary basalt zone), 2.5 g/cm^3 (intermediate zone), and 2.3 g/cm^3 (central volcanic zone), the boundaries of the density zones being determined from the geological map. The resulting gravity field is more quiet as compared with the gravity picture obtained with a uniform density of 2.6 g/cm^3 , although the regional behaviour of gravity does not vary much (Schleusener et al. 1976).

2. Gravity field of local structures

In northern Iceland some local structures (basalt mountains, tuff volcanoes, shield volcanoes, open fissures) of the young volcanic zone and the adjacent tertiary basalt zone have been investigated by special gravity survey. Possible density models have been discussed by Schleusener (1974).

3. Time variations of gravity and height

In continuation of the high precision gravity observations, carried out in northern Iceland between 1965 and 1975 (Torge and Drewes 1977), special gravimetric investigations were performed in the axial rift zone, in 1976 and 1977 (another resurvey is planned for 1978). The gravity and height determinations should give, by comparison also with the results of the 1965/1975 survey, information about the current rifting episode in northern Iceland, which started at the end of 1975, and is still going on. From the first results (Torge and Drewes, Jökull, in press), one finds gravity and height variations along the rift zone, of the 0.1 mgal - respectively some $0.1 \dots 1 \text{ m}$ - order, and concentrated on relatively small (some km) areas. At Námaskard, being the southern edge of the Krafla caldera, gravity increase and height decrease are clearly correlated. Over an activity period of one year, the gravity-height factor is $-0.1 \dots 0.2 \text{ mgal/m}$, which could correspond to the combined

effect of the removal of a Bouguer plate and a superposed gravity decrease (Torge 1978). More details are given in the IAG - SSG 3:40 report.

The Geological Survey of Finland has carried out gravity measurements for the purposes of prospecting and investigation of geological structures in the uppermost crust. About 50 000 observations have been made each year. Helicopter transportation has been used in regional gravity surveys in Lapland. During the winter time detailed gravity measurements have been made on lake ice. Underground gravity measurements have been made in the Pääjärve tunnel.

Bedrock density profiles were derived from surface and underground gravity measurements along the Pääjärve tunnel. The anomalies due to the overburden, topography and tunnel were evaluated by means of two-dimensional models and removed from the observed gravity values. The calculated densities were compared at 25 locations to the weighted averages of measured densities of rock specimens collected from the tunnel. The mean and the standard deviation of the differences were 0.03 and 0.06 g/cm³ respectively. The observed negative correlation between these differences and the densities determined in laboratory is probably due to anomalous free-air gradients caused by density variations under the tunnel.

Work has been made to incorporate density and geological data in interpretation of gravity anomalies as described in the paper by Puranen, Elo and Airo, presented at the symposium on the Role of Density in Aarhus in 1978.

From Earth Physics Branch, Canada, an extract from the National Report on Gravity Research is listed below.

Gravity Interpretation Studies

Since 1974, a number of interpretation studies using gravity and related data have been undertaken. These have included regional interpretations connected with the issue of new maps in the Gravity Map Series, modelling of intrusive bodies, and studies of fossil meteorite craters. Perhaps the most interesting ones are those continuing studies which have concentrated on the Arctic Ocean, the continental margins and the

structural boundaries in the Canadian Shield.

Interpretation

C.E. Keen has studied the Backus-Gilbert techniques in the inversion of gravity data to put limits on possible density distributions in models of continental margins, and has applied these techniques to an area on the Nova Scotian margin. An interactive computer programme has been developed to generate geological models which fit both gravity and magnetic observations. R.A. Folinsbee has completed an interpretation of the gravity data on the northeast Newfoundland margin. A broad zone of free-air anomalies greater than ± 75 mgal indicates that the depth to the mantle beneath the outer northeast Newfoundland shelf is only 18 km. R.J. Haworth has mapped the marine extension of the Paleozoic oceanic rocks surrounding Notre Dame Bay in Newfoundland. These Paleozoic "oceanic" units can be traced across the Newfoundland shelf by gravity, magnetic, refraction seismics and drill hole evidence, and they lie so close to the Labrador coast at $52^{\circ}30' N$ that a major salient/recess must have existed at the western edge of the Paleozoic collision zone.

At the Geodetic Survey of Canada the application of least squares collocation to astrogravimetric levelling was studied (Lachapelle 1975a, 1975b). The use of a combined integral formulae and collocation approach to estimate geoid undulations and deviations of the vertical is described (Lachapelle 1976a). Results obtained when using geopotential coefficients and surface gravity data are given in (Lachapelle 1977a, 1977b) while results with the use of geopotential coefficients, surface gravity data and astrogeodetic deviations of the vertical are given in (Lachapelle 1976b). The evaluation of $1^{\circ} \times 1^{\circ}$ mean free air anomalies in Canada from surface gravity data and $5' \times 10'$ or $1^{\circ} \times 1^{\circ}$ mean topographic heights was carried out by (Lachapelle 1978).

At the Laboratory of Geophysics, Aarhus University, the research has consisted partly of detailed surveys of different geological structure, e.g. salt domes and synclines, partly of studies of the applicability of gravity to ground water problems, and partly of theoretical investigations and model calculations.

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- Lachapelle, G. (1978): Evaluation of $1^{\circ} \times 1^{\circ}$ mean free air gravity anomalies in Canada. Presented at the 8th Meeting of the International Gravity Commission, Paris, September 12-16.
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REPORT TO
WORLD GRAVITY STANDARDS
WORKING GROUP
ON THE
ADJUSTMENT OF THE
LATIN AMERICAN GRAVITY
STANDARDIZATION NET 1977
(LAGSN 77)

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EARTH PHYSICS BRANCH
OTTAWA, Canada

September 1978

1. Introduction

The Latin American Gravity Standardization Net 1977 (LAGSN77) results from a unified adjustment of the national networks of some 20 countries in Latin America. Diagrams of each national net and the complete LAGSN77 are given in the Appendix.

LAGSN77 has been presented to the SILAG (Sistema Informativo Latinoamericana de Gravedad) Working Group of the Pan American Institute of Geography and History at its August 1977 meeting. This group recommended that LAGSN77 be adopted as a reference standard for Latin America and a resolution to this effect was passed by the Geophysics Commission of PAIGH.

The purpose of the present report is to provide a brief description of the adjustment technique sufficient to permit discussion in WG2 with a view to having LAGSN77 endorsed by the IGC.

2. Structure of LAGSN77

LAGSN77 contains some 4500 LCR gravimeter measurements inter-connecting 964 stations of which 250 are common to IGSN71. The national nets which make up LAGSN77 are, in some cases, well linked together e.g. Argentina, Bolivia and Paraguay. In other cases (Peru, Chile, Ecuador etc.) the nets are essentially independent. Fortunately, all the national nets have been tied to one or more IGSN71 stations. Since the same gravimeters have been used on several nets, LAGSN77 has relatively good structure from the mathematical point of view.

IGSN71 stations (notably those in Brazil) which are not connected to LAGSN have been included in the solution. The adjusted values for these stations in the LAGSN77 system will be identical to their IGSN71 values.

3. Data Description

National gravity networks in Latin America have, for the most part, been observed to a uniform set of standards developed by the Interamerican Geodetic Survey (IAGS) in Panama. Raw field observations and station documentation were forwarded to EPB by Mr. Roman Geller of IAGS. Observations over the ACL in 1972 resulted from a joint project of EPB, IAGS and Hawaii Institute of Geophysics. National net data for Brazil was not in suitable form for inclusion in LAGSN77 but will be incorporated in a later adjustment as the Brazilian network project develops.

All data has been observed with Lacoste Romberg gravimeters only.

A summary of the surveys is given in Table 1.

4. Data Reduction

The gravity difference between two stations having readings R_i and R_j respectively was computed as

$$R_{ij} = \int_0^{R_i} I dR + C_i - \int_0^{R_j} I dR + C_j \quad (1)$$

where I is the gravimeter interval factor (supplied by the manufacturer) and C_i and C_j are the earth tide corrections computed according to Longman's formulae (Longman, 1959). The Honkasalo correction (Honkasalo, 1964), has not been applied since it is essentially linear over the range of the observations and will be implicit in the scale correction factor determined in the adjustment for each gravimeter. Periodic screw error corrections were not available for any of the meters used.

5. Adjustment Model

Physical Considerations

Errors in gravity measurements arise from factors related to conditions at each observing site and to conditions during transport between observing sites. Both types of errors may have random and systematic components, the latter being the more troublesome. Systematic errors due to site misidentification, instrument drift, dial calibration, atmospheric pressure, temperature effects and magnetic effects are treated in two ways depending on the frequency with which they occur. For those which occur rarely, the affected observation may be rejected or, if the systematic error is suspected to appear in all observations, by including appropriate parameters in the observation equation to account for it.

In the present analysis, only linear approximations of instrument drift and scale correction factor are included as unknowns in the observation equation. The non-linear component of drift produced by instantaneous reading changes commonly referred to as "tares" are directly related to inadvertent jarring of the instrument during transport and are presumed to be removed by the rejection limit are not specifically accounted for in the observation equation. Their presence will be reflected in the internal consistency of the measurements with a particular instrument.

Observation Equation

The gravimeter observations are represented by the system of equations

$$\sqrt{P_m} (g_i - g_j - K_p R_{ij} - d_p T_{ij} = \epsilon_{ij}) \quad (2)$$

where

- g_i is the unknown value of gravity at the i th station
- g_j is the unknown value of gravity at the j th station
- K_p is the unknown scale correction factor for the p th instrument
- R_{ij} is the observed gravity difference given by equation (1)

d_p is the unknown drift rate for the pth instrument

T_{ij} is the time difference between the ith and jth station

ε_{ij} is the observational error in R_{ij}

P_m is the weight of the mth observation, $m = 1, 2, \dots, n$.

Substituting trial values $g_i^0, g_j^0, K_p^0, d_p^0$ for g_i, g_j, K_p, d_p ,

Equation (2) becomes

$$\sqrt{P_m} \left[(g_i^0 - \delta g_i) - (g_j^0 - \delta g_j) - (K_p^0 - \delta K_p) R_{ij} - (d_p^0 - \delta d_p) T_{ij} = \varepsilon_{ij} \right] \quad (3)$$

If the discrepancy between the observed and trial gravity differences

is defined by $g_i^0 - g_j^0 - K_p^0 R_{ij} - d_p^0 T_{ij} = \varepsilon_{ij}^0$

then (3) becomes

$$\sqrt{P_m} \left[\delta g_i - \delta g_j - \delta K_p R_{ij} - \delta d_p T_{ij} = \varepsilon_{ij} - \varepsilon_{ij}^0 \right] \quad (4)$$

or in matrix form

$$P^{-1} A \delta X = P^{-1} \varepsilon - P^{-1} \varepsilon^0 \quad (5)$$

where

A is an $n \times r$ matrix of coefficients for r unknowns and n observations,

δX is an $r \times 1$ vector of corrections to the trial values,

ε^0 is an $n \times 1$ vector of corrections to residuals computed from the trial values,

ε is an $n \times 1$ vector of observational errors,

P^{-1} is an $n \times n$ diagonal matrix of observation weights

The minimum variance solution of equation (5) is

$$\delta \hat{X} = -(A^T P A)^{-1} A^T P \varepsilon^0 \quad (6)$$

The estimates of the unknown gravity values, scale factors and drift terms are given by

$$\hat{X} = X^0 + \delta \hat{X} \quad (7)$$

In this analysis the observations with each gravimeter are assumed to form separate populations with different variances.. Since the weights are not known a priori, we take $P = 1$ for the first cycle of the adjustment and then calculate new weights P_p for each instrument according to

$$P_p = \frac{S_o^2}{S_p^2} \quad \text{where} \quad S_p^2 = \frac{\sum P_m \epsilon_{ij}^2}{l - 1}$$

summed over the l observations with the p th instrument and

$$S_o^2 = \frac{\sum P_m \epsilon_{ij}^2}{n - r} \quad \text{is an estimate}$$

of the standard error of unit weight. The adjustment is then recycled with these weights and with the previous solution values used as trial values. On the first cycle of the adjustment no observations are rejected. On the second and subsequent cycles measurements are rejected if $|\epsilon_m / \sqrt{P_m}| > 4S_o$ [where S_o is taken from the previous cycle, the purpose of the rejection limit being to separate a small number of gross errors from measurements whose errors are otherwise normally distributed.

Datum and scale in LAGSN77 are provided by entering IGSN71 gvalues through equations of the form:

$$P_m (\delta g_i = \epsilon_i - \epsilon_i^0)$$

where ϵ_i^0 is the difference between the IGSN71 gvalue and the trial value

$$\text{and} \quad P_m = \frac{S_o^2}{\sigma_{ji}^2 \times 2}$$

where σ_{ji} is the published error estimate of the IGSN71 station and the factor 2 is the "Uotila correction factor" required to provide correct scaling of the IGSN71 error estimates.

6. Adjustment Procedure

Data Editing

The flow diagram for the data processing system is given in Fig. 1. Each national net was adjusted separately for internal consistency fixing IGSN71 stations for datum control and the scale factor of one gravimeter. This provided a basis for detecting and correcting errors in data encoding.

Since no coherent station numbering system had been used in the original data some confusion arose where more than one station existed in a given city. The connections to the IGSN71 stations were particularly difficult to identify. Over a period of 3 years with the co-operation of IAGS and the national agencies in Latin America these problems were gradually resolved. The agonies and frustrations of this process will not be described here.

Combined Adjustment

Datum and scale for the combined adjustment of the national nets and their interconnecting measurements was determined by the IGSN71 g values introduced as described in the previous section.

For the initial cycles of the adjustment scale unknowns were assigned to each instrument/year combination. This resulted in unrealistic variations in scale factor (up to 5 parts in 10^4) from one year to the next for a given instrument. Standard errors of the scale factors showed a considerable variation reflecting the relative strength of the "calibration" of each instrument/year group against IGSN71. Since the scale factors of LCR gravimeters rarely change by more than 1 part in 10^4 over periods of several years, except where internal repairs or adjustments have been made, the manufacturer was consulted on the maintenance history of each instrument.

On the basis of this information it was deemed appropriate to solve for a single scale unknown for each instrument with the exception of G11 which required separate scale unknowns for the two years it was used.

Drift unknowns were also included for each instrument/year combination during initial cycles of the adjustment but were later dropped as none were significant at the 5% level on a t-test.

New weights were computed for each instrument/year combination after each cycle of the adjustment and normalized to a mean of one. Before the final cycle the dependence of residual size on T_{ij} was examined. This was done by sorting the equations by T_{ij} , subdividing them into 10 groups of 440 observations each and computing the variance of the weighted residuals in each group. The results of this analysis are shown in Fig. 2 along with the derived T_{ij} weighting functions. The appropriate function was applied in the final cycle of the adjustment.

The standard error of unit weight of the final adjustment was 0.034 mGal. There were 32 observations rejected at the 4 σ level. Standard errors of the 16 scale unknowns varied from 1.2×10^{-5} to 6.8×10^{-5} with the exception of G61 which had a standard error of 2.5×10^{-4} . The latter gravimeter was the sole instrument used on the Uruguayan net which is only weakly connected to IGSN71.

Weights of the 43 individual instrument/years varied from extremes of 0.10 to 4.93 with most falling in the range 0.50 to 1.50. Standard errors of the gravity values ranged from 0.011 to 0.068 mGals.

