

ASSOCIATION INTERNATIONALE DE GEODESIE

BUREAU GRAVIMETRIQUE INTERNATIONAL

BULLETIN D'INFORMATION

N° 46

Juin 1980

18, avenue Edouard Belin
31055 TOULOUSE CEDEX
FRANCE

B U R E A U G R A V I M E T R I Q U E
I N T E R N A T I O N A L

Toulouse

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

Juin 1980

N° 46

Publié pour le Conseil International des
Unions Scientifiques avec l'aide financière
de l'UNESCO

Subvention UNESCO 1980 DG/2.1/414/50

ANNOUNCEMENT

THE BUREAU GRAVIMETRIQUE INTERNATIONAL HAS BEEN MOVED TO THE CENTRE NATIONAL D'ETUDES SPATIALES IN TOULOUSE, IN THE LAST WEEK OF JUNE, ACCORDING TO THE PROPOSAL WHICH WAS ACCEPTED AT THE LAST IUGG GENERAL ASSEMBLY IN CANBERRA.

CONSEQUENTLY, WE KINDLY ASK YOU TO SEND ALL CORRESPONDENCE TO THE FOLLOWING ADDRESS :

ASSOCIATION INTERNATIONALE DE GEODESIE

BUREAU GRAVIMETRIQUE
INTERNATIONAL

CENTRE NATIONAL D'ETUDES SPATIALES

18, Avenue Edouard Belin
31055 TOULOUSE CEDEX
(FRANCE)

TEL. : (61) 53.11.12 Ext. 5072
TELEX : CNEST B 531 081 F

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RESULTS OF THE QUESTIONNAIRE CONCERNING THE BULLETIN D'INFORMATION
AND DOCUMENTATION OF THE BGI ENCLOSED IN Bull. Inf. N° 45, Dec. 1979.

		Sent	Returned
Number of sheets sent	: 238	Europe 157	83
" " " returned	: 123	Asia 20	11
		America 39	20
		Africa 15	5
		Australasia 7	4

Answers :

Are you interested in bibliog. references :	with abstract	102
	without abstract	18
" " " in general anomalies maps :	free-air	90
	Bouguer	84
	another type	60
" " " in gravity measurements at sea :		70

Some remarks submitted for the next issues of the Bulletin

- 1°) Publication of minutes of gravity meetings should be inserted earlier.
- 2°) Announcement of gravity international symposium and information on national gravity projects.
- 3°) As far as possible, insert english texts.
- 4°) Publish abstracts of bibliographic references in french.
- 5°) Publication of a bibliography section for various countries in Africa.

STATUS OF BGI HOLDINGS AS OF JUNE 1st 1980

The Data Bank is held by the "Bureau de Recherches Géologiques et Minières" (BRGM) in Orléans. It is considered as an archiv file from which any set of data can be retrieved. A copy of this file is presently at GRGS in Toulouse, where a specific data management system is being developped for the purpose of evaluating the measurements, and merging different data sets according to various criteria still under study.

HOLDINGS

1°) The BGI data base includes about 282000 marine observations and 547000 land stations. The repartitions of these data is shown on map 1 for each square degree of the Earth surface, with the following code numbers :

Symbol	Number of data point in a square degree
blank	0
1	1-10
2	10-25
3	26-50
4	51-100
5	101-250
6	251-500
7	501-750
8	750-1000
9	1001-2500
*	> 2500

Such a map will appear once a year in the January Bulletin (and twice this year for the reason given below).

2°) Our holdings also include :

. Mean free-air anomalies

- one set of 1° x 1° mean gravity anomalies computed at BGI in 1978
- one set of 1° x 1° mean gravity anomalies provided by DMAAC
- one set of 5° x 5° mean gravity anomalies computed at BGI (issued in June 1979)

. Mean elevation of topography :

- one worldwide set of 1° x 1° mean values provided by DMAAC
- one set of 0.9° x 0.9° mean values for Europe
- one set of (0.05 gr in long.) x (0.04 gr in lat.) mean values for France and its vicinity.

These files, or part of them can be obtained on request.

3°) We received in 1979 about 1.5 million gravity measurements (on land, at sea) from DMAAC, covering various parts of the world. This set, considered as a qeparate data base, should be hopefully merged this year, at GRGS, with the BGI data bank, and the resulting file sent back to BRGM. Consequently, the next map summarizing our holdings and to appear in the next Bulletin, should show a considerable increase in the coverage.

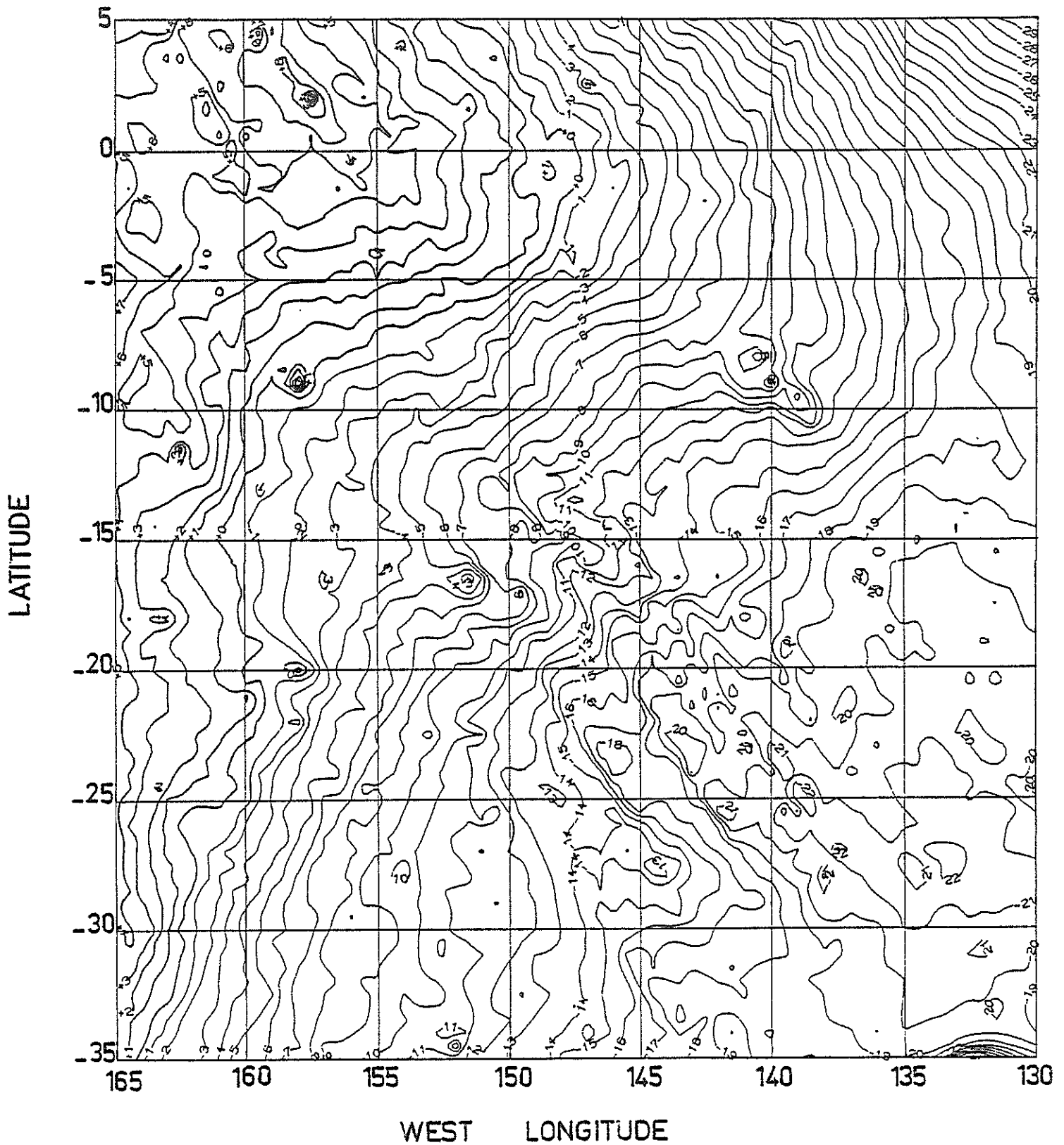
By this time, we think we shall have developped some capabilities in data evaluation ; although most of it is being done at DMAAC, we intend to implement specific methods of marine data evaluation with respect to satellite altimetry derived geoid heights. The algorithms will be tested in the Indian Ocean (Kerguelen Island area) and the results reported in the Bulletin d'Information when appropriate.

SOME SERVICES WHICH BGI CAN PROVIDE

The list of the services given below is indicative of some of the tasks which BGI can perform for the users.

Although in many cases (e.g. when dealing with a user on a data or documentation exchange basis) some of these services can be provided free of charge, in other cases we shall have to cover some of our expenses. A proposal of charging the incremental costs to the users will be submitted to our Directing Board this summer, and when approved will appear in the Bulletin.

- Data retrieval on any support (tape, punched cards, printout).
- Data coverage plots and detailed indices of BGI holdings, as shown on maps 2 and 3, for areas extended over 20° in longitude and latitude (fixed blocks) - standard procedure, or for any area of any size.
- Contour maps of Bouguer or free-air anomalies, at a given scale, with a chosen projection - Map 4 is an example of what our automatic contouring program can draw (this map represents the level curves, at one meter interval, of the geoid heights as derived from Geos 3 satellite altimetry data in part of the Pacific Ocean).
- Data screening over some areas.
- Gridding (interpolation at regular intervals)
- Computation of mean gravity anomalies (free-air, Bouguer, isostatic).



Map 4 - Example of automatic contouring at BGI

EXTRAORDINARY APPEAL TO CONTRIBUTE DATA
FOR THE PRODUCTION OF WORLD GRAVITY ANOMALY MAP SERIES
(W G A M S)

We recall your attention on the importance of the WGAMS, for which Mr. J.J. Levallois sent a circular letter to the Presidents of all National Committees of the IUGG last fall, of which you will find a copy next page.

The production of these maps is fundamental to the whole IUGG community, as stressed in this letter.

Unfortunately, we have received so far five positive answers only, and that is why we urge you to forward our request to the most appropriate person(s).

The data may be submitted in any form. Suggestions were given by my predecessor in an appendix to his letter ; others can be found in this issue of the Bulletin d'Information, on page I - 41.

BUREAU GRAVIMETRIQUE INTERNATIONAL

4, Place Jussieu, tour 14

75230 PARIS Cedex 05

(France)

October 19, 1979

Mr. President of the National Committee
of the I.U.G.G.

Dear Mr. President,

Recently the International Gravity Bureau (Bulletin d'Information N° 43, November, 1978) drew attention to the need for gravity data to fulfill its mandate to establish a world wide data bank on behalf of the International Association of Geodesy and issued an appeal to all countries to contribute their national holdings to the file as soon as possible. Subsequently the Directing Board of the International Gravity Bureau (IGB) reached an agreement to produce a series of world gravity maps at a scale of 1:15,000,000. The specifications for this World Gravity Anomaly Map Series (WGAMS) are currently being drawn up and it is expected that final production details will be available for presentation to the XVII General Assembly of the IUGG in Canberra, Australia, December 1979. As these maps are intended to represent as comprehensively as possible the global gravity anomaly field, great interest has already been expressed by geophysicists and geologists as well as geodesists and we therefore feel we must proceed with this project as quickly as we can.

Clearly it is important that WGAMS contain all possible gravity anomaly information. Therefore, at the request of the presidents of Section III of the International Association of Geodesy and the International Gravity Commission, I am making this extraordinary appeal to all National Sections to the IUGG to support our efforts and encourage their national agencies to contribute their data to the world data bank and hence to the production of WGAMS. In this context, I would like to note that it is the normal practice of the Bureau to make all data freely available to the world geoscientific community and I would therefore expect that all data used on the maps will be openly available upon publication of the maps. If, however, countries wish to limit the use of data for their national regions to the compilation of regional or global maps or to the computation of mean anomaly catalogues in connection with IGB-sponsored activities without further approval on their part, this should be clearly indicated in their response. I hope, however, that this will not be the case.

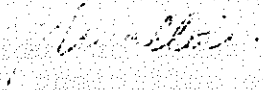
As with any project of this scope, I expect that the collection of data from many sources and their conversion to a uniform system will be the most difficult and time-consuming part of the compilation task. In order to minimize the problems in this area, I have attached suggestions for submitting the data. Data submitted will be melded with that already in our IGB files and contributors should not worry unduly about duplication of data. Procedures are available to check routinely for this, so the emphasis should be given to presenting the most complete data set possible.

.../...

It is also possible that member countries may not be in a position to present their data in a computer processable format. In these cases the IGB will gladly accept typed listings of principal facts for gravity stations or contoured gravity maps showing the locations and anomaly values of the stations. In these cases contributors are requested to describe the reference system (e.g., IGSN 71 - GRS 67) upon which the measurements are based and the procedures followed in this reduction.

In conclusion, I believe WGAMS will constitute a major contribution to our knowledge of the global gravity field as we plan to present the results of measurements in most countries as well as for many oceanic regions of the earth. I therefore urge you to co-operate fully with this exacting undertaking.

Yours sincerely,


Ing. Gal Geogr. J.J. LEVALLOIS
Director of the International Gravity Bureau

P.S. : As you probably know, I am retiring and I resign my functions of Director at the beginning of the General Assembly of IUGG (December 1979).
The new Director will no doubt get in touch with you for the same purpose. Help him as much as possible. Thank you.