7. Presentation of LAGSN77

LAGSN77 station locations are in general well documented and a large percentage have photographs. Therefore the descriptions were reproduced by photo offset printing and are available in 7 loose leaf volumes as follows:

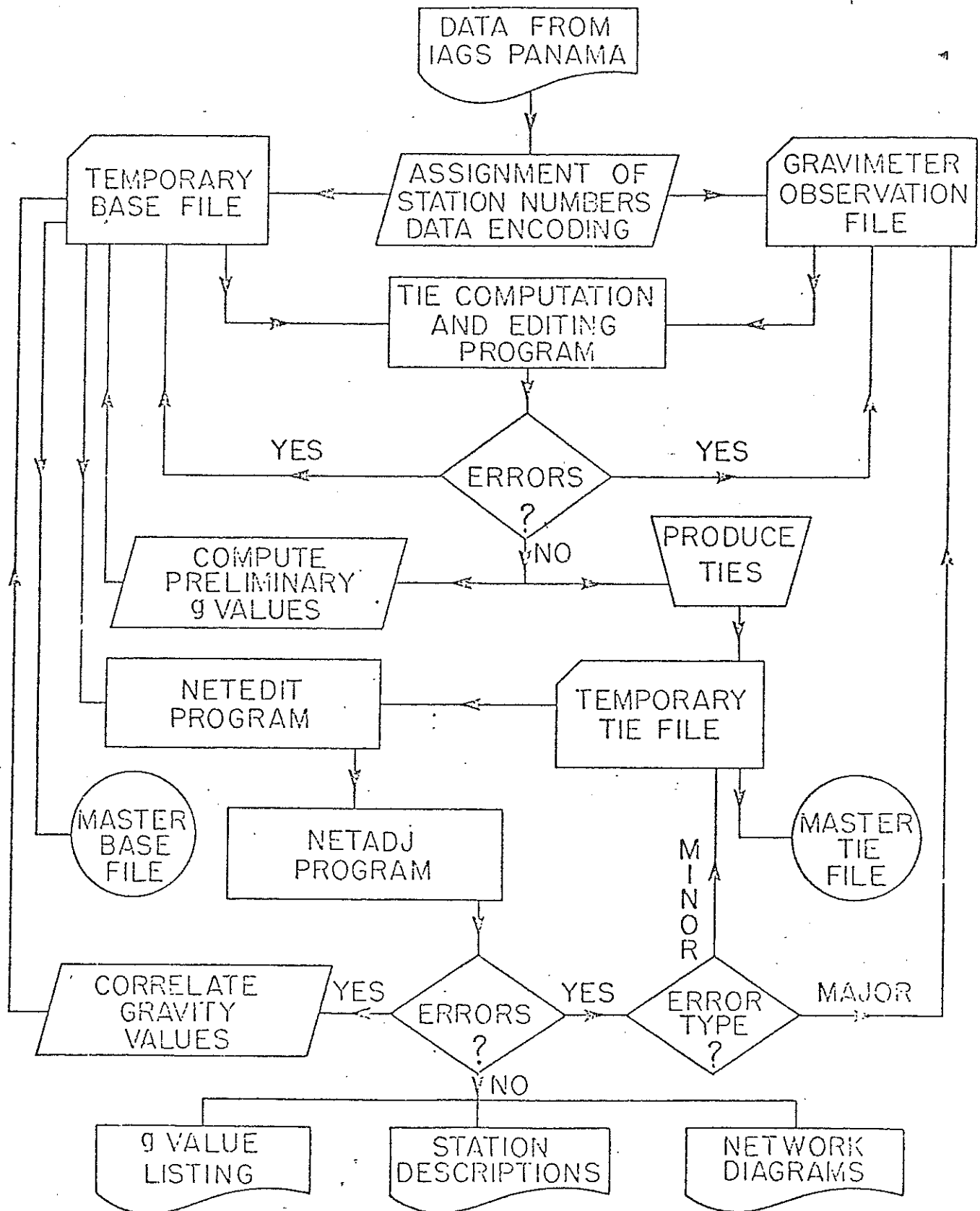
| <u>Volume Number</u> | <u>Area</u> |
|----------------------|---|
| 1 | Mexico A to M |
| 2 | Mexico N to Z |
| 3 | Central America |
| 4 | Brazil, Guyana, Surinam and the Caribbean |
| 5 | Colombia, Ecuador and Venezuela |
| 6 | Argentina, Paraguay and Uruguay |
| 7 | Peru, Bolivia and Chile |

Explanatory notes, network diagrams and principal facts listings are included in each volume. Sample station descriptions are attached to this report.

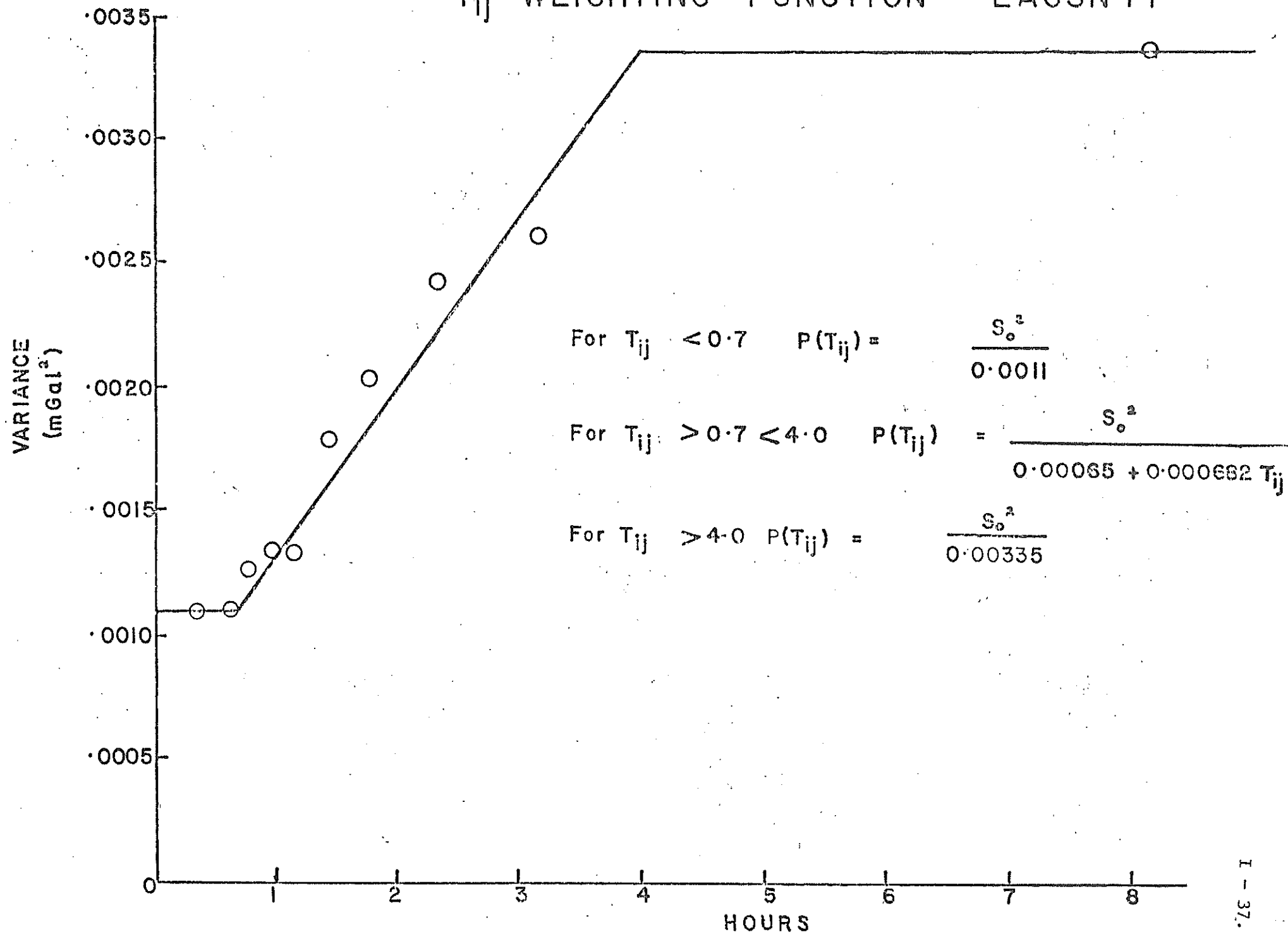
TABLE 1

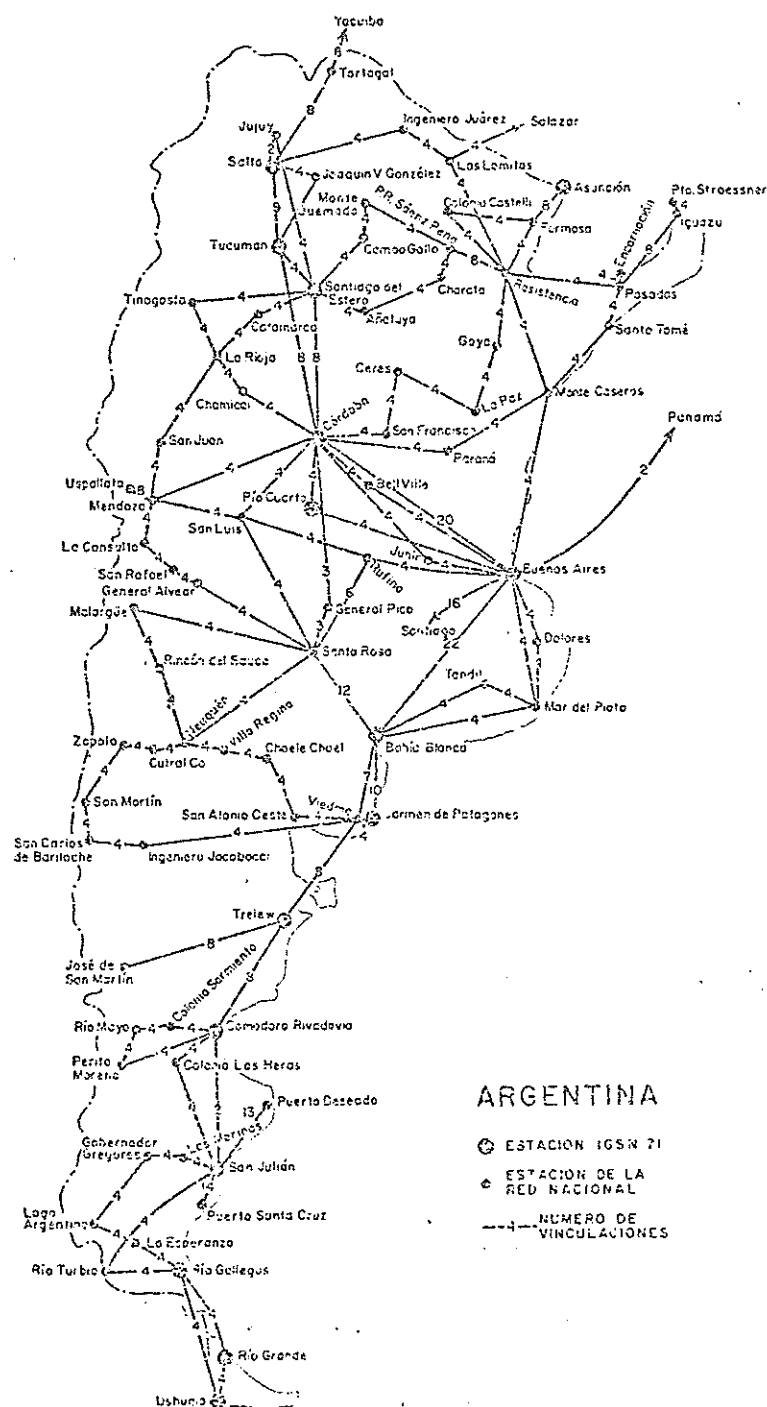
| <u>SURVEY</u> | <u>NO. OF BASES ESTABLISHED</u> | <u>NO. OF CONNECTIONS</u> | <u>GRAVIMETERS USED</u> |
|---------------------------------------|---|-------------------------------|------------------------------|
| Mexico and Central America 1962 | 112 | 565 | G11, G19 |
| Ecuador 1966 | 22 | 86 | G11, G56, G57 |
| Panama 1967 | 29 | 59 | G56 |
| Peru 1967 | 30 | 124 | G56, G57 |
| Argentina Paraguay 1968 Bolivia | 99 | 640 | G56, G57, G145, G146 |
| Uruguay 1968 | 25 | 53 | |
| Dominican Republic 1969 | 39 | 231 | G50, G56, G57 |
| Mexico 1969 | 140 | 977 | |
| Honduras 1969 | 34 | 224 | G56, G57, G193 |
| Colombia 1970 | 47 | 238 | G56, G57 |
| Paraguay 1970 | 11 | 78 | G145, G146 |
| Chile 1970 | 21 | 131 | G56, G57, G193 |
| Venezuela 1970 | 57 | 331 | G50, G56, G57 |
| Nicaragua 1971 | 44 | 265 | G56, G57 |
| ACL 1972 | 4 | 302 | G57, G74, G93, G172, G193 |
| Miscellaneous | 0 | 221 | various |
| IGSN71 | <u>250</u> | <u>(0)</u> | |
| | 964 | 4525 | |

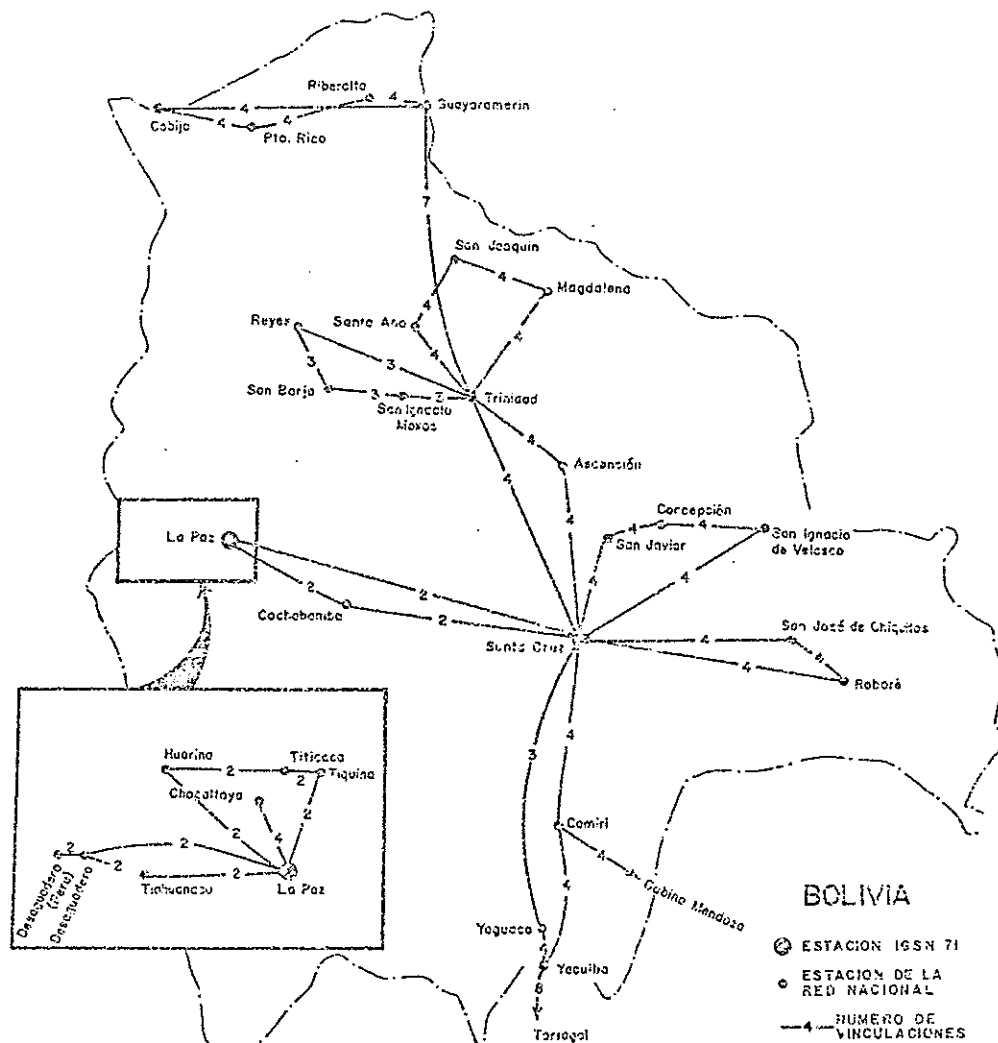
Fig. 1
LAPGN DATA PROCESSING SYSTEM

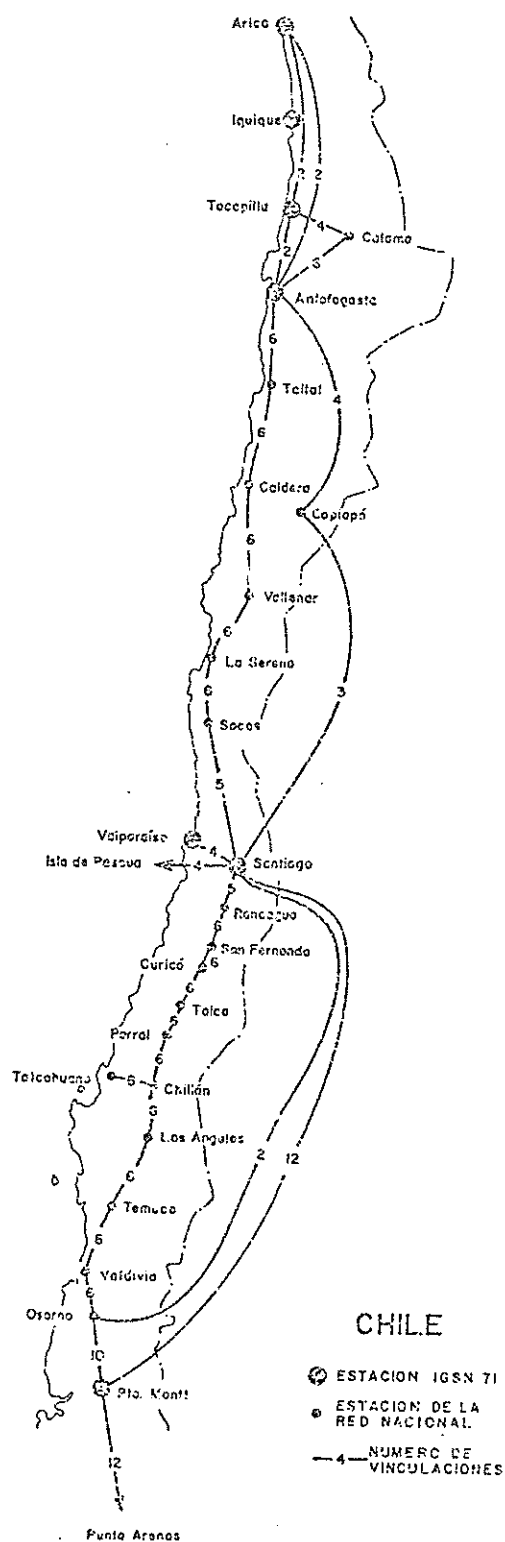
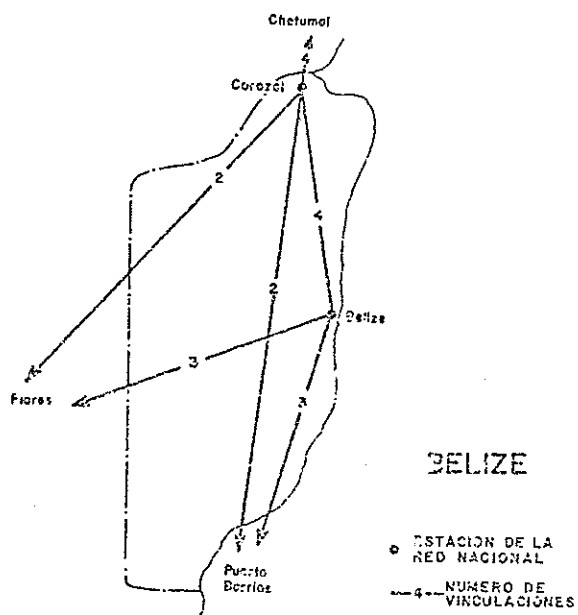