SUGGESTIONS FOR DATA SUBMISSION

1. The data may be submitted as punched cards, magnetic tape files, coding forms, published tables or maps. Digital data are preferred but not essential.
2. If magnetic tape files are submitted, the data should be coded in card-image format and the tape should be readable on an IBM 360/370/3033 computer system. Header and trailer labels should not be used if the files are generated on other computer systems. The contributor should include a description of the tape, including the number of tracks, the recording density, record blocking factor, recording code, etc., so that the file can be easily read. A record description which defines position, length, units of measurement, etc., should also be included.
3. If copies of coding forms or published data are submitted, the copy quality must be sufficient to ensure easy readability. Any explanatory notes or references that could be provided would be appreciated.
4. It is often difficult to convert purely anomaly data from one reference system to another ; if possible, the data submitted should include the value of observed gravity, elevation and water depth for each observation.
5. If the data are not tied to the IGSN 71 reference system, a list of the reference bases and of their gravity values as used in the data reduction should be included.
6. Each contributor should supply a listing of the formulae used in the reduction of the submitted data ; this is particularly important if the theoretical value of gravity was not computed on the GRS 67 ellipsoidal reference system or if the Bouguer anomalies were computed with a density other than 2.67 gm/cc.

- A -

MINUTES of the XVIIth GENERAL ASSEMBLY of I.U.G.G.
in Canberra, December 1979

SUMMARY OF THE PRESIDENTIAL ADDRESS
TO THE INTERNATIONAL GRAVIMETRIC COMMISSION

5.12.1979

1. Present situation

1.1 The 8th Meeting of the I.G.C. was held in Paris, 12-16 Sept. 1978. At this meeting, an extended Report was presented by the writer, comprehensive of all the relevant facts (scientific, operational and organizatory ones) pertinent to the activity of IGC.

The scientific advancements were presented subdivided in the different chapters, with the pertinent references :

Theoretical gravimetry	New gravimetric instrumentation
Absolute measurements	Microgravimetry
IGSN 71	Secular variation
New Nets and Adjustments	Space gravimetry
Gravity at sea	Lunar gravity

The organizatory problems concerned mainly the restructuration of the I.G.B. and the activity of the Working Groups created by I.G.B. to improve this activity.

1.2 The scientific advancements since Sept. 1978 are already presented in the Report on the activities 1975-79 of Sect. III (Gravimetry) by J.G. Tanner and W. Torge . The Report on the 8th I.G.C. Meeting is published in Bull. d'Inform. I.G.B. n. 43, Nov. 1978.

The I.G.B. situation deteriorated and culminated at the Meeting of the D.B. in Paris (23-24 June 1979) with the letter of resignation of the Director, J.J. Levallois, effective from Canberra's IUGG opening session.

At the same D.B. meeting, a first proposal for the future of I.G.B. was presented by the Groupe de Recherches de Géodésie Spatiale (G.R.G.S.) - Toulouse. After subsequent discussions, the proposal was officially presented by the President of the French. Nat. Comm. for Geodesy and Geophysics, Prof. Goguel, at the Canberra Meeting, and approved in principle by the IGC Extraordinary Meeting on Dec. 5th, 1979. The open questions were discussed with the new Director, Dr. Balmino, Prof. Goguel and Dr. Weber of B.R.G.M. in a Meeting of the D.B. on December 8th, 1979.

A two year (1980-81) period of transition is forecasted. In this time, the international scientific support (through the D.G. W.G.'s and coordinators channels) and the French administrative and logistic support will be strengthened.

2. Immediate future

In addition to the activity through the S.S.G.'s, the I.G.C. tasks for the next two years (a Meeting of IGC is scheduled during the I.A.G. General Meeting in Tokyo, 10-15 May 1982) can be outlined as follows :

2.1 Absolute measurements (coordinated by W.G. n.2)

- Purposes :

- | | |
|---------------------------|---|
| a) World wide Super-Net ; | c) Calibration and non-linear effects ; |
| b) Geodetic control ; | d) Regionalization. |

- Intercomparison of the newly developed transportable apparatuses (in Sèvres and USA) ;
- Selection of new absolute sites, with following requirements :
 - on bedrocks and so far as possible near anfidromal points to be selected through earth tides profiles ;
 - good environmental control (water level, meteorology, microgravimetric and altimetric ties ;
 - possibly near monitoring stations of space techniques (VLB or Laser) ;
 - tidal recording.

2.2. IGSN'71

Improvements and extensions (to be coordinated by W.G. n. 2).

New regional adjustments.

2.3. Satellite altimetry

The D.B., in the Paris 1979 meeting, proposed to I.G.C. to consider that "the formation of a new W.G. related to the problem of satellite altimetry data might be necessary".

It is proposed that W.G. n. 1 forms a Sub-Group to study the recommendation and to present the proposal to the next D.B. Meeting (scheduled for the 2nd half of March 1980 in Paris).

2.4. Regionalization

The By-laws of I.A.G. state "The structure of each Commission may be organized according to its own requirements".

To fullfill the tasks above discussed, it is proposed that for the problems connected with

- new absolute measurements ;
- IGSN 71 improvements and extension ;
- new regional adjustments.

I.G.C. be structured in Sub-Commissions (S.C.). The first ones proposed, and the Coordinators, are the following ones :

- S.C. for North America : Strange ;
- S.C. for Central & South America : Tanner ;
- S.C. for Europe : Boedecker ;
- S.C. for Africa : Coker ;
- S.C. for the NE Pacific : Nakagawa ;
- S.C. for the SW Pacific : Reilly.

The Coordinators are requested to send proposals and Programs to the President of I.G.C. before March 15, 1980 (in time for a meeting of the Executive of I.G.C. to be held in the 2nd half of March, 1980).

5.12.1979, 11.00 - 12.30 :

EXTRAORDINARY MEETING
OF THE INTERNATIONAL GRAVITY COMMISSION

This meeting followed the I.A.G. section III-meeting, where the French proposal to establish the Bureau Gravimétrique International at G.R.G.S. in Toulouse, had been extensively discussed.

Prof. Morelli, president of the I.G.C., gave a short introduction and reopened the discussion about the proposal. Main items coming out from the I.G.C.-members were :

- that the primary task of the B.G.I. be the collection, analysis and distribution of surface gravity point data (W.I. Reilly, Yu.D. Boulanger, C.C. Tscherning),
- that the national agencies in coordination with the B.G.I., should collect and homogenize the gravity data according to a uniform scheme, before supplying them to B.G.I. (C.C. Tscherning, S. Bakkelid, W.E. Strange) ; this problem has already partly been solved and will be further attacked by W.G.1 and W.G.2 of the B.G.I. Directing Board (C. Morelli, J.G. Tanner),
- the problem of the continuity of B.G.I. work during the transition period (Yu.D. Boulanger), and the question of the eventual shifting of the present B.G.I. staff to Toulouse (C.C. Tscherning). It was stressed that in a two-years transition period the continuity of data collection will be guaranteed by Dr. Coron, acting in Paris in cooperation with B.R.G.M., and that the personnel problem will be solved partly by retirements and partly by transfers to Toulouse (C. Weber),

- that an expansion of the B.G.I. Directing Board is not necessary, since the Director of B.G.I. is member of the Directing Board working groups. In addition a small coordinating group will be set up by G.R.G.S. and B.R.G.M., in order to solve any internal problems (C. Weber).

Prof. Morelli then presented a draft resolution on B.G.I., which will be forwarded to the I.A.G.. This resolution was unanimously accepted by the I.G.C..

W. Torge, recorder

INTERNATIONAL ASSOCIATION OF GEODESY

SECTION III - GRAVIMETRY

ACTIVITIES AT THE XVII I.A.G.-GENERAL ASSEMBLY, CANBERRA 1979

5.12.1979, 9.00 - 10.30 : Meeting of Section III - Gravimetry

The session was opened by the President of section III, Dr. J.G. Tanner. He discussed briefly future section activities, which will include

- proposed continuation of S.S.G. 3.37 - Special Techniques of gravity measurements - (E. Groten),
- the proposed continuation of S.S.G. 3.40 - Secular variations of Gravity - (Yu.D. Boulanger),
- a project of carrying out high-precision relative gravity measurements along the 50°N parallel, as proposed by Dr. Kiviniemi,
- the studies of the marine gravity field, especially the evaluation of the sea gravity data, the use of satellite altimetry data, and preparation of a harbour control stations catalogue. The question of establishing a Special Study Group was briefly discussed (Dr. Woodside).

The main topic of the meeting was the proposal of the French National Committee on Geodesy and Geophysics, to establish the Bureau Gravimétrique International (B.G.I.) at the Groupe de Recherches de Géodésie Spatiale (G.R.G.S.) in Toulouse. After the proposal had been introduced and background comments given by Dr. Tanner and Prof. Morelli, an open and intensive discussion followed. The major points arising during the discussion were :

- that the primary emphasis in the B.G.I. work will be the collection, analysis and distribution of surface gravity data (U.A. Uotila, R.H. Rapp, Yu. Boulanger, L.E. Wilcox),
- the question, whether regional data banks shall cooperate in the gravity data collection, and forward their results then to B.G.I. for inclusion in the global data bank and subsequent distribution to users (W.E. Strange, Ch. Whalen). It was remarked that in many countries national data banks exist or are established (U.S.A., Canada, Denmark, Australia, New Zealand), these national gravity data collections can be directly forwarded to B.G.I., although the establishment of regional centres may also have advantages in some areas particularly with respect to data analysis (W.E. Strange, U.A. Uotila, W.I. Reilly, C.C. Tscherning). This problem will be further handled by W.G.1, Directing Board, B.G.I. (L.E. Wilcox, J.G. Tanner),
- the use of satellite altimetry data at the B.G.I.. It was stated, that the satellite data are now being analyzed very well only by a few agencies, and that in the B.G.I. the satellite data may be used for comparison and control of the surface data, but must not be mixed or combined with them (C. Morelli, R.H. Rapp, Yu.D. Boulanger),
- the continuation of the B.G.I. work in collecting and analyzing gravity data during a transition period of about 2 years (Yu.D. Boulanger), the problem of employing a sufficient number of people in the B.G.I., for efficient operations especially in the data bank work (L.E. Wilcox, J.M. Woodside) and
- the necessity for the B.G.I. staff, to do their own scientific research (C.C. Tscherning).

Dr. Weber stated, that emphasis in B.G.I. work will remain on the land and sea surface gravity data, that more full-time

staff shall be engaged in the B.R.G.M. with data bank if necessary, and that a combination of space and surface data in the data bank will not happen.

Summarizing the point of view of the I.A.G., Prof. Moritz stressed

- the importance to have one bureau as a central gravity data depository,
- the necessity of clearly distinguishing terrestrial data from other data, and clearly specifying the interrelations between different data,
- the importance of the B.G.I. being a FAGS institution, doing its own scientific research. In this respect, the new B.G.I. relation to CNES is very fortunate.

Finally, Prof. Morelli concluded that the French proposal be accepted in principle with thanks, but that discussions between the B.G.I. Directing Board and the French National Committee on Geodesy and Geophysics be held to clarify some details in accordance with the consensus of the general discussion in Section III. He promised that the B.G.I. will obtain all possible scientific support by the Association, through the Directing Board and the Working Groups.

W. Torge, recorder

6.12.1979, 14.00 bis 17.30 :
INTERSECTION MEETING C
"GLOBAL GRAVITY MEASUREMENTS"

Convenor : J.G. TANNER

Meeting dedicated to the memory of
Donald A. RICE

- 14.00 - 14.05 The life and career of Donald A. Rice.
John Bossler.
- 14.05 - 14.20 Comparison of Soviet absolute gravity results in the
Australian region with IGSN 71, GAG-2 and Soviet
pendulum gravity measurements.
Yu. D. Boulanger, S.N. Scheglov,
G.D. Karner and G.P. Arnautov.
- 14.20 - 14.35 The new gravity base net of the Federal Republic
of Germany (DSGN 76).
G. Boedecker, E. Reinhart, B. Richter
- 14.35 - 14.50 Gravity measurements in the province of Buenos Aires.
A.A. Cerrato, F.L.A. Masciotra, O. Nuñez,
F.C. Ignazzi.
- 14.50 - 15.05 A digital acquisition system for LaCoste-Romberg
gravity meters.
C. Poitevin.
- 15.05 - 15.20 An intercomparison of 14 absolute gravity stations
in Europe using LaCoste-Romberg gravimeters.
R.K. McConnell, I. Marson, R. Berutt, B. Toro,
D.B. Hearty. Presented by J.G. Tanner.

- 15.20 - 15.35 Comparison of 5 LaCoste-Romberg gravimeters on the Belgian gravity net.
C. Poitevin and B. Ducarme.
- 15.35 - 16.00 Break
- 16.00 - 16.15 Periodic calibration errors of LaCoste-Romberg model G and D gravity meters.
W. Torge, E. Kanngieser.
- 16.15 - 16.30 Instrumentatl capabilities of LaCoste-Romberg gravity meters for the detection of small gravity variations with time
G. Boedecker.
- 16.30 - 16.45 Constraint on the planetary scale value of the Newtonian Gravitational constant from the gravity profile within a mine
J.G. Tuck, F.D. Stacey.
- 16.45 - 16.50 A new set of global $1^{\circ} \times 1^{\circ}$ mean gravity anomalies.
R.H. Rapp.
- 16.50 - 17.05 A new absolute gravity apparatus.
A. Sakuma.
- 17.05 - 17.15 The world gravity standardization system.
U. Uotila.
- 17.15 - 17.30 On the Honkasalo term.
M. Heikkinen.