T_{ij} WEIGHTING FUNCTION - LAGSN 77

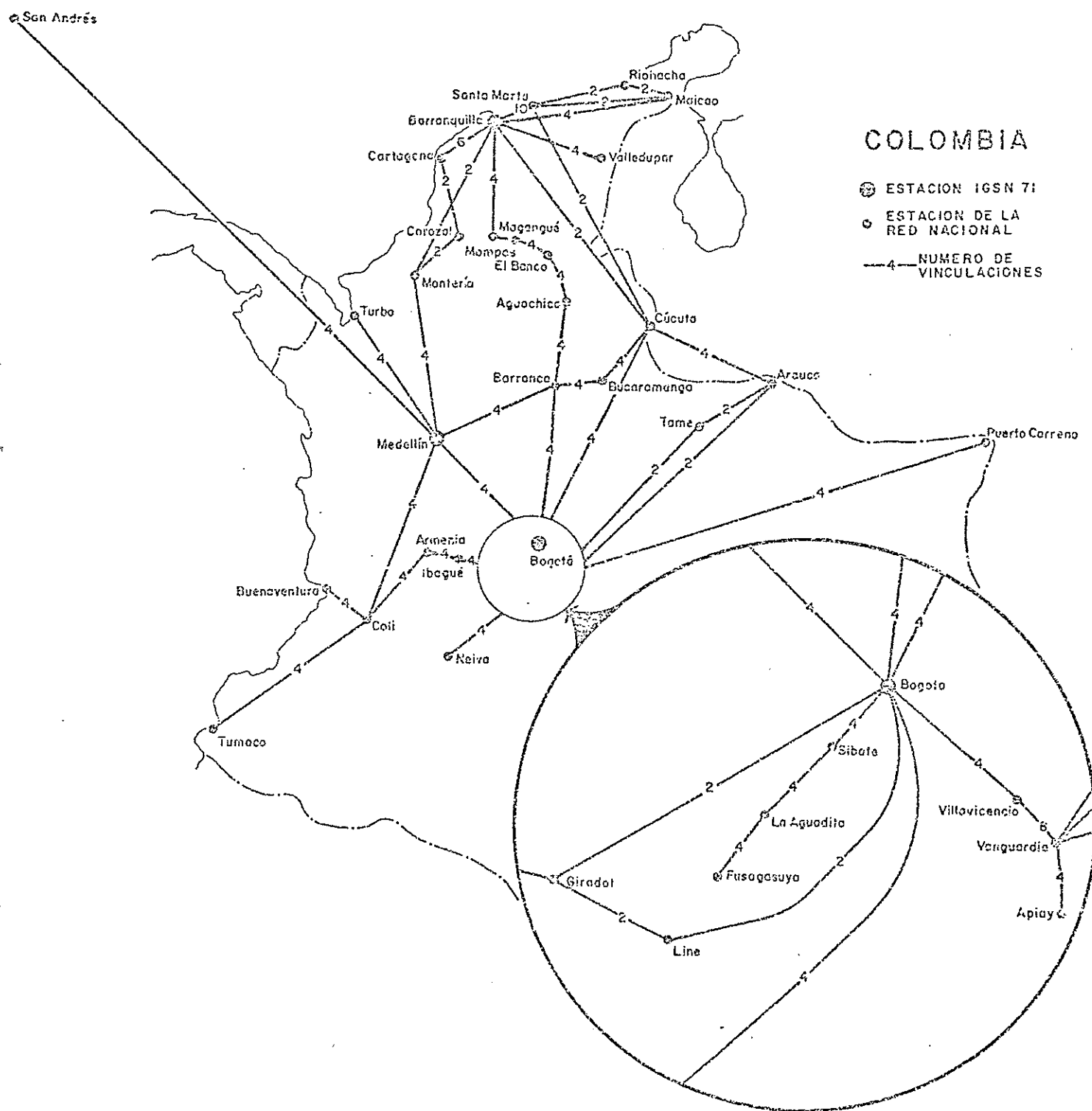


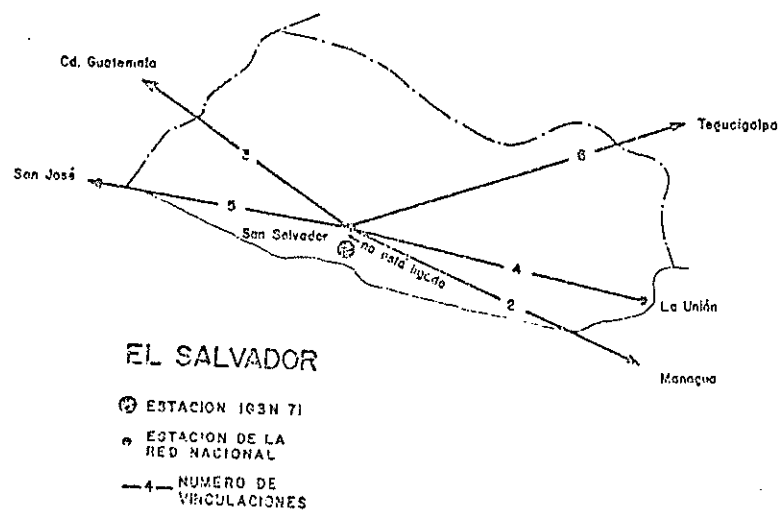
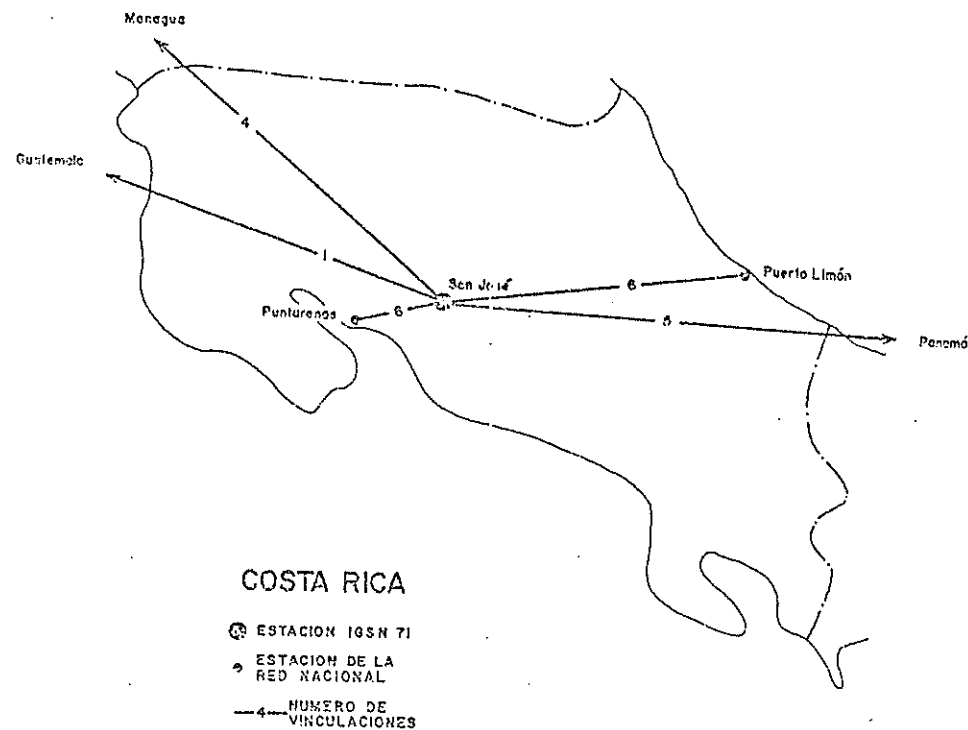