8.12.1979, 10.30 - 11.45 :

MEETING OF THE DIRECTING BOARD
BUREAU GRAVIMETRIQUE INTERNATIONAL

Present : C. MORELLI, President International Gravity Commission, member.
F.G. TANNER, President Section III (IAG), member.
W. TORGE, Secretary Section III (IAG), member.
Yu. D. BOULANGER, member.
J. NAKAGAWA, member.
U.A. UOTILA, member.
J.M. WOODSIDE, member.
J. GOGUEL, President CNFGG.
G. BALMINO, proposed Director BGI.
C. WEBER, BRGM (last third of session)
H.M. DUFOUR, IGN.
L.E. WILCOX, DMAAC.

After a short introduction by Prof. Morelli, Dr. Balmino explained and clarified some points of the French proposal to establish the BGI at the Groupe de Recherches de Géodésie Spatiale (GRGS) in Toulouse :

- It is well understood that the international gravimetric community primarily needs surface gravity data, so the collection etc. of these data will continue to be the primary task of BGI.,
- Satellite altimetry data, being processed by GRGS, will primarily help in validating gravity measurements at sea,
- The BGI needs technical services of other agencies, as provided by the working groups,
- Near future activities of the BGI will comprise continuing data collection in Paris (Dr. Coron), the inventory of the state of the data bank (with BRGM), and circulation of the results to the national agencies. Such activities will have to consider the question whether and how to update the data for the resp. countries,
- The BGI activities will follow the guidelines given by the International Gravity Commission and the Directing Board,
- The BGI will have complete independence from the host agencies - the GRGS and BRGM simply provide some manpower and facilities but will not interfere with the mission of the BGI in any way.

These explanations were followed by a general discussion, in which the Directing Board members expressed their appreciation of the proposal. The following items were discussed in more detail :

- Visit of the data bank specialists to the EPB system in Ottawa, following an invitation of Dr. Tanner,
- Restrictions on certain data sets, given by the national agencies for special international projects like the WGAMS, but not free for general distribution (Tanner). Prof. Goguel stated that BRGM can and will respect faithfully restrictions on distribution imposed by national sections,
- The control of data, which is important for data analysis and adjustment (Boulanger). Dr. Balmino explained the control procedure as taking place at two levels : a rough control by hand or by a special computer program in Toulouse (M. Sarrailh), and a subsequent more refined at BRGM (M. Leprêtre). Prof. Boulanger and Dr. Tanner offered the technical service and computer programs and help from specialists in converting the data to a uniform global system,
- The circulation to the gravimetric community of the Bulletin d'Information will be continued, with at least two issues per year ; in addition, circulars will be sent out for rapid information purpose if necessary (Balmino).

Prof. Goguel, speaking for the French National Committee of Geodesy and Geophysics and BRGM, reviewed the historic development of the BGI, with emphasis on the progress in data storage and processing. He stressed that all necessary help will be given in order to obtain an effective data handling at BRGM. While the Director of BGI will be completely responsible for the BGI work, a small coordinating group will be set up for solving any problems arising between the different French agencies that will host the BGI.

Dr. Tanner reported that the IAG Executive Committee meeting of 7.12.1979, accepted the recommendation of the IGC and agreed to the nomination of Dr. Balmino as Director of BGI.

Prof. Morelli presented the draft resolution on BGI, prepared at the extraordinary meeting of the IGC, Canberra 5.12.1979, and scheduled as IAG resolution at the Canberra IUGG General Assembly, asking for acceptance by the French National Committee of Geodesy and Geophysics. Prof. Goguel agreed, with the modification "remain" instead of "be" in line 9 of the draft. In addition, the words "on principle" (line 7) have been cancelled, and "and BRGM" have been added after "GRGS" (line 13).

In closing the session, Prof. Morelli thanked the French National Committee of Geodesy and Geophysics for the generous support, and congratulated the new Director of the IGB, wishing him full success.

The next meeting of the Directing Board of the IGB was scheduled to be held in Paris, during the second part of March 1980.

Recorder,
W. TORGE

10.12.1979, 10.30 - 12.30 :

INTERSECTION MEETING D
"NON-TIDAL GRAVITY VARIATIONS"

Chairman : W. TORGE

Meeting dedicated to the memory of
Tauno HONKASALO

- 10.30 - 10.35 The life and career of Tauno Honkasalo.
T.J. Kukkamäki
- 10.35 - 10.50 Global gravity network for the study of non-tidal
gravity variations.
Yu. D. Boulanger, N. Pariisky
- 10.50 - 11.20 Report S.S.G. 3.40 "Non-tidal gravity variations".
Yu. D. Boulanger
- 11.20 - 11.35 East-west transcontinental gravity profiles :
comparison of their measurement with results
obtained 20 or 30 years ago.
A.A. Cerrato, J.L.A. Masciotra,
V.L. Massini, J.A.R. Pardo
- 11.35 - 11.50 Assessment of secular gravity changes in
Fennoscandia.
E. Klingele, H.G. Kahle
- 11.50 - 12.05 Graphic representation of gravity changes.
J. Nakagawa, Y. Fukuda, M. Satomura
- 12.05 - 12.15 Report "Recent crustal movements".
P. Vyscočil

11.12.1979

- 11.00 - 11.30 Report S.S.G. 3.37
"Special Techniques of Gravity Measurements".
E. GROTEN
- 11.30 - 12.30 Business meeting of S.S.G. 3.37
E. GROTEN

Meeting of I.G.B. Working Group N° 1 (WG1)

"DATA PROCESSING AND EVALUATION"

Tuesday, 11 December 1979

Attendees : J. TANNER, Convenor
L. WILCOX, member
W. STRANGE, member
C. MORELLI, ex-officio member
G. BALMINO, ex-officio member
U. UOTILA, member IGB Directing Board
I. NAKAGAWA, " " " "
J. WOODSIDE, " " " "
W. TORGE, guest
D. ECKARDT, guest
C. PERRY, guest
E. FITSCHEN, guest
B. ROUSSEAU, guest
plus several additional guests.

Convenor TANNER suggested that an inventory of IGB data holdings should be completed as soon as practicable. At first this inventory could be in the form of a dot plot of the data held in digital form. The maps and non-digitized data need not be indexed for the time being since this is a very time consuming and a difficult task.

This suggestion was agreed to by WG1.

The non digitized data may be mostly older material, and one possibility is to ignore this material especially when newer material is renewed that covers the same areas as the old. This could save processing costs. The IGB could await the outcome of the WG1 appeal for new gravity data to support the World Gravity Anomaly Map Series (WGAMS). What to do with the older material may become clearer after all the new material has been renewed.

The dot plot inventory is to be circulated to all national Committees to supplement the WGAMS appeal.

TANNER suggested that only the observed gravity data value be worked in the IGB data banks - gravity anomaly values can be computed as needed and with respect to the geodetic system requested by users. This is particularly important after adoption of the GRS-80 by the IAG. Some users may still desire use of GRS-67 International, or other systems.

BALMINO announced that 1,100,000 data points are currently available in the IGB in the form of tapes, listings and cards of these, about 900,000 stations are available in the digitized data base. Another 1,500,000 stations have been renewed in digitized form. After checking for duplication, these will be entered into the data bank.

Documentation of the data base, including formats, is still an open question. BALMINO indicated that comments to a documentation scheme, proposed by the IGB last September are still being renewed by the IGB. He will attempt to finalize this by next March in time for the next meeting of the IGB Directing Board.

WGI needs to establish criteria for accuracy of the various data elements (observed gravity, elevation, position etc.) in material contributed to the IGB. WILCOX cautioned that some potential contributions might be discouraged if minimum accuracy criteria were established. TANNER requested WILCOX to make recommendations with respect to the accuracy of data submitted to the IGB.

Procedures also need to be established for adjusting oceanic surface gravity data especially where significant differences in gravity occur at cross-over points. WGI decided to recommend that a special sub-group be established for this purpose.

L.E. WILCOX
Recorder

Meeting of IGB Working Group N° 2 (WG2)

"GRAVITY STANDARDS"

Tuesday, 11 December 1979

Attendees : U. UOTILA, Convenor
W. TORGE, member
L. WILCOX, member
C. MORELLI, ex-officio member
G. BALMINO, ex-officio member
J. TANNER, member IGB Directing Board
I. NAKAGAWA, " " " "
J. WOODSIDE " " " "
D. ECKARDT, guest
W. STRANGE, guest
C. PERRY, guest
E. FITSCHEN, guest
B. ROUSSEAU, guest
plus several additional guests.

Convenor UOTILA reminded the current situation with respect to global absolute gravity measurements. There have been a large number of new absolute gravity measurements in the USSR and Australia by the BOULANGER apparatus, in Europe and North America by the Italian apparatus, and in the USA by the HAMMOND apparatus. Although only fine absolute measurements were indicated in the IGSN 71 adjustment, the IGSN 71 system has been proven by the new absolute measurements to be well within its design accuracy specification of $\pm 0,1 \text{ mGal}$, ($\text{mGal} = 10^{-5} \text{ m sec}^{-2}$). The IGSN 71 is more than adequate to control gravity anomaly computations, and may be retained indefinitely as a standard for this purpose. WG2 has recommended that no new global gravity network adjustment be undertaken to replace the IGSN 71 for scientific applications. Instead local or regional adjustments tied into new absolute measurements have been recommended. The absolute stations used should be sufficiently far apart in latitude in each case to control the scale of relative gravimetric work.

UOTILA further emphasized the importance of making intercomparisons between the different absolute apparatus at a number of sites before extensive absolute measurement programs are begun in order to detect any systematic differences that may exist between the different instruments. The IGC has recommended that such intercomparisons be done along the European Calibration Line (ECL).

The Italian apparatus has already made measurements along this line. The Russian and Hammond apparatus should now do this also.

TANNER pointed out that there is an IAG resolution made at Grenoble with respect to absolute gravity intercomparisons that is still in effect.

STRANGE mentioned that by next Spring, intercomparisons between the Italian and Hammond instruments should be available at a number of sites in the United States. He reemphasized the importance of such intercomparisons. Comparisons between the two instruments to date suggest that they agree in most instances but, occasionally and apparently in a random fashion, disagree by unacceptable amounts. The reasons for the occasional disagreements must be resolved.

UOTILA suggested that comparisons also be made in the Southern Hemisphere to determine whether absolute gravity instruments behave differently in the Southern Hemisphere than they do in the Northern.

ECKHARDT urged that comparisons be made in Paris at an early date. This will enable comparisons with the permanent Sakuma apparatus. He also stressed the value of bringing all instruments together at the same time so that each observer can view and discuss the others.

UOTILA recommended that continuously recording tidal gravimeters be installed at each intercomparison station to detect small changes of gravity with time.

TANNER reported that such a recommendation is going to the IAG from Section 3.

It was generally agreed that all intercomparison stations should be located at very stable sites, preferably on bed-rock.

UOTILA summarized the intercomparison question by observing that adequate solutions have been proposed, and an IAG resolution already exists so it is only necessary for WG2 to reemphasize the importance of making an adequate number of intercomparisons.

UOTILA next directed the discussion to a consideration of a proposal by Prof. BOULANGER and SSG 3.40 to establish a global network of absolute gravity stations to detect non-tidal changes in gravity. Since WG2 is responsible for absolute site selection in connection with gravity standards work and there are a limited number of absolute instruments available, it is appropriate that WG2 provides its recommendations with respect to the SSG3.40 proposal.

STRANGE recommended that absolute gravity sites be co-located with space stations (i.e., VLBI laser etc.) so that changes in gravity and geodetic position can be monitored simultaneously. This recommendation was generally agreed to by WG2.

Current and potential sites for space station location will be closely monitored by the group. ECKHARDT agreed to provide a lot of current and planned space stations.

BALMINO informed the group that SAKUMA plans to move his equipment to the space site at Grasse in the future.

ECKHARDT and UOTILA urged that absolute stations in the global net be located at very stable sites. Thus we must be concerned not only with site distribution but also site quality.

UOTILA noted that BOULANGER does not always follow stability criteria in his absolute site selections.

MORELLI recalled the proposal made by LEVALLOIS in 1970 that specified criteria for absolute site selection.

LEVALLOIS proposal includes specification for horizontal and vertical control of absolute sites and specifies environmental conditions that are appropriate. It was agreed that good knowledge of local environmental conditions are essential so that, if gravity changes are detected, their causes can be accurately determined. That is, we should be able to ascribe the change to local conditions or actual changes in the gravity field itself.

As to the number of stations requested at the start for a global absolute network, TANNER recalled that a 1975 IAG resolution called for 10 stations. BALMINO agreed that 10 well distributed stations is sufficient to begin, but there should be at least one or two stations within each continent or margin land area. This number and distribution were generally agreed to, but the group also accepted the fact that many additional absolute stations are likely to be established in particular areas to meet the particular needs of national and local organizations.

Thus WG2 feels that the large number of absolute stations recommended by SSG 3.40 is not appropriate at this time. Instead, precise relative ties from a few absolute stations can be used to detect secular changes at the remainder of sites in the SSG 3.40 proposal at least in the near future.

STRANGE recommended that, if possible, each absolute determination consists of measurements at three sites interconnected by relative measurements. If the gravimeter differences between the three sites agree with the differences in absolute measurements, then we have most assurance that the absolute instruments are working properly.

It was agreed that this procedure is valid, but might be too expensive in some cases.

It was agreed that the criteria to be used for selecting sites for the basic global absolute network recommended by WG2 should consider space site locations, good areal distribution, stability plus geodetic and environmental factors such as those enumerated by LEVALLOIS.