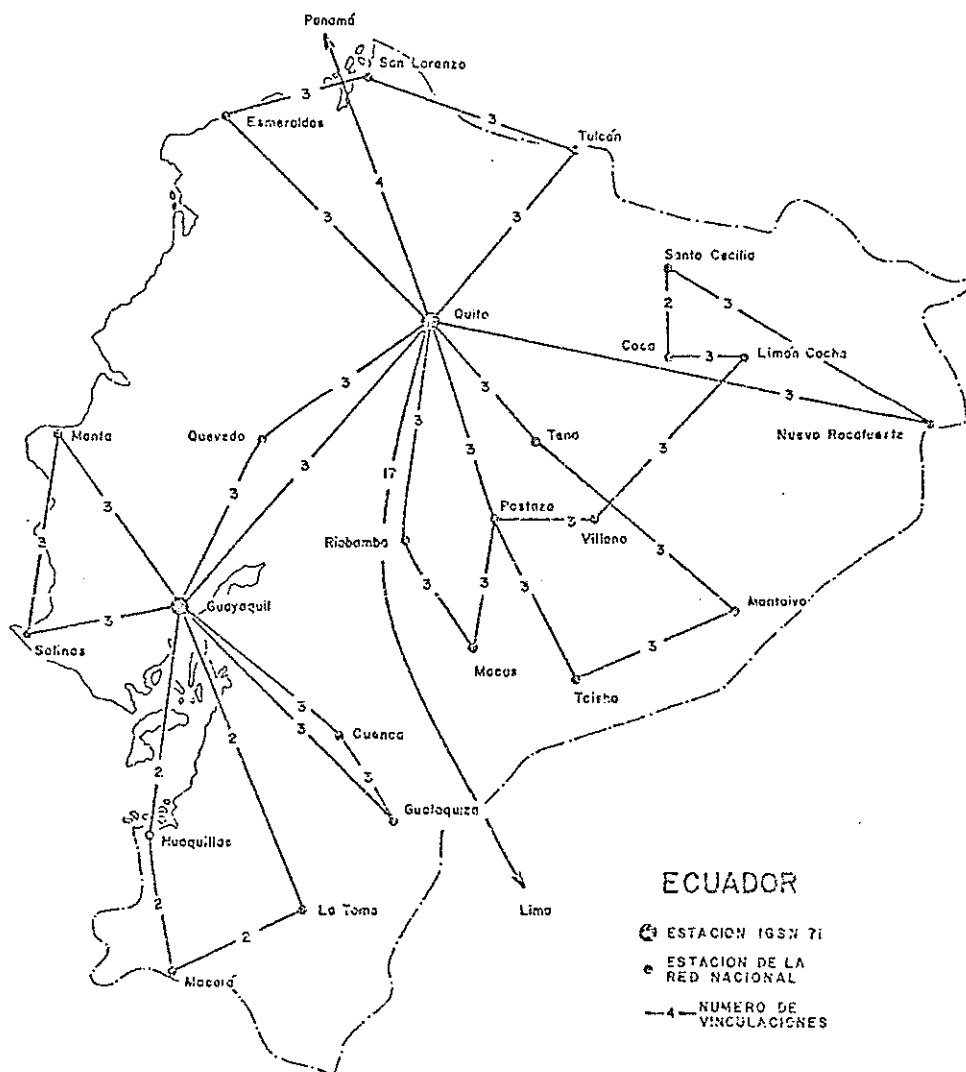


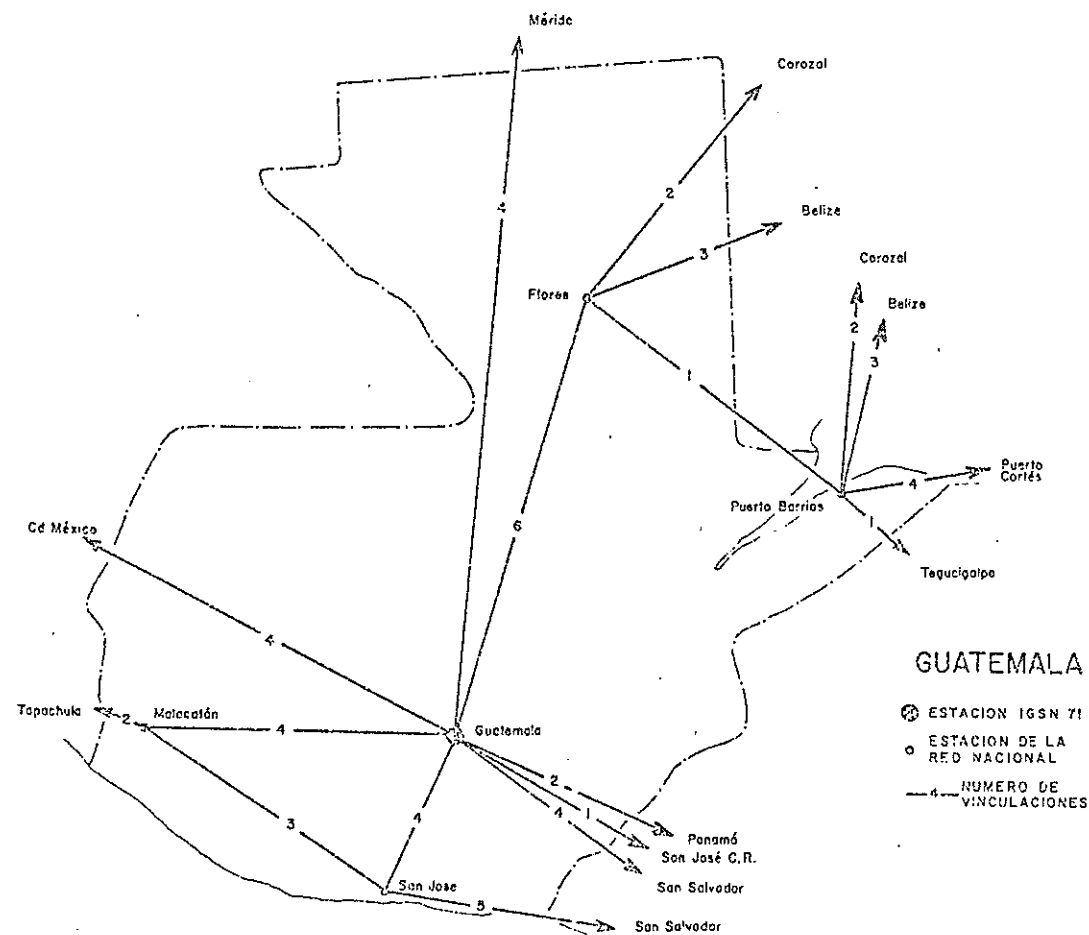


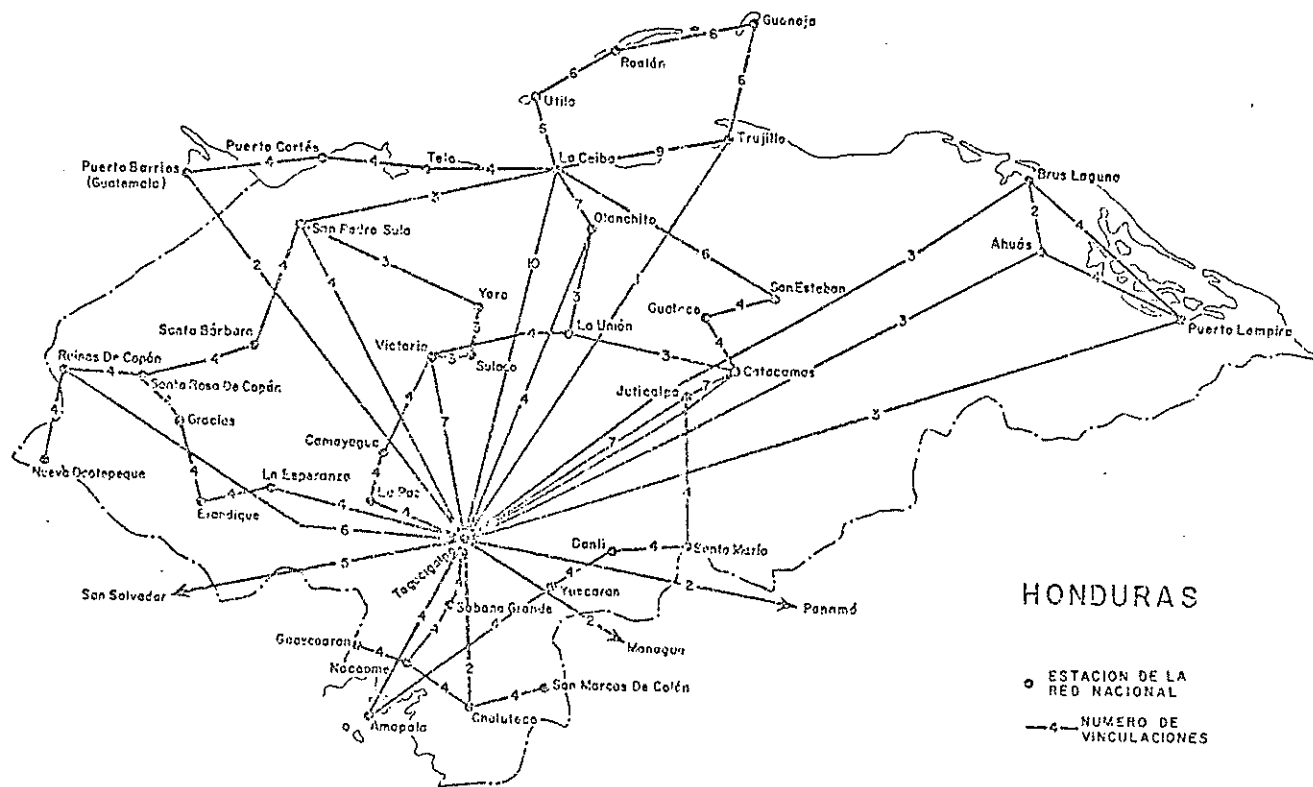


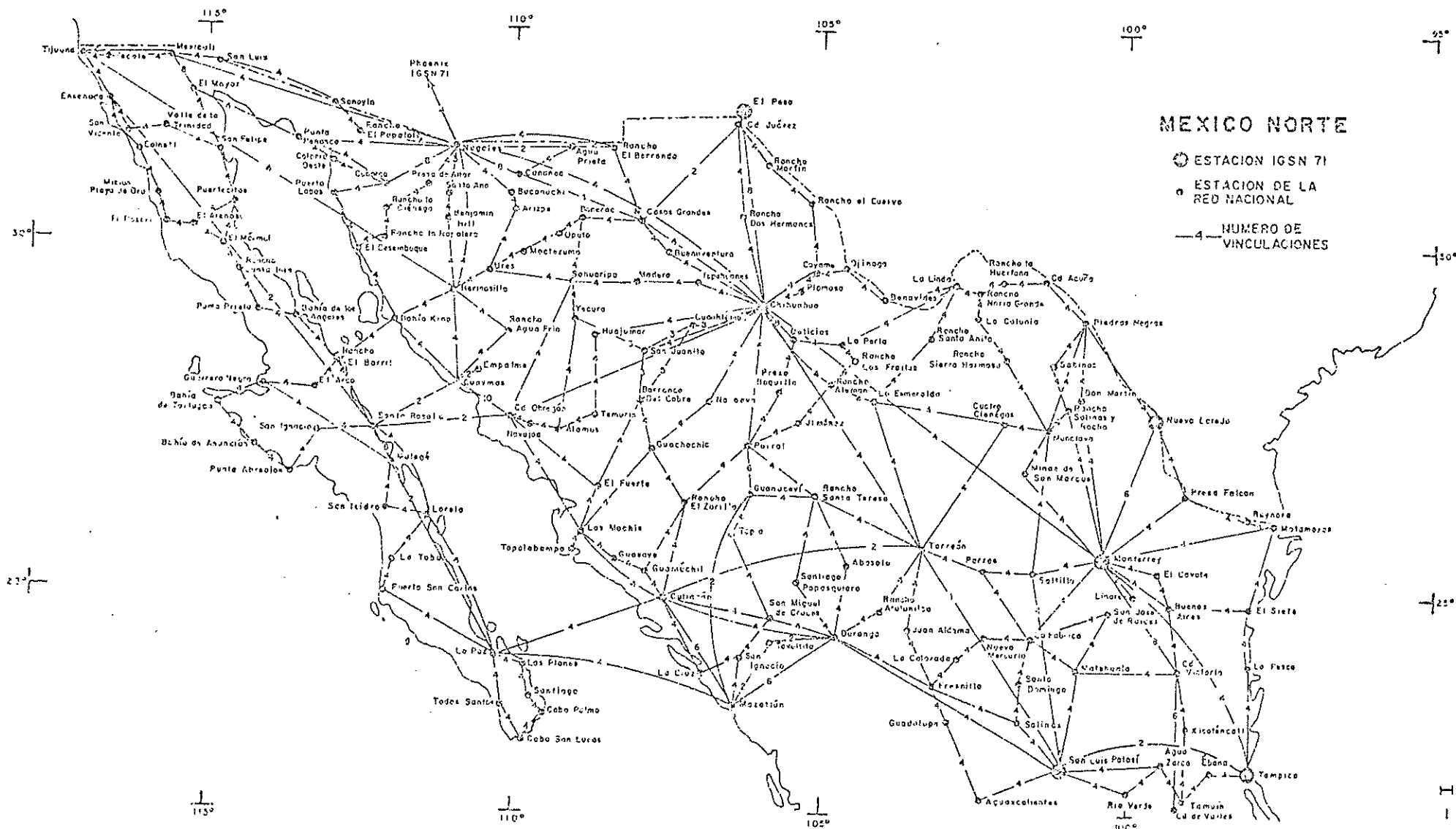


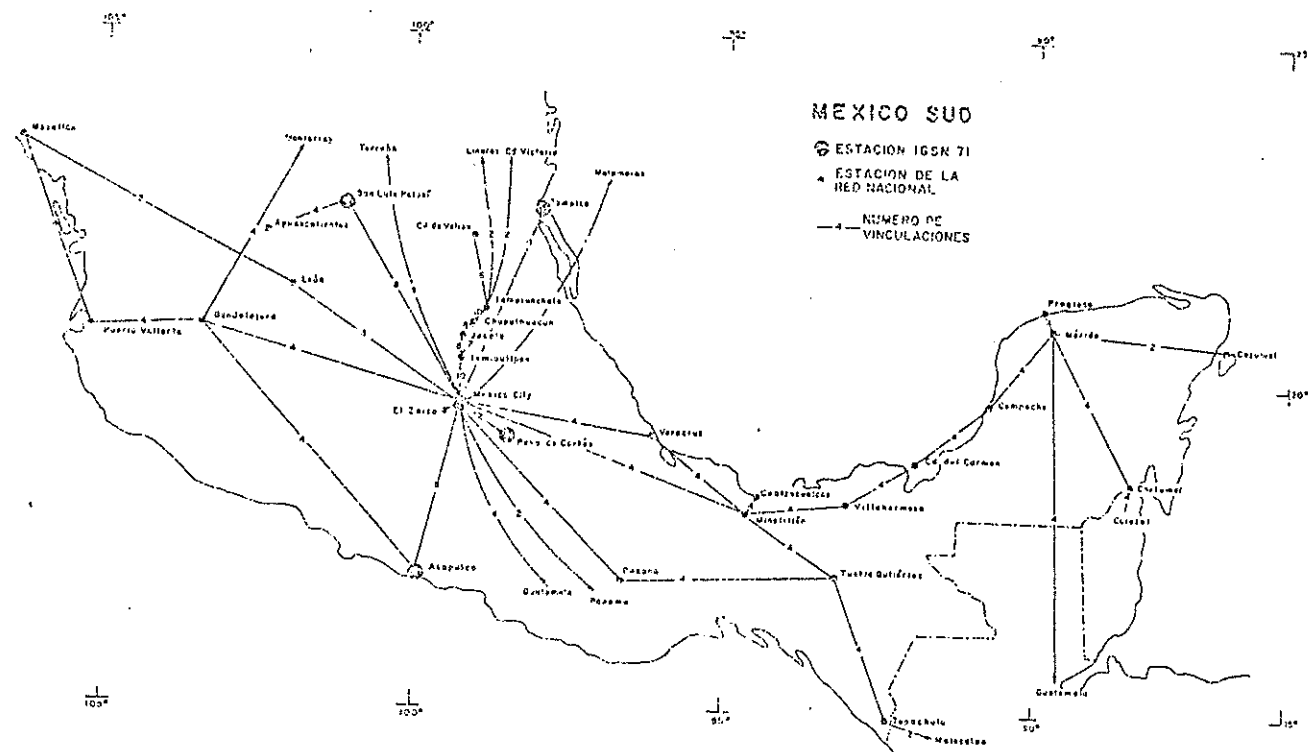






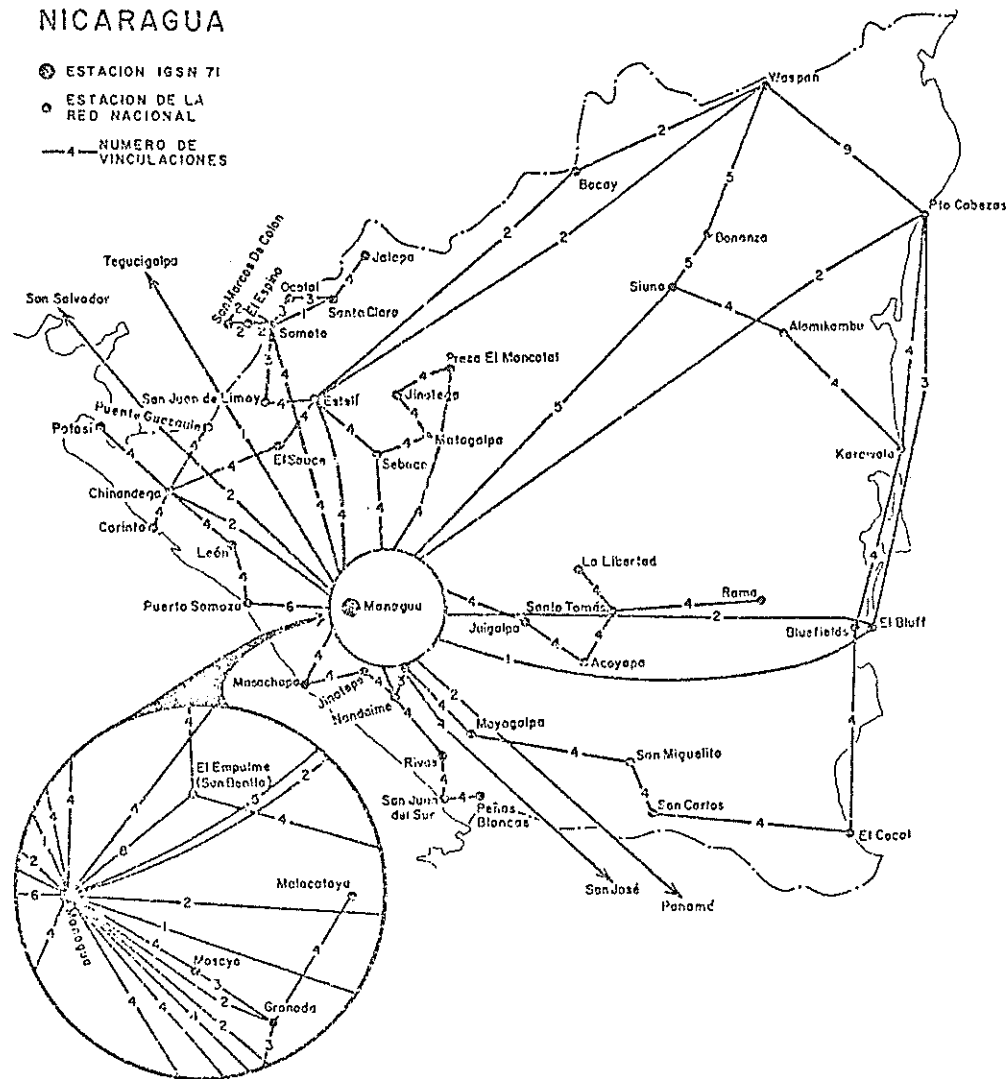


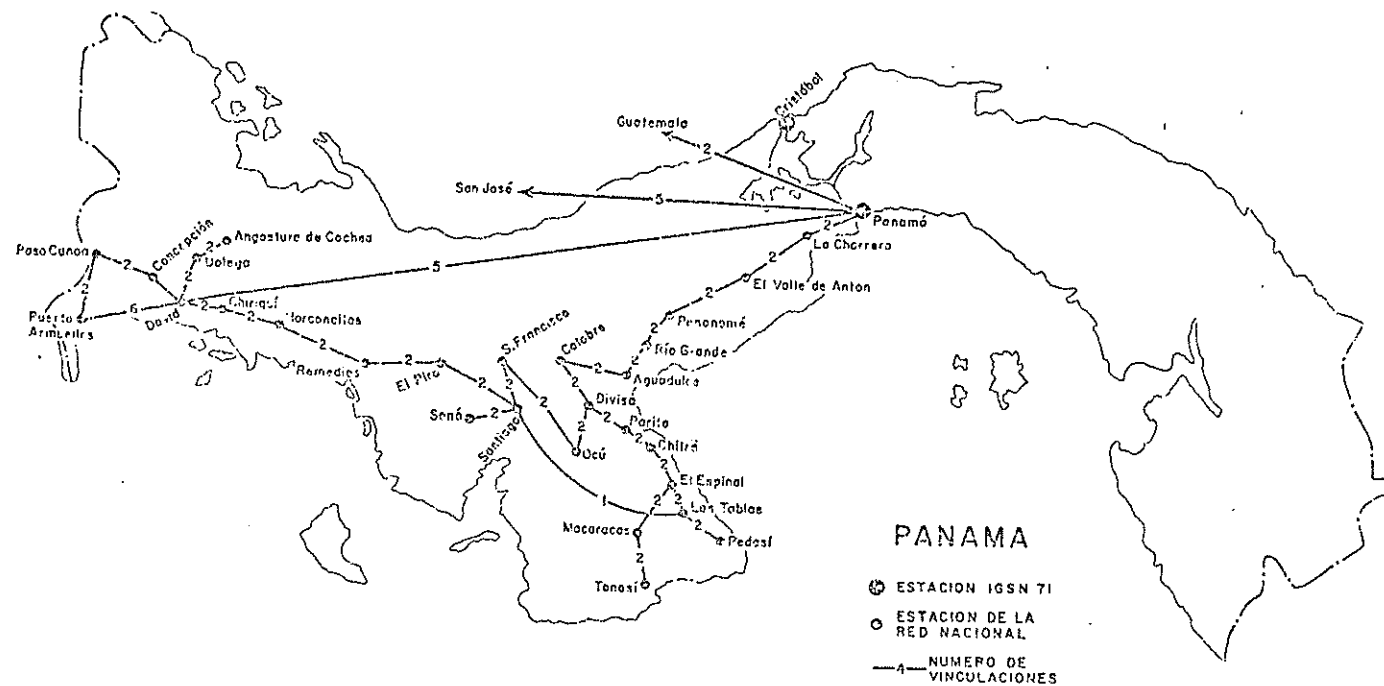


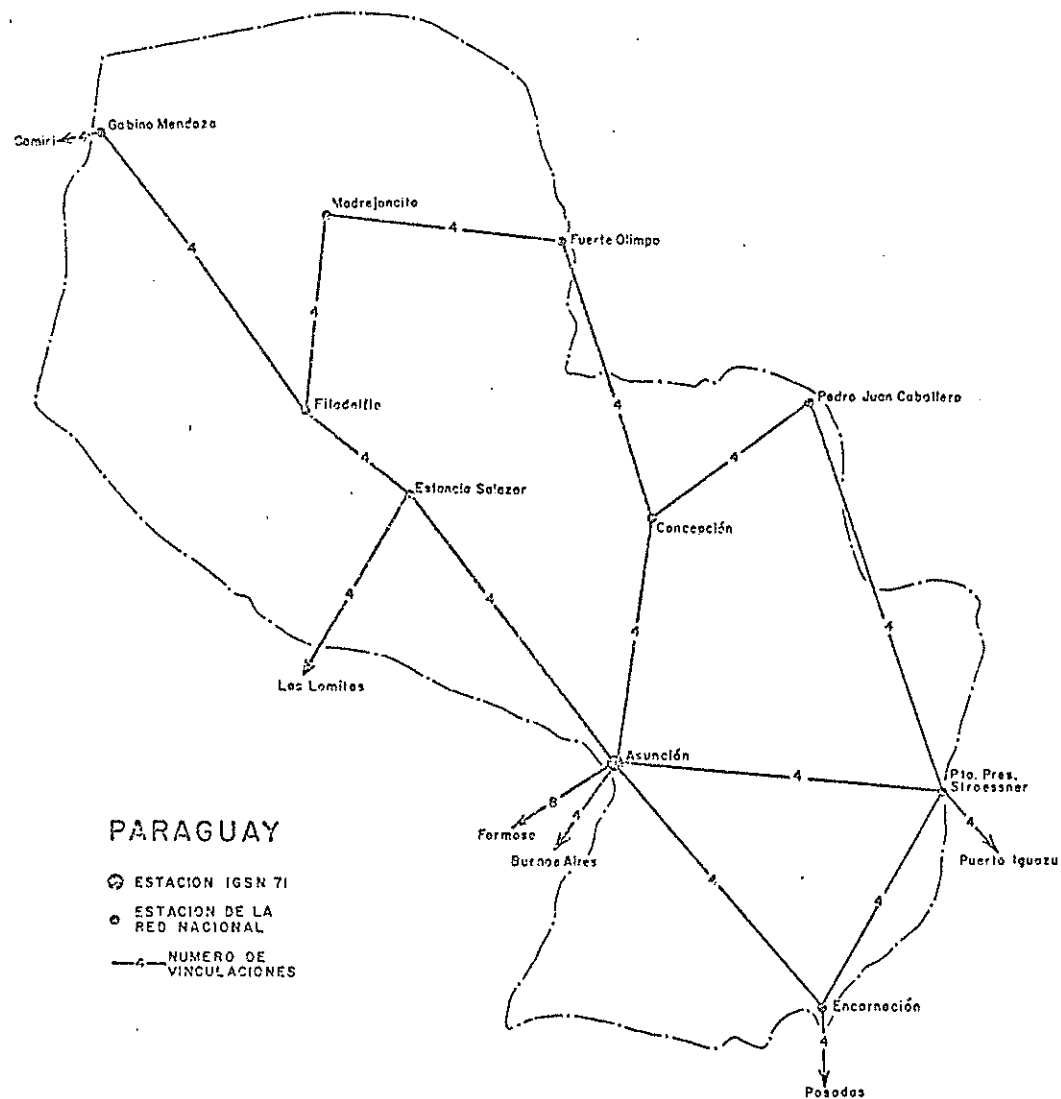


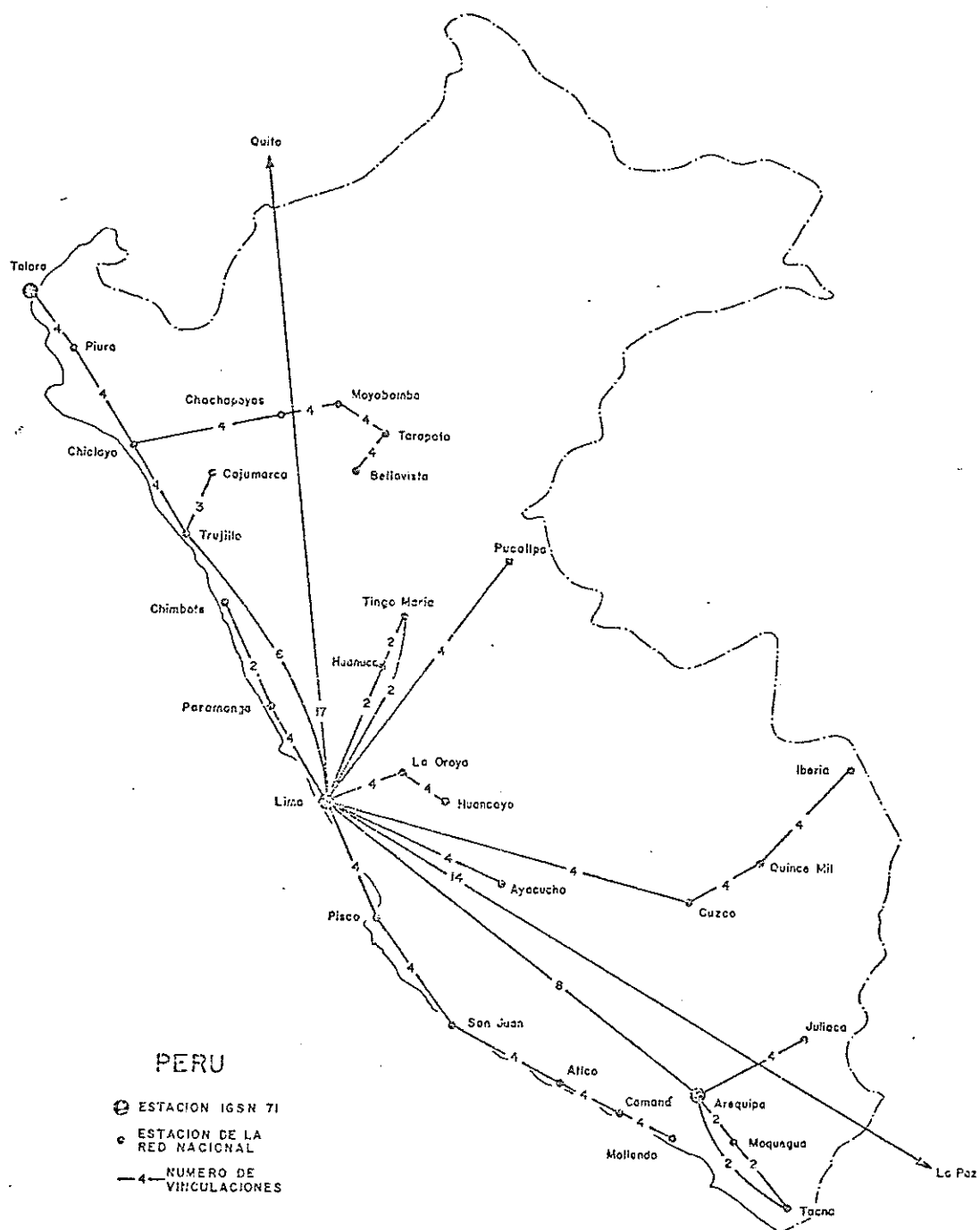
NICARAGUA

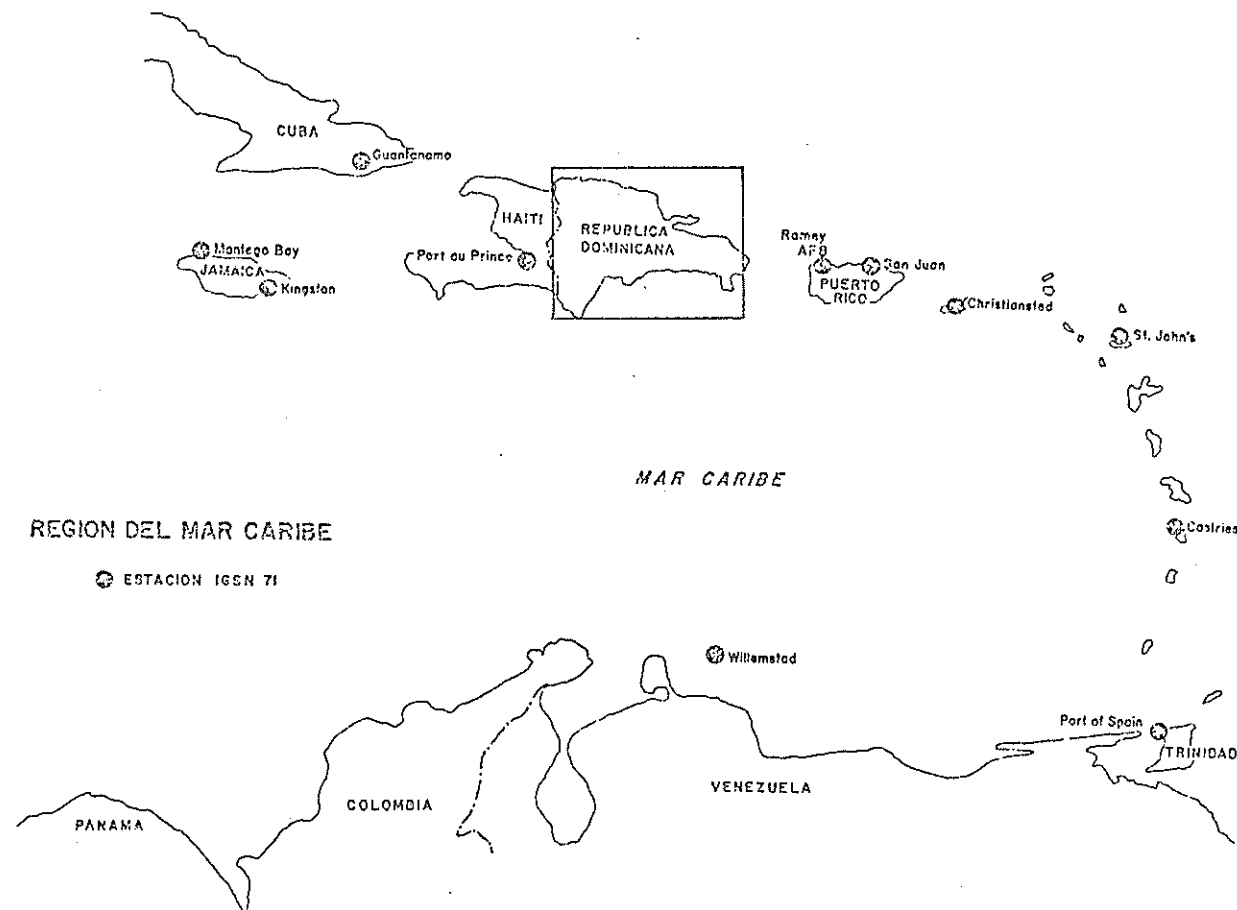
- ESTACION IGSN 71
- ESTACION DE LA RED NACIONAL
- 4— NUMERO DE VINCULACIONES

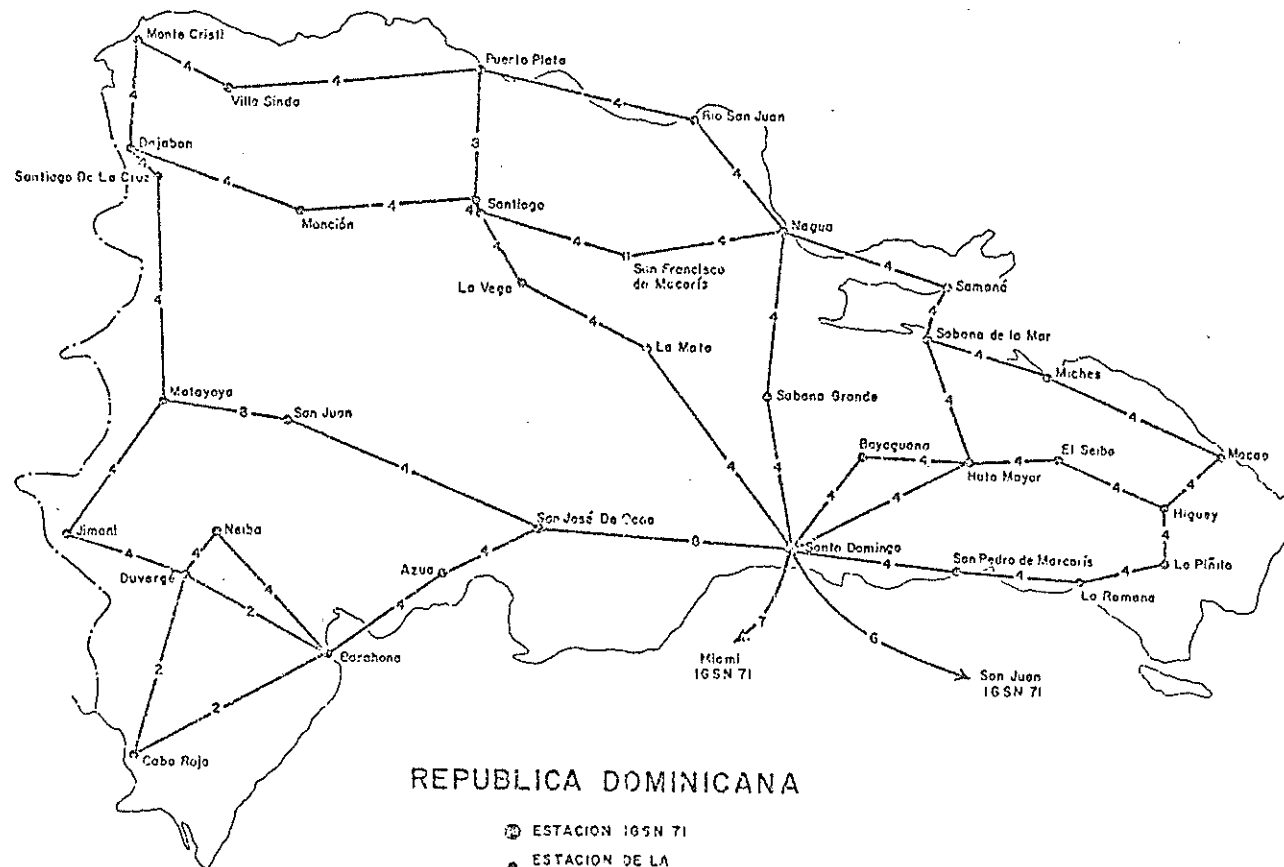








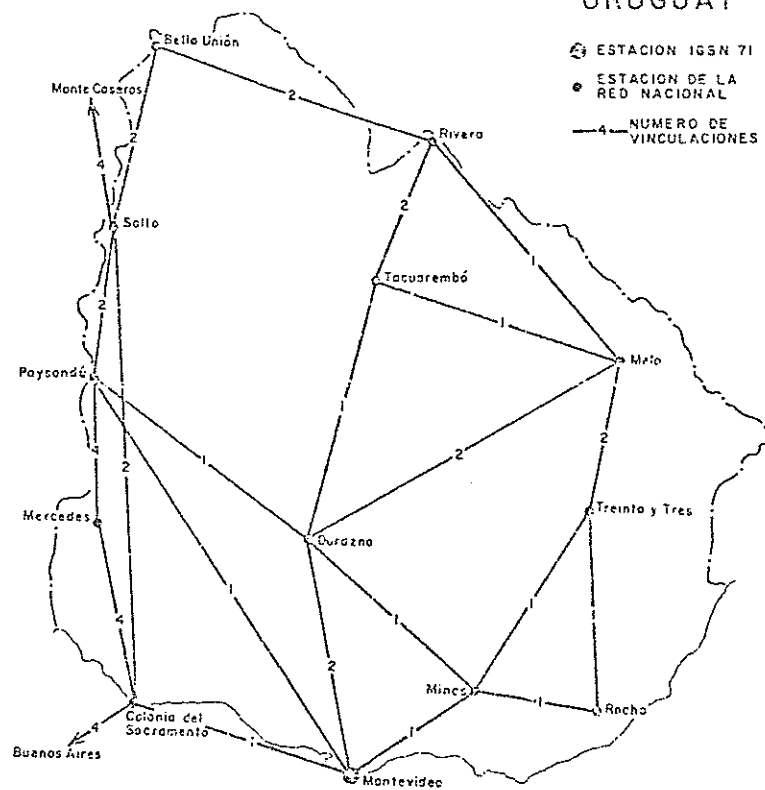


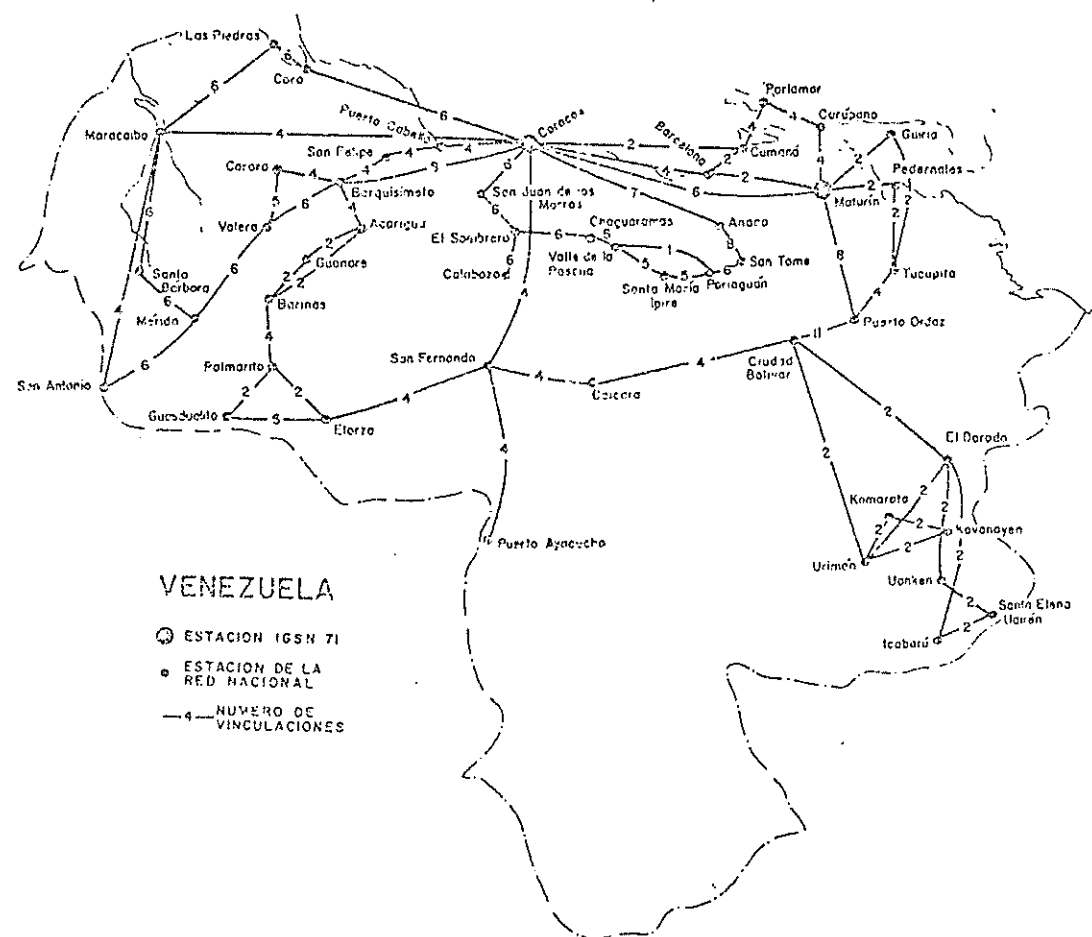


REPUBLICA DOMINICANA

- ESTACION 105N 71
- ESTACION DE LA RED NACIONAL
- 4— NUMERO DE VINCULACIONES

URUGUAY





NUMERO DE ESTACION

9322-68

STATION NUMBER

PAIS

ARGENTINA

COUNTRY

NOMBRE DE ESTACION

GOBERNADOR GREGORES

STATION NAME

PROVINCIA O ESTADO RIO GALLEGOS

ESTABLECIDO POR SHN/UNBA

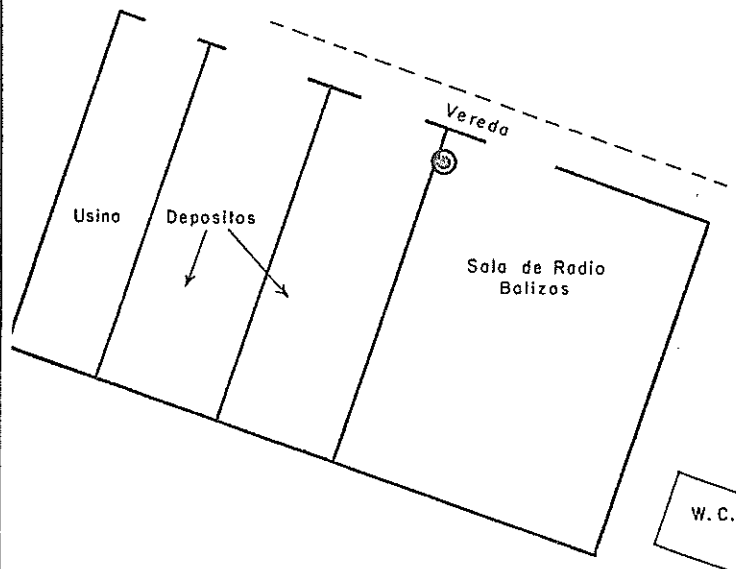
FECHA DE LA ULTIMA REVISION 1968

OTRA DESIGNACION UNBA : FI24

La estación se encuentra en la aula de radio balizas al aeropuerto de Gobernador Gregores. Está sobre un piso de cemento a 1.24 m. de la pared de frente y a 0.37 m. debajo de la referencia de la U.N.B.A. empotrado en la pared.

----0----

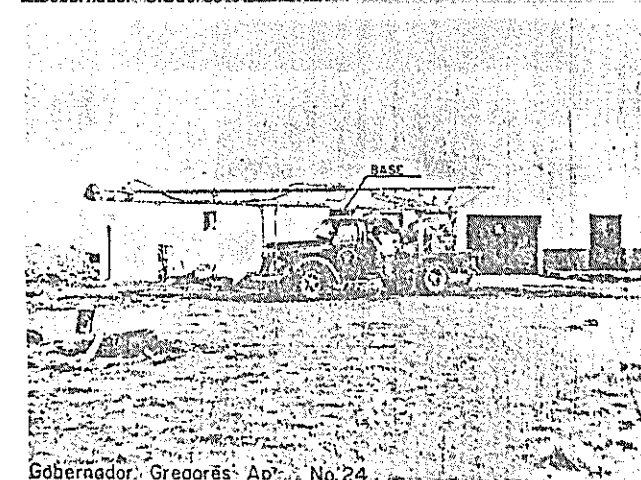
The station is located in the radio beacon room at the Gobernador Gregores airport. It is on the cement floor 1.24 m. from the front wall and 0.37 m. below a U.N.B.A. reference marker set in the wall.



ARGENTINA, BACARA. 1968



Gobernador Gregores, Ap. No. 24



Gobernador Gregores, Ap. No. 24

STATION NO.

43914 K

IGSN STATION DESCRIPTION

QUAD. DEG. SQ.

3

31064

Station Name CORDOBACountry ARGENTINAOther Designation EPB : 9670-63National Contact Agency UNBA

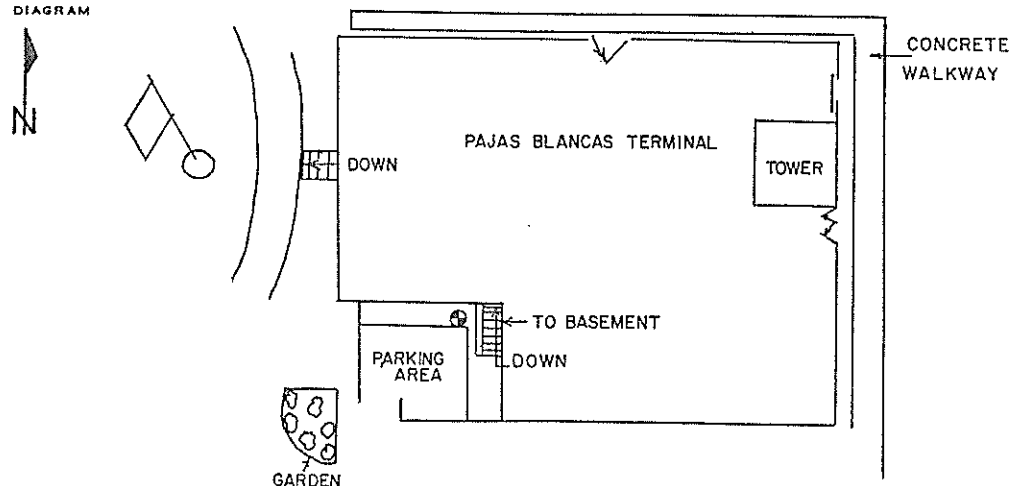
Access Restrictions _____

The station is located at Pajas Blancas Airport. It is on the concrete sidewalk at the SW corner of the terminal in a patio area 1.3 m. S from the S wall and 1.3 m. W of the stairway leading to the terminal basement. The station is monumented with a bronze disc inscribed "IGM ECG 2".

----0----

La estación se encuentra en el Aeropuerto Pajas Blancas. Está en la acera de hormigón, en la esquina SW de la terminal, en un patio a 1.3 m. S de la pared S y a 1.3 m. W de la escalera que lleva al sótano de la terminal. La estación está identificada por un disco de bronce marcado "IGM ECG 2".

DIAGRAM



Item IX - NEW GRAVIMETRIC INSTRUMENTATION

Chairman : O.W. WILLIAMS

One session held on Thursday 14 September 1973, 2.15 - 3.00 pm.

The Chairman recalls the previous attempts of measuring gravity from an aircraft and announces that 3 contributions will be presented on the new gravimetric instrumentation.

First, Mr. P.M. SCHWIMMER gives lecture of the paper prepared by Mr. W. GUMERT :

"On the status of helicopter gravity development and application"

"For over two decades, various government agencies and private industries have attempted to measure gravity from a moving fixed-wing-aircraft. A system was needed that could collect gravity data rapidly throughout the world to satisfy geodetic requirements, and could assist in geophysical exploration for minerals and oil.

During the mid-1960's, a different form of airframe was examined: the helicopter. Several feasibility trials were conducted using various gravity instruments, navigation techniques, and altimetry systems. These efforts have culminated in the design and selection of instruments for the Helicopter Gravity Measuring System (HGMS)."

He reviews the different tests of measuring gravity from a helicopter from 1963 to 1974, pointing out the difficulties and the improvements in each attempt.

He gives many details concerning the instrumentation :

- The LaCoste and Romberg sea-air gravity meter (model S) consists of a highly overdamped, spring type gravity sensor mounted on a gyro stabilized platform with the associated electronics for obtaining gravity readings and for recording the results on strip chart and magnetic tape records.

The model S gravity meter has a range without resetting of 12,000 milligals, and a static accuracy of better than 0.01 milligals. However, readings are recorded only to the nearest tenth milligal.