It was agreed that actual site selection be done by regional groups. In the U.S. the U.S. Gravity Base Coordination Committee will do the selection. EPB can do the job for Canada. Latin American sites will be selected by the U.S. Gravity Base Coordination Committee and EPB in association with the Inter American Geodetic Survey (IAGS). The Geodetic Commission for Africa will handle that continent. Prof. NAKAGAWA has agreed to handle the Pacific. (Europe and the USSR are open).

It was agreed that frequency of repetition of absolute measurements at each site would be specified after the rate of local environmental changes are determined for each site.

MORELLI requested that consideration be given to calibration needs. In this connection, FITSCHEN offered cooperation of U.S. Africa to establish absolute gravity sites at space and other sites in that country. The group agreed that this is desirable since sites in South Africa and Rhodesia can have the effort of extending the ECL closer to the equator, and fill in "South" of Catania.

UOTILA raised the question of whether relative ties are still needed between continents. TORCE stated that if absolute and relative control is precisely established within the continents, intercontinental relative ties are no longer required. However, relative ties should be made to islands that do not have absolute measurements. Also, he recommended periodic relative ties between absolute stations and other stable site in the vicinity.

The question of publicizing completion of new regional or local absolute gravity network adjustment was discussed next. It was decided that scientists will be requested to keep WG2 and the IGB informed by such work. Any new adjustments can be published in the IGB Bulletin d'Information. Every few years, a map can be published showing where more accurate absolute adjustments are available.

Finally, the question of tying in base stations used for sea gravity measurements was raised. It was agreed that a tie to IGSN 71 is sufficient. It is probably incumbent on each ship's crew to transfer gravity from a stable shore site where an IGSN 71 value is known to the ship.

Harbor stations are usually unstable and, generally, poorly marked and, in many cases, should not be used. WG2 recommends establishment of well monumented IGSN 71 stations close to harbors for use by ships. WG2 also recommends that stations already used as bases for ship surveys be tied to the IGSN 71 where this has not been done previously.

L.E. WILCOX
Recorder

MINUTES OF BGI DIRECTING BOARD, March 1980

FIRST SESSION OF MEETING OF WORKING GROUP 1
HELD ON MONDAY, MARCH 24, AT 9.00 HOURS

Attendees : Prof. C. MORELLI
Dr. G. BALMINO
Melle S. CORON
Dr. L. WILCOX
Prof. U. UOTILA
Prof. Yu. D. BOULANGER
Mr. R.K. McCONNELL
Mr. J.P. LEPRETRE
Prof. I. NAKAGAWA
Mr. M. OGIER
Dr. J. TANNER

Mr. BALMINO and Mr. Leprêtre reported on their progress toward achieving an index of holdings in the BGI data base.

Currently some 800,000 observations were current in the files with another 1.5 million observations waiting to be meshed with them. An index of holdings, by ten degree squares, has been compiled for the northern hemisphere. The working group briefly reviewed this index and the status of the report describing the data base.

It was agreed that this latter report should be updated by the time of the next meeting of the I.G.C. in Tokyo. It was also apparent that an economical means of advising the world geodetic and geophysical community of the distribution of holdings of the BGI through the medium of the Bulletin d'Information. A discussion of this question and other matters lead to the formation of a sub-group to investigate in detail the following questions :

- a) The contents and lay-out of the report describing the BGI data base and its operation,
- b) Meshing of new data sets with existing files,
- c) An economical way of indexing the data base for the information of the world geodetic community,
- d) The strategy for submitting data to the BGI,
- e) The strategy for dealing with marine gravity data.

Topic (e) was defined tentatively and subject to the results of a more general working group discussion to follow (see below). It was agreed the sub-group would report back to the main working group at its next session on Tuesday, March 25 at 11.30 hours.

Dr. Wilcox presented three reports which had been requested at previous meetings of the working group. The first of these contained a suggested set of guidelines for contributors of gravity data to the BGI. The report recommended a philosophy which made the process as simple as possible. He proposed a simple set of instructions broken down into :

- (a) Essential information,
- (b) Optional information.

The essential information would consist of position of the observation, elevation of the observation and the measured gravity value together with any information necessary to describe the reference system in which these quantities have been observed. Optional information would consist of any other information such as terrain correction, instrumentation, techniques, etc... which would be useful in evaluating or qualifying the measurement. After discussion it was agreed to accept this simple approach and the working group requested the BGI to prepare a notice to this effect. In doing so the BGI should clearly separate the two categories so that potential donors would not be led into confusing optional with essential and possibly be discouraged by the effort necessary to supply what appeared to be a great amount of detail. It was also agreed that, while a computer processable format was desirable, data would be accepted in any format.

The second report discussed the general principles of quality control and concluded by recommending a set of standards for the data base which could serve as an ultimate goal with respect to accuracy of the measurements. The working group accepted this report as an internal document, and decided to refer the question of standards for accuracy to the international community. Consequently it was recommended that this question be discussed at the next meeting of the IGC and its approval or other recommendations obtained.

Specifically the report recommended an accuracy goal of 0.1 mGal for observed gravity and 1 mGal for anomalies.

It also recommended that new absolute measurements should seek an accuracy of 0.01 mGal.

The third report described existing methods and procedures followed in evaluating data currently in the files of the BGI. Recipients were asked to review the report and pass the comments directly to Dr. Wilcox with a copy to the Chairman of the working group.

Dr. Balmino reported that no response had been received from National Sections regarding the extraordinary request for gravity data in support of WGAMS. In the discussion it was apparent that a number of these letters had apparently gone astray as many of those persons were unaware of its receipt in their respective countries. It was agreed the appeal should be renewed through the medium of the Bulletin d'Information.

In its discussion of the problems of marine gravity data (specifically cross-over values which differed by tens and as much as hundreds of milligals) the working group concluded it would not appear profitable to set up a group of experts to carry out a world wide adjustment of marine data. Instead it was decided to recommend a set of procedures for doing so and to identify agencies which might help others in carrying out such an exercise.

Recorder,
Dr. J. TANNER

REPORT OF WORKING SUB-GROUP TO CHAIRMAN OF WG.1

March 24th, 1980

As requested by the Chairman of WG 1 the Sub-Group deliberated on the requested topics and produced the following recommendations and observations :

1. Publication of Indices of Data Held by BGI

- BGI should maintain detailed indices (20° lat. by 20° long.) of data holdings for internal use. Sample of these indices should be published in the Bulletin and made available at cost on request.
- BGI should publish and distribute a generalized index of data holdings at a scale of approx. 1:50,000,000 showing station density by degree square. The first issue of this index should be distributed by June 1980 and should reflect present data holdings of BGI. The next edition should appear about December 1980 and should show holdings after melding of data set supplied by DMA. Thenceforth, this index should be updated and redistributed at yearly intervals.