- Different navigation systems were used, particularly the Del Norte's Trisponder which is an electronic positioning system which provides accurate line of sight distance information from a master station to one or more remote stations. This is done by measuring the round trip times of radio frequency signals transmitted between the two stations. Each distance displayed is an average of 10 to 100 measurements, which reduces statistical error and increases system accuracy and stability.

- The altimetry system used is a combination of a precise pressure sensor, digitally timed radar, and a highly accurate laser distance measuring device. The pressure sensor was designed for precise measurements of the static pressure position of an aircraft and is utilized in this system as a narrow range altimeter.

The laser system provides absolute reference altitudes using the reflectance of its coherent light from the ground surface.

Ground tests of the laser altimeter show an accuracy of .15 meters in 1,850 meters. The pressure altimeter is calibrated to repeat to ± 7.5 centimeters over a 50 meter range. In flight the combined system gives absolute control to better than 25 centimeters.

-All data is monitored in flight by analog strip chart recorders with common time events. Simultaneously signals are digitized and sampled at a one to ten second sampling interval, put onto tape, and then onto a printer that reads the tape after writing. The digital system used is the Monitor Labs data logger mated to a Digi Data incremental tape deck.

The gravity data accuracy can be evaluated in analysing the results at line intersections and in comparing the airborne gravity data to data measured on the ground (Bouguer or free-air if the topography is flat).

-During a survey over an area in New York, a total of 244 line intersections were made. This analysis was performed on the Bouguer gravity values before any mistie corrections or intersection adjustments were made. The R.M.S. mistie error is 2.3 milligals.

*Two methods of comparison to the existing gravity data were made. Method one consists of plotting profiles of the airborne Bouguer gravity data and comparing these plots to profiles made from U.S. Government data that exists in the area. Method two is to compare the final contoured airborne data to the contoured existing data.

Method one produced profiles that showed R.M.S. errors of 1.8 to 3.2 milligals for values compared along the line values were compared at 50 second intervals along the lines. No upward or downward continuation was made.

Method two produced contour maps that for the regional expression compared to within 2 milligals of each other.

In conclusion, the results of this survey, and of several thousand line miles of data run since the mid-part of 1977, show that the system with the current instrument package, and the present state of data processing can create useful Bouguer gravity contour maps. These maps will show anomalies associated with medium to large geological features of half wave length from a minimum of $1 \frac{1}{2}$ to 2 miles. Accuracies of the data will be in the range of $1 \frac{1}{2}$ to 2 milligals."

Mr. W.G. HELLER presents the paper on :

"Developments in moving-base gradiometry"

" Gravity gradiometry, the measurement of the spatial rate of change of the gravity vector, has, in recent years, been the object of considerable attention in the United States. Since the report to the Seventh International Gravity Commission (Williams, 1974), the development of a moving-base gradiometer instrument has progressed considerably (Ames 1978), (Metzger 1978), (Trageser 1978).

Attention has also been given to the integration of moving-base gradiometry with other technologies such as multisensor gravimetric survey data processing (Thomas 1976), aided inertial mapping (Heller 1977), and navigation (Gerber 1978). Geophysical and geological applications have also been addressed, e.g., (Hammer 1975), (Jordan 1977).

Prototype gravity gradiometers have continued to be developed by three manufacturers : The Bell Aerospace Division of Textron, Inc., The Charles Stark Draper Laboratory and the Hughes Aircraft Corporation. Each developer has demonstrated, under carefully controlled laboratory conditions, resolutions of the order of a few E^* and approached residual instrument noise power levels of $10E^2$ -sec.

The developer's gradiometers are quite different from each other.

W.G. HELLER summarises key features and the status of the 3 gradiometer programs. Then, he presents the various applications of gradiometers and points out some concluding remarks and perspective.

On the basis of both theoretical design limits and observed data it is likely that initial moving-base gradiometer operations will take place in the early 1980's. The performance level of the first mobile instrument will probably be modest - several Eötvös referred to a ten second moving window averager. Nonetheless, such an accuracy level will be adequate to explore a variety of gradiometric applications such as :

- Real-time vertical deflection compensation for marine inertial navigation systems.
- Position determination using a prestored map of the gravity gradient field.
- Improved definition of the very short wavelength portion of the Earth's gravity field for future world geodetic systems.
- Airborne or seaborne gravity mapping of areas in which highly densified gravimetric data is desired.
- Improved accuracy of ground-based inertial survey systems.
- More accurate specifications of geophysical structures and resources."

Dr. L.E. WILCOX gives lecture of the paper :

"Determination of gravity anomalies and deflections of the vertical from inertial surveying".

prepared by H. BAUSSUS von LUETZOW.

"Based on considerable progress in inertial technology and on a technical proposal by Litton (1970), the U.S. Army Engineer Topographic Laboratories (ETL) developed a Position and Azimuth Determining System (PADS) for U.S. Army field surveying needs. ...

ETL tests at White Sands Missile Range in 1976, described by Fishel and Roof (1977) established the system's capability of determining gravity anomalies and deflections of the vertical with average rms errors of 2 mGal

* $E = \text{Eötvös unit} : 0.1 \text{ mGal/km} = 10^{-9} \text{ sec}^{-2}$.

and 2 arcsec, respectively for 50 km runs. Critical present hardware consists of an A1000 vertical accelerometer, two A200 horizontal accelerometers, and two G200 gyroscopes. The unit operates as an optimal local-level system in the Inertial Positioning System (IPS) mode and as a quasi-local-level system in the Rapid Gravity Survey System (RGSS) mode. The RGSS mode without Kalman platform tilt corrections has advantages concerning gyro bias estimations."

Then, the speaker indicates the methods for the determination of the gravity anomalies and the deflections of the vertical. He points out that "the following RGSS applications appear to be promising :

- Rapid Δg , ξ , η -determinations along solitary courses of about 60 km length.
- Establishment of regional Δg , ξ , η -grid information networks suitable for use in a gravity-programmed inertial positioning system and for analytical continuation in space in the case of flat or moderate terrain by means of computable horizontal derivatives $\frac{\partial \Delta g}{\partial x}$, $\frac{\partial \Delta g}{\partial y}$, $\frac{\partial \xi}{\partial x}$, $\frac{\partial \eta}{\partial y}$ for a first-order Taylor expansion of Δg , ξ , η to a level surface and subsequent application of Laplace's equation.
- Improved point positioning approaching or equaling classical surveying accuracy.
- Flood plane profiling and mapping under consideration of the underlying geoidal structure.
- Geophysical prospecting, including detection of significant subterraneous mass anomalies."

In conclusion, it can be noted that "modern inertial technology in combination with advanced mathematical techniques can achieve rapid extension or densification of continental Δg , ξ , η -data with accuracies sufficient for many geodetic applications. It is expected that an advanced RGSS, potentially available in 1981, can make significant geodetic-geophysical contributions. Provided that the system's reliability is also increased during the next three years, the advanced RGSS will prove to be highly cost-effective. The establishment of regional Δg , ξ , η -networks with 2 km spacing by means of an advanced RGSS or by a gradiometer-aided RGSS will facilitate the development of a gravity programmed inertial surveying system with great potential benefits."

Item XI - PREDICTION OF GRAVITY VALUES

Chairman : Prof. U.A. UOTILA

One session held on Thursday 14 September 1978, 11.45 - 12.30 am.

Mr. G. LACHAPELLE presents the paper

"Evaluation of $1^\circ \times 1^\circ$ mean free-air gravity anomalies in Canada"

" $1^\circ \times 1^\circ$ mean free-air gravity anomalies for Canada and surrounding areas are derived from surface gravity data and mean topographic heights. A regular $5'$ grid is first evaluated and reduced to mean heights (where available) of blocks ($5'$ or 1°) using standard Bouguer factors. $1^\circ \times 1^\circ$ gravity anomalies are then obtained by straight arithmetic means of smaller block blocks. Variances are given by an estimator which is a function of signal and error covariances. The final data set is compared with that of RAPP (1977) and that derived directly by least squares collocation."

Mr. C.C. TSCHERNING presents the paper

"Gravity prediction using collocation and taking known mass density anomalies into account"

"The anomalous (gravitational) potential of the Earth, T , is split in two parts, $T = T^C + T_M$. Here T_M is a harmonic function generated by known mass density anomalies and $T^C = T - T_M$. This function will also be a harmonic function, which therefore may be approximated using the method of collocation, based on known gravity anomalies or altimeter derived geoid undulations, for example. Gravity anomalies can then be predicted using the known linearized relationship between T and Δg . This procedure may give a 40 - 50 % increase in the precision of the prediction results as compared to a procedure where mass density anomalies are not taken into account".

The speaker points out specially that "the technique of removing and restoring the masses has been tested in a $1^\circ \times 1^\circ$ area in New Mexico, USA with strongly varying gravity anomalies due to a mountain chain running North-South through the area. Details describing a similar test, where deflections of the vertical were predicted, can be found in Tscherning and Forsberg (1978)*. Two approximations to T was computed using the method of stepwise least squares collocation. As data was used a set of potential coefficients, 1° - equal area mean free-air gravity anomalies, point free-air gravity anomalies (98 values spaced $6'$ apart in the $1^\circ \times 1^\circ$ area) and density values in the form of topographic heights. The terrain was considered to be isostically compensated at a depth of 30 km. One approximation was computed without using the density information. ~~the density information.~~

* "Prediction of deflections of the vertical". Proc. Second International Symposium on problem related to the redefinition of North American Geodetic Networks. Washington D.C., April 1978.

The two approximations were then used for the prediction of 113 values of free-air gravity anomalies in the 30' x 30' block in the middle of the area. The standard-deviations of the difference between observed and predicted values are shown in the following table:

Standard deviation of the observed and the difference
between observed and predicted gravity anomalies.

| | |
|---|------|
| Observed free-air anomalies | + 10 |
| Difference <u>not</u> using density information | 5 |
| Difference using density information | 3 |

Let us finally notice that a similar improvement in the prediction results can be expected in general. The improvement will depend on the magnitude of the variation of the topographic-isostatically reduced gravity anomalies as compared to the variation of the free-air gravity anomalies."

The Paper "Prediction of mean gravity anomalies in unsurveyed areas"

by Dr. L.E. WILCOX and W.J. ROTHERMEL was also distributed at the meeting.

"In this text a number of geophysical-gravity anomaly prediction methods have been briefly described and discussed. Of these, the NOGAP⁺, EXGAP⁺, UNGAP⁺, and GAPFREE⁺ Methods have been used to obtain 1° x 1° mean gravity anomalies in regions that contained very limited, if any, measured gravity data. Two interpolation methods, GRADE⁺ and GAIN⁺, have been used to densify existing fields of gravity data for the purpose of 1° x 1° mean gravity anomaly prediction. All these methods give values in unsurveyed or partially surveyed areas that are superior to those which could be obtained using conventional averaging techniques and only the sparse amount of measured data available. Some new ideas which utilize multi-regression are being developed.

Since no two geologic and tectonic settings are exactly identical, it is safe to say that none of the geophysical methods have ever been applied twice in exactly the same manner. In fact, many variations of each method are possible and the scientist doing the prediction always must be alert for new ways to adapt the standard methods so that they properly apply to different regions. Experience, insight, and judgement are very important factors in geophysical prediction."

- ⁺ NOGAP : Normal Gravity Anomaly Prediction
- EXGAP : Extended Gravity Anomaly Prediction
- UNGAP : Unreduced Gravity Anomaly Prediction
- GAPFREE : Normal Gravity Anomaly Prediction-Free Air Version
- GRADE : Gravity Densification and Extension
- GAIN : Geologic Attraction Interpretation.

Item XII - COMPARISON AND COMBINATION OF SATELLITES RESULTS WITH SURFACE DATA

Chairman : Dr. R.H. RAPP

One session held on Thursday 14 September 1979, 11.00 - 12.30 am.

Mr. O.W. WILLIAMS presents the paper "Contribution of satellite radar altimetry to Earth gravitational field definition".

by O.W. WILLIAMS and K.L. BRACE

Since the early 1960s, considerable effort has been expended in an attempt to accurately define the Earth's gravitational field. Holdings of surface gravity data have increased and numerous representations or models of the Earth's gravitational field have been developed, usually in the form of geopotential coefficient sets. The data used either singly or in combination in the development of the geopotential models has included surface gravity, Doppler, optical, and laser satellite tracking data, etc. The geopotential coefficient solutions have been made to different degrees and orders, parameters other than coefficients have been solved for simultaneously, and various weighting schemes and mathematical techniques have been used.*

Also, the solutions have been affected by the different number and location of tracking stations providing data and the practice of preassigning values to certain coefficients. (The latter has been especially true with respect to the zonal harmonic coefficients). Thus, despite the availability of ever increasing amounts of conventionally-obtained surface gravity and satellite data, including improved calculation techniques, progress toward an accurate definition of the Earth's gravitational field has been slow. However, results from the National Aeronautics and Space Administration (NASA) GEOS-3 Satellite, launched 9 April 1975, promise considerable change in this unsatisfactory situation.

Then, the speaker indicates the main objectives of the GEOS-3 program with respect to altimetry, the GEOS-3 and the geoid height comparisons with similar data computed by spherical harmonic expansion using the Goddard Earth Model 10 (GEM 10) and the Smithsonian Astrophysical Observatory Smithsonian Standard Earth II (SAO SSE II) geopotential coefficient sets.

He shows also the comparison of subsets of the GEM-10 and GEOS-3 geoid heights for 3 oceanic areas :

- off the West coast of the United States,
- off the East coast of the United States, the GEOS-3 calibration geoid area,
- and ocean area South and East of Australia.

From these results, it can be concluded that "although only approximately 25 % of the GEOS-3 data has been processed, preliminary results have been impressive. Based on analyses completed to date, it appears that GEOS-3 data (available between 65° north and south latitude) is capable of providing :

* Data from different satellites of varied inclinations and altitudes have influenced the different solutions.

An oceanic geoid accurate to approximately ± 1 meter.

Ocean-area $1^\circ \times 1^\circ$ mean free-air gravity anomalies accurate to approximately ± 8 milligals.

Ocean-area deflection of the vertical components accurate to approximately ± 2 arc seconds.

The major portion of the data needed to define a worldwide geoid of far greater accuracy than heretofore possible.

A substantial improvement in Earth gravitational field modeling either singly or in combination with (sufficiently accurate) conventional land and ocean gravity survey data, satellite-deduced geopotential coefficients..

Information on the location of seamounts.

More accurate results will be achieved as data reduction and calculation procedures improve and as additional data is incorporated into the GEOS-3 data base. With the availability of Seasat-1, DOD efforts will continue toward the development of ocean-area geoid heights, deflection of the vertical components, and mean free-air gravity anomalies of the best possible accuracy and resolution.

Dr. R.H. RAPP presents "A combined terrestrial altimeter
 $1^\circ \times 1^\circ$ mean gravity anomaly field".

He describes recent improvements in our knowledge of $1^\circ \times 1^\circ$ mean free-air gravity field of the Earth. This improvement is described in two main ways. First we consider the status of the $1^\circ \times 1^\circ$ values based only on the terrestrial gravity measurements. The second is based on recent anomaly determinations made from the Geos-3 satellite altimeter measurements.

A set of 39405 $1^\circ \times 1^\circ$ anomalies based on terrestrial information only, and a set of 27465 (std.dev. ≤ 15 mGal) anomalies based on the Geos-3 altimeter data were formed. These anomaly sets were merged to form an almost global set of anomalies of 50650 blocks.

Although the average standard deviation of the terrestrial data is ± 15 mGal, and for the altimeter anomalies, ± 8 mGal, we found 203 anomalies where the differences exceeded 50 mGal when restricting the comparisons to anomalies having no standard deviations greater than 25 mGal (for terrestrial) and 15 mGal for the altimeter. (Considering all terrestrial data the number of such 50 mGal differences increases to 208).

There remains significant areas in which work needs to be done. This includes finding the source of the large discrepancies between terrestrial and altimeter anomalies. In addition better documentation is needed on the methods and accuracies for the computation of $1^\circ \times 1^\circ$ anomalies.

If the reliability of the altimeter derived anomalies can be further substantiated, with more Geos-3 data, and data to become available from the Seasat-1 satellite (launched in June 1978) the need for, and use of ship measurements for $1^\circ \times 1^\circ$ mean anomaly estimation should drastically be reduced.

Mr. G. DESVIGNES presents the paper "Some numerical results on the statistical behaviour of gravity anomalies".

He gives some preliminary numerical results on the covariance function and semi-variogram for local mean gravity anomalies over a test area, particularly results concerning isotropy's properties.

The test area extends from 10°W to 20°E in longitude and from 35°N to 60°N in latitude, so covering the whole occidental Europa and Mediterranean.

On this area, altitudes are between - 5000 m and 2700 m so it corresponds to various topographic features.

All BGI data on this region have been homogeneized in order to compute 11250 mean 12' x 20' free-air anomalies (and also mean isostatic anomalies).

From these computations the speaker points out the following conclusions which can be considered as somewhat representative :

- Free-air anomalies covariance shows an anisotropy which exists for all distance (20 km up to 700 km) ; average rate of anisotropy is about 16 % but its maximum values can exceed 50 %.
- The use of isostatic anomalies strongly reduces the anisotropy of the covariance function : mean rate is only 8 % ; so the interest of this kind of anomalies for prediction problems is emphasized.
- The behaviour of semi-variogram is quite different : anisotropy is smaller and chiefly important at small distances

So we can say in conclusion that the error in prediction methods assuming isotropy of the covariance function may be not negligible if free-air anomalies are used.

Dr. R.H. RAPP gives lecture of the paper : "The geoid and continental gravity data banks ; the role of satellite altimetry".

by R.S. MATHER. The program of research on the unification of geodetic levelling datums is done in collaboration with C. RIZOS and T. MORRISON.

"Point gravity values have to be processed in conjunction with a geopotential difference (ΔW) before use in high precision geodetic computations. Users expect these values of ΔW to be differences with respect to the geoid. In fact, they are differences in relation to the height of local mean sea level (MSL) at the regional levelling datum.

Satellite altimetry provides, in principle, a means of defining a unique geoid. The parameters defining the geoid obtained from GEOS-3 altimetry are presented and their significance is discussed.

A geoid defined in this manner can be used in conjunction with a continental gravity anomaly data bank to obtain the height of MSL at the regional datum for levelling provided the gravity anomalies are based on a levelling network related to this datum.

Preliminary computations using the gravity anomaly data bank for Australia (AUSGAD 76) provide estimates of the height of MSL at the Jervis Bay datum for the freely adjusted level network for Australia. At first glance, this is found to be in good agreement with oceanographic estimates. A closer analysis of the GEOS-3 ephemeris indicates a continuing uncertainty in the definition of the potential W_0 of the geoid which has still to be resolved.

The problems involved in applying this technique to gravity anomaly data banks which are not unambiguously related to levelling networks, are illustrated by a study of the gravity anomaly file computed for North America. Despite these reservations, the difference in the height of MSL between Jervis Bay and a Galveston datum for North America obtained using this technique, is in good agreement with the oceanographically determined value.

LISTE des PUBLICATIONS
reçues au
BUREAU GRAVIMETRIQUE INTERNATIONAL
(Janvier à Juin 1979)

CONCERNANT LES QUESTIONS DE PESANTEUR

LISTE des PUBLICATIONS

- * 617 - SEARLE R.C. & R.B. WHITMARSH - "The structure of King's Trough, Northeast Atlantic, from bathymetric, seismic and gravity studies". from : Geophys. J., R. Astr. Soc., N° 53, p. 259-287, 1978.

We present new seismic and gravity data from the linear chain of deeps and flanking ridges known collectively as King's Trough, and combine them to produce crustal models of the western end of the complex. These models show that there is an abnormally low-velocity, low-density crust under the trough itself, and that the whole King's Trough feature is situated in a region of slightly thicker than normal oceanic crust. The flanks and basins of King's Trough are not in local isostatic equilibrium, although the feature now appears to be inactive. We believe these data indicate a history of extension and of hot-spot activity at King's Trough, and that the feature was formed either as a slow-spreading arm of an R-R-R triple junction associated with a Mid-Atlantic Ridge hot-spot, or by subsequent rifting of a pre-existing hot-spot trace.

- 623 - CHOWANSKA-OTYS D. - "Gravimetric methodical research works at the south part of Baltic Sea". Proc. Inst. Geod. & Cartog., t. XXIV, Z. 1(55), p.3-22, Warszawa, 1977.

In 1971-72 Institute of Geodesy and Cartography organized four gravimetric sea expeditions. Investigations, having character of general gravimetric survey, were carried out at the area of south part of Baltic Sea along the Polish seacoast in the zone of about 100 km from the shore. Measurements were made along the profiles running parallel to the shore in the mutual distance about 5 nm and along the profiles crossing this area. Besides, semidetailed gravimetric survey on the area of 1300 km² was made in the shape of regular network of profiles being 2 ÷ 3 nm away one from another. Many of these profiles were measured twice. Gravimetric instrumentation consisted of three strongly suppressed russian gravimeters of GAL-M type, placed on the giroscopically stabilized plates. System Decca was used for ship navigation, and during the semidetailed survey system Sea-fix was utilized additionally.

As a result of measurement elaboration gravimetric data for points placed at mutual distance on the average 1,7 nm were obtained. Rate of general gravimetric survey can be estimated as one point/5 nm². Mean error of determination value g at given point after adjustment is $\pm 1,6$ mGal. For semidetailed gravimetric survey mean error of acceleration gravity value after adjustment was $\pm 0,7$ mGal. The rate of this survey is much higher than at the area of general survey ; it is one point / 1,4 nm².

Gravimetric data obtained for south part of Baltic Sea have made possible realizing a number of further geodesical and geological works.

* Les numéros font suite à ceux indiqués dans le Bull. Inf. N° 44, Mai 1979.

- 624 - KRYNSKI J. - "Application of low-low satellite observations to local geoid determination".
Geod. i Kartog., Polska Akad. Nauk, Komitet Geod., t. XXVII, Z. 1,
p. 17-27, Warszawa, 1978.

Low-low satellite observations are 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 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 it is sufficient to have a limited number of satellite observations in a $7^\circ \times 7^\circ$ area around the estimation point with distances between profiles of about 3° and between two satellites of the order of few hundred kilometers. The accuracy of the geoid determination is strongly dependent on the degree and order of the reference field used. An accuracy of about ± 2 m can be achieved with a reference field of (18, 18).

The influence of measuring errors is discussed and it is shown that only low-low satellite observations with accuracies better than 0.5 mm/sec will give an improvement of the geoid. Finally, some results on the combination of low-low satellite observations and terrestrial gravity measurements are given.

The proposed method seems to be especially interesting for unsurveyed areas. Furthermore, it has the practical advantage that only, a local coverage data is needed.

- 625 - BARLIK M. - "Investigation of the geoid shape in Tatra Mountains".
Geod. i Kartog., Polska Akad. Nauk, Kom. Geod., t. XXVI, Z. 3, p. 211-217,
Warszawa, 1977.

There are given some notices of the author connected with the determination of the geoid shape on the territory of special testnetwork in the Tatra Mountains. Author presented some properties of the astro-gravimetric levelling in mountain areas which are different from works in flat terrain. There are given conception of calculation of the vertical deflections and a proposition of taking into account some new stations in order to improve results of the astro-gravimetric levelling. Author points out that empirical formulae given hereafter are not adequate for estimation of the geoid height errors in mountains.

- 626 - KRYNSKI J. & K.P. SCHWARZ - "Application of satellite gradiometry measurements to local geoid determination".
Geod. i Kartog., Polska Akad. Nauk, Komitet Geod., t. XXVI, Z. 2,
p. 38-101, Warszawa, 1977.

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 undulation and that it is sufficient to have gradiometer data in a $5'' \times 5''$ 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 ± 1 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 ± 0.05 E will give a significant improvement of the geoid. Finally, some results of 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 accuracy. 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.

Geophysical Institute of the Czechoslovak Acad. Sci., Praha.

- 627 - Studia Geophysica & Geodaetica, t. 21, n° 1, 105 p, 1977.
 628 - " " " t. 21, n° 2, p. 107-206, 1977.
 629 - " " " t. 21, n° 3/4, 1977.

- a) BURSA M. - "Expansion of a function given over an equipotential surface into spherical harmonics".
 p. 217-227.
- b) BERANEK B. & M. ZOUNKOVA - "Investigations of the Earth's crust in Czechoslovakia using industrial blasting".
 p. 273-280.

Results obtained in studying the M-discontinuity by means of deep seismic sounding in Czechoslovakia are presented. Apart from profile measurements, surface surveys are being carried out in Czechoslovakia using industrial blasting, where the measured sections are at epicentral distances of 80 to 120 km. The international profiles and points, at which data from surface measurements were obtained, are given in Fig. 1. The suitability of using the method (Fig. 3, 4) is discussed, and a structural map of the M-discontinuity for Czechoslovakia has been constructed from the results obtained (Fig. 5). The M-discontinuity in Czechoslovakia is connected with its layout in the neighbouring countries and the map of the M-discontinuity has been established for Central Europe (Fig. 6). It was found that the zones of larger crust thicknesses in the Alps and Carpathians are very important for treating the contact between the European Platform and the foundations of the Alpine System.

634 - Bulletin Géodésique, A.I.G., v. 52, n° 3, p. 165-250, Paris, 1978.

- a) PAUL M.K. - "Recurrence relations for integrals of associated Legendre functions".
p. 177-190.

Recurrence relations for the evaluation of the integrals of associated Legendre functions over an arbitrary interval within (0° , 90°) have been derived which yield sufficiently accurate results throughout the entire range of their possible applications. These recurrence relations have been used to compute integrals up to degree 100 and similar computations can be carried out without any difficulty up to a degree as high as the memory in a computer permits. The computed values have been tested with independent check formulae, also derived in this work ; the corresponding relative errors never exceed 10^{-23} in magnitude.

- b) TSCHERNING C.C. - "Collocation and least squares methods as a tool for handling gravity field dependent data obtained through space research techniques".
p. 199-212.

Least squares adjustment and collocation methods have in the last decade been the tool for extracting gravity field information from data obtained through space research techniques (satellite orbit tracking, altimeter observations, doppler determined positions), and when combining these data with data observed at the surface of the Earth.

The mathematical framework for the two models is described and the models are compared. It is shown that the two methods only become equivalent in cases where the number of parameters are equal to the number of observations.

It is pointed out that several arbitrary choices (of parameters, weights and norms) will have to be made before the methods can be applied, and that further investigations are needed in order to justify the specific choices.

635 - Osser. Geof. Sper. - Boll. di Geof. teor. appl., v. XIX, N° 75-76, p. 107-295, Trieste, Sett.- Dec. 1977.

- a) MORELLI C., P. GIESE, M.T. CARROZZO, B. COLOMBI, A. HIRN ...
"Crustal and upper mantle structure of the Northern Apennines, the Ligurian Sea and Corsica, derived from seismic and gravimetric data".
p. 199-260. (6 chapitres).

In 1974, the crustal structure between Corsica and the Northern Apennines was investigated by seismic refraction measurements within a French, German, and Italian cooperation. This offers the possibility to discuss the structure of this area involving also other geophysical methods. The first paper (Morelli and Giese) outlines the general aim of this project and presents some technical data.

The second report, given by Nicolich, deals with seismic reflection data of the area under study which completes the picture in the uppermost part of the crust. Some time-contour maps (base of the Pliocene-Quaternary, base of the upper Miocene, top of the crystalline basement) delineate the structure of the sedimentary cover under the Ligurian Sea.

The next three papers, presented by Colombi et al., Letz et al., Hirn et al., describe the results obtained by the seismic refraction project 1974.

The main facts are the following : Corsica shows a typically continental crust, 30 km thick. Elba and the NE Ligurian Sea are characterized by two discontinuities, both having the properties of a crust/mantle boundary. The deeper boundary (40-50 km) belongs to the Corsica-Sardinia block whereas the shallow one (15-25 km) must be associated with the Adria microplate.

Carrozzo and Nicolich checked the cross-section, derived from the seismic data, by gravimetric calculations. In general, the seismic results could be confirmed. In some cases, minor modifications must be applied. E.g. under the Corsica channel a small updoming of the crust/mantle boundary must be claimed in order to compensate the thick sedimentary fill of this graben.

A short contribution by Rower et al. deals with the results of a seismic refraction profile observed in 1966, running from the Massif Mercantour along the Ligurian coast. A crustal overlapping for the transition between the Northern Apennines and the Western Alps W of Genova could be evidenced.

The last paper by Giese et al. summarizes the results and contains some geological remarks.

The crustal structure presented here is understandable only when considering simultaneously the tectonic structure and development of the southern Western Alps and the Northern Apennines. Two different continental units have to be distinguished. The Corsica-Sardinia crust, being a fragment of the European continent, is of normal continental composition and extends, under reduction of its thickness, some ten kilometers east and northwards under the crust of the Adria microplate.

The Adriatic crust has a minimum thickness of 20 km under Elba and 15-20 km in the northern Ligurian Sea. Proceeding towards the crest of the Apennines, crustal thickness increases at least to 35 km.

Comparing the structure of the area under investigation with that of other Mediterranean orogenic zones, a distinct difference is recognizable. In the Ligurian region the crust of the hinterland, that is Corsica, plunges under the Apenninic and Adriatic crust. In the Alps and the Carpathians, however, the crust of the hinterland overlies geosynclinal series and the crust of the foreland. The different situation in the Ligurian Sea has to be seen in a larger frame, that is the transition from the Alps to the Apennines. Just in this area, the Adria microplate behaves as hinterland in respect to the Western Alps whereas it is foreland with regard to the Northern Apennines.

The given formula for calculating the vertical gradient of the gravity field is based on the well known Poisson's integral for two-dimensional problems. The integral equation representing the new function was divided into three integrals, integrated and then expressed in the form of the given summation.

$$V_{zz}(0, 0) = \sum_{i=1}^n A_i [V_z(0, 0) - V_z(x_i, 0)] + R$$

The values of the coefficient A_i are given in a table. This formula was checked on theoretical models of simple body forms and of a set of two spherical bodies located at different depths.

Results of calculations show that the accuracy of the suggested formula is good enough and its resolving power too. Besides, it is in a form easy for manual computations and also for electronic computer programming.

- 638 - MARSON I. & F. ALASIA - "Absolute gravity measurements in the United States of America".
AFGL-TR-78-0126, AFSC, USAF, 79 p, Hanscom AFB Mas., 1978.

The measurements of gravity acceleration described in the report were performed in 1977 within a grant program sponsored by the US Air Force. The introductory part of the report illustrates the transportable absolute gravimeter and ancillary instrumentation used in measurements, and describes the measurement method applied; uncertainty and errors are analysed as well. Measurements of gravity acceleration made in Europe prior to the USA program are also briefly considered before a detailed account is given of the measurements made in the USA. The numerous tables in the text and at the end of the report form an essential part of it. Six stations were observed in the USA and approximately 100 measurements made per station. The results show an overall uncertainty in g measurements of the order of 10^{-6} Gal.

- 642 - MILLER H.G. & E.R. DEUTSCH - "The Bouguer anomaly field of the Notre Dame Bay area, Newfoundland with map : N° 163 - Notre Dame Bay".
Earth Physics Branch, Gravity Map Series, 6 p, N° 163, Ottawa, 1978.

Gravity observations at 705 locations in the Notre Dame Bay area of Newfoundland delineate an arcuate belt in which closely spaced gravity anomaly contours tend to follow the coastline. This belt marks the surface contact between mafic volcanics and ophiolite sequences within the Notre Dame tectono-stratigraphic zone and (1) sedimentary and volcanic rocks in the Exploits zone to the south and east and (2) predominantly meta-sedimentary and metavolcanic rocks in the Fleur de Lys zone to the west. Positive Bouguer anomalies over the Fleur de Lys zone to the east of the Baie Verte lineament indicate a westerly subsurface extension of the oceanic rocks found in the Notre Dame zone. Sedimentary rocks in the Exploits zone have no perceptible effect on the gravity anomaly field".

- 643 - WATTS A.B. - "Gravity field of the Northwest Pacific Ocean Basin and its margin : Hawaii and vicinity".
The Geol. Soc. of America, 1975.
Lamont-Doherty Geol. Obs. Col. Univ., Contr. n° 2214, 6 p, Palisades.

A total of 14,425 surface-ship and pendulum gravity measurements have been combined with land measurements in a new free-air gravity anomaly map of the Hawaiian Islands and adjacent sea areas. The map has been contoured at 25 mGal intervals, and gravity anomaly values have been annotated at maxima and minima between contours. Defined on this map is a narrow belt (about 120 to 180 km wide) of large-amplitude positive anomalies (as much as + 700 mGal) associated with the Hawaiian Ridge, a narrow belt (about 120 to 180 km) of large amplitude negative anomalies (as much as - 136 mGal) that flank the ridge, and a broad belt (about 200 to 300 km) of positive anomalies (as much as 25 mGal) that border the negative anomalies. We discuss here the significance of these belts of positive and negative anomalies, which extend for distances of as much as 1,000 km across the map area, and their correlation with features of sea-floor topography.

- 644 - WATTS A.B. - "Gravity field of the Northwest Pacific Ocean Basin and its margin : Aleutian Island, arc-trench system".
The Geol. Soc. of America, 1975.
Lamont-Doherty Geol. Obs. Col. Univ., Contr. n° 2242, 5 p., Palisades.

Surface-ship and pendulum sea gravity measurements have been combined with land measurements in a new free-air anomaly map of the Aleutian island arc-trench system. The most prominent features of the map are a narrow belt of large amplitude positive anomalies that reach a maximum value of + 242 mGal over the northwest part of the Aleutian island arc and a narrow belt of large-amplitude negative anomalies that reach a minimum value of - 219 mGal over the central part of the Aleutian Trench. The map also defines the main features of the free-air anomaly field landward of the Aleutian arc and seaward of the Aleutian Trench. Free-air anomalies are generally zero over the Aleutian Basin landward of the central part of the Aleutian island arc and generally positive (as much as + 50 mGal) seaward of the Aleutian Trench.

- 645 - WATTS A.B. - "Gravity field of the Northwest Pacific Ocean Basin and its margin : Philippine Sea".
The Geol. Soc. of America, 1976.
Lamont-Doherty Geol. Obs. Col. Univ., Contr. n° 2311, 4 p, Palisades.

Surface-ship and pendulum gravity measurements have been combined with land measurements in a new free-air anomaly map of the Philippine Sea. The map defines the main features of the free-air anomaly field associated with the island arc-trench systems that border the Philippine Sea. The Japan, Bonin, and Mariana island arcs are associated with narrow belts of large amplitude positive anomalies that reach a maximum value of + 386 mGal and negative anomalies that reach a minimum value of - 352 mGal. The map also defines the field associated with the marginal basins that comprise the Philippine Sea.

The Shikoku and Parece Vela marginal basins are associated with positive anomalies in the range + 15 to 25 mGal. The West Philippine basin is associated with a variable free-air anomaly pattern. The deepest parts of the basin (>6.1 km) are associated with negative anomalies in the range of 0 to - 10 mGal.

- 646 - DREWES H. - "La compensacion de redes gravimetricas". Univ. del Zulia, Postgrado Ing., Pub. Interna N° 23, 28 p, Maracaibo, 1977.

The theory of the adjustment of gravimetric network is described and applied in a network around the Lake of Maracaibo (Venezuela). The given method is different to the models used in former evaluations and is based on a strict development, while the others include approximations and neglections.

A computer-program is given and described at full length. The program is universal and may be used for different types of adjustment (e.g. free networks or connected networks).

- 647 - NAKAGAWA I., Y. TANAKA, M. SATOMURA, M. KATO & K. OIKE - "International connection of gravity between Japan and South America". from : J. Geod. Soc. Japan, v. 23, n° 2, p. 82-87, 1977.

An international connection of gravity was carried out by using a couple of LaCoste & Romberg gravimeters, G-29 and G-196, at Kyoto, Tokyo, Oahu-Honolulu, Los Angeles, Mexico City, Lima, Arequipa and Santiago. The gravity difference was of about 2.1 Gals.

After the data obtained were adjusted, correction factors for the scale constant of the gravimeters G-29 and G-196 given by the manufacturer were determined to be 1.000893 and 1.000526, respectively. The value of the correction factor for the gravimeter G-29 was slightly larger than that of another international gravimetric connection among Tokyo, Moscow, Potsdam and Paris which was performed by the Geographical Survey Institute.

Using these correction factors, the gravity value at each measuring station was recalculated under the assumption that the mean value of gravity at all stations registered in the IGSN 71 was assumed to have undergone no change. The discrepancy between the value thus obtained and that of the IGSN 71 was less than ± 0.05 mGals at all stations.

- 648 - ROWELL U.H. - "Geology and geophysics in Hawaii : a bibliography of theses and dissertations 1909-1977".

A total of 278 academic theses are included in the bibliography : 39 % from the University of Hawaii, and 11 % from universities and colleges outside Hawaii. Roughly two thirds are regional studies on the Hawaiian Islands ; the remaining third, all by University of Hawaii graduates, are partly theoretical works, partly works on non-Hawaiian geology and geophysics.

The bibliography has two main sections, both with full bibliographic information : one is chronological , and one is arranged by subject. There are three indexes that all refer to the chronological section by year and author : one geographical index, one alphabetical author index, and one list of universities and colleges represented in the bibliography.

The sources consulted for the compilation of the bibliography are listed in the introductory chapter.

- 649 - KELLER G.V., C.K. SKOKAN, J.J. SKOKAN, J. DANIELS, J.P. KAUAHIKAUUA ...
 "Geoelectric studies on the East Rift, Kilauea Volcano, Hawaii Island".
 Univ. of Hawaii, HIG-77-15, Geothermal Resources Exploration in Hawaii
 N° 3, 195 p, 1977.

Three geophysical research organizations, working together under the auspices of the Hawaii Geothermal Project, have used several electrical and electromagnetic exploration techniques on Kilauea volcano, Hawaii to assess its geothermal resources. This volume contains four papers detailing their methods and conclusions. KELLER et al. of the Colorado School of Mines used the dipole mapping and time-domain EM sounding techniques to define low resistivity areas around the summit and flanks of Kilauea. Kauahikauua, and Klein of the Hawaii Institute of Geophysics then detailed the East Rift with independent, two-loop induction and time-domain EM soundings. Finally, Zablocki of the U.S. Geological Survey delineated four anomalous areas on the East Rift with an extensive self-potential survey ; one of these areas was chosen as the site of a test hole.

- 650 - BERG E., J.A. CARTER, D. HARRIS, S.H. LAURILA, B.E. SCHENCK, G.H. SUTTON ...
 "High precision laser distance measurement in support of lunar laser ranging at Haleakala, Maui, 1967-1977".
 Univ. of Hawaii, HIG-78-5, 184 p, 1978.

The United States lunar laser ranging program utilizes two observatories, one of which is atop Haleakala on the island of Maui, Hawaii. The Hawaii Institute of Geophysics has implemented a comprehensive geodetic-geophysical support program to monitor local and regional crustal deformation on the island of Maui. The program includes repeated geodetic laser surveys between the LURE Observatory and an island-wide and inter-island networks, gravimetric surveys and first order levelling ; also ocean tide gages, tiltmeters for monitoring the local vertical, and seismic surveillance of crustal activity, (CARTER et al., 1977 ; BERG and SUTTON, 1977).

This report describes the results of the first high-precision electronic distance measurements accomplished in the support program : the instrumentation used and instrument modifications, the procedures adapted, and the atmospheric conditions that preclude standard methods on long lines through an inversion layer.

We aimed at an overall distance accuracy of 1 part in 10^7 for the individual lines. This objective is reflected in the discussions and calibrations of the Range-master II, the laser distance measuring instrument used, the barometers and thermometers used to obtain atmospheric data on the ground and in the air by helicopter to determine the refractive index, and finally, in the calculation procedures.

The report presents the actual laser-measured line lengths and new coordinate computations of the line terminals, and discusses the internal consistency of the measured line lengths. Several spacial chord lengths have been reduced to a Mercator plane, and conditional adjustments on that plane have been made.

The report also compares the old Hawaiian data and the new measurements, and discusses the relative merits of the direct integration versus modeling approach to obtain the mean refractive index along a laser line.