2. Mechanism for melding BGI and DMA data

- DMA and BGI data will be matched by source. When duplicate data is found, the DMA version will be accepted. BGI data not in DMA data set will be forwarded to DMA, on an on-going basis, for evaluation and subsequent return to BGI.
BGI will attempt to complete melding process by December, 1980.
- BGI will send a duplicate copy of their present data holdings to DMA at the earliest possible opportunity. In the event that BGI encounters specific difficulties in the matching of BGI/DMA data, DMA will assist in resolving these problems.
- BGI will maintain an archive file of all gravity data received, in its original (unadjusted) form.

- The data base will contain adjusted data for the most part but unadjusted data, properly flagged, may be included at the discretion of BGI.

3. Strategy for Data Submission and Retrieval

- BGI will prepare draft instructions, by April 15, 1980, for contributing data to BGI data base. This draft will be circulated to WG 1 members and suggested revisions returned to BGI thorough the Chairman of WG 1.
- BGI will supply WG 1 members with a report on the questionnaire sent out with the December 1979 Bulletin by April 15, 1980.
- BGI will prepare a draft information circular containing instructions for requesting data from BGI data base, including the schedule of charges for various services offered, by July 1980. The Director, BGI should forward this to WG 1 members and seek approval of the schedule of charges from the Directing Board.

4. Satellite Altimetry

- BGI should maintain a file of mean gravity anomaly and geoid height data derived from satellite altimetry. This file should be maintained as a low priority task, i.e, it should not interfere with the maintenance of the surface gravity data base.

5. Strategy re Marine Gravity Data

- Potential contributions of marine gravity data should ensure that, in future, gravimeters are calibrated using suitable laboratory procedures or land calibration lines to 5 parts in 10^{-4} or better. Failing this, marine gravity surveys should be tied to at least two port stations whose gravity values span the gravity range of the area surveyed. The matter of compiling a catalogue of port stations will be referred to WG 2.
- BGI should provide EPB with a data set from the Indian Ocean for use in developing and testing an automated procedure for adjusting marine gravity data to a satellite altimetry derived datum.

- BGI will test a similar procedure independently. Satellite altimetry data will be supplied to BGI and EPB by DMA as soon as it is available. BGI and EPB will evaluate these adjustment procedures and, if viable, will develop a recommended procedure which, upon approval by WG 1 will be published in the Bulletin.

6. Report on Data Base for Tokyo meeting (May, 1982)

- BGI should prepare, in collaboration with WG 1, a report on the status of the data base. This report should include the following :
 - 1) Description of BGI data collection program,
 - 2) Description of holdings (anomaly, reference station, altimetry data),
 - 3) Instructions for contributing data,
 - 4) Instructions for requesting data including description of services available and schedule of charges,
 - 5) Summary of data evaluation procedures,
 - 6) Comments on marine gravimetry including suggested adjustment procedure,
 - 7) Any other issues which may arise up to the time of the Tokyo meeting.

Item 1, 2, 3, and 4 will be the responsibility of BGI.

Item 5 will be drafted by DMA and item 7 will be drafted jointly by BGI and EPB with possible input from DMA.

Recorder,
R.K. McCONNELL

SECOND SESSION OF WORKING GROUP 1

TUESDAY, MARCH 25, AT 11.30 HOURS

Attendees : Prof. C. MORELLI
Dr. G. BALMINO
Melle S. CORON
Dr. L. WILCOX
Prof. U. UOTILA
Prof. Yu. D. BOULANGER
Mr. R.K. McCONNELL
Mr. J.P. LEPRETRE
Prof. I. NAKAGAWA
Mr. M. OGIER
Prof. W. TORGE
Dr. G. BOEDECKER
Dr. J. TANNER

The working group received the report of the sub-group established to look into the organization of the report describing the BGI data base to be available by the Tokyo meeting in 1982, integrating the new DMA file with the present BGI holdings, publication and distribution of indexes of BGI data base, a strategy for submitting data and an approach to the adjustment of marine gravity data. A point-by-point review of the report of the sub-group was conducted with no problems of any consequence emerging. It was recommended, however, that the BGI and EPB should consider the possibility of publishing the results of their studies of techniques for adjusting marine gravity data.

The report of the sub-group (copy attached) was accepted unanimously.

Recorder
Dr. J. TANNER

ESSENTIAL QUANTITIES & INFORMATION
FOR GRAVITY DATA SUBMISSION

1. Position of the site :
 - latitude, longitude (to the best possible accuracy),
 - elevation or depth :
 - . for land data : elevation of the site (on the physical surface of the Earth)*
 - . for water stations : water depth.
 2. Measured (observed), gravity corrected to eliminate the periodic gravitational effects of the sun and moon, and the instrumental drift.* *
 3. Reference (base) station(s) used. For each reference station (a site occupied in the survey where a previously determined gravity value is available and used to help establish datum and scale for the survey), give name, reference station number (if known), brief description of location of site, and the reference gravity value used for that station. Give the datum of the reference value ; example : IGSN 71.
-

* Give supplementary elevation data for measurements made on towers, on upper floor of buildings, inside of mines or tunnels, atop glacial ice. When applicable, specify whether gravity value applied to actual measurement site or it has been reduced to the Earth's physical surface (surface topography or water surface). Also give depth of actual measurement site below the water surface for underwater measurements.

** For marine gravity stations, gravity value should be corrected to eliminate effects of ship motion.

OPTIONAL INFORMATION

The information listed below would be useful, if available. However, none of this information is mandatory.

- Instrumental accuracy :
 - Identify gravimeter(s) used in the survey. Give manufacturer, model, and serial number, calibration factor(s) used, and method of determining the calibration factor(s).
 - Give estimate of the accuracy of measured (observed) gravity. Explain how accuracy value was determined.
- Positioning accuracy :
 - Identify method used to determine the position of each gravity measurement site.
 - Estimate accuracy of gravity station positions. Explain how estimate was obtained.
 - Identify the method used to determine the elevation of each gravity measurement site.
 - Estimate accuracy of elevation. Explain how estimate was obtained. Provide supplementary information, for elevation with respect to the Earth's surface or for water depth, when appropriate.
- Miscellaneous information :
 - General description of the survey.
 - Date of survey ; organization and/or party conducting survey.
 - If appropriate : name of ship, identification of cruise.
 - If possible, Eötvös correction for marine data.
- Terrain correction :

Please provide brief description of method used, specify : radius of area included in computation, rock density factor used and whether or not Bullard's term (curvature correction) has been applied.
- Isostatic gravity :

Please specify type of isostatic anomaly computed.
Example : Airy-Heiskanen, T = 30 km.
- Description of geological setting of each site.

March 25th, 1980

Summary of
Informal DMAAC-BGI Gravity Data
Exchange and Processing Agreement
January 1980

1. Initial gravity data bank update.

a. During 1979, DMAAC provided magnetic tapes containing approximately 1,500,000 gravity stations to BGI.

b. During 1980, BGI will provide magnetic tapes containing BGI automated data holdings to DMAAC.

c. Both DMAAC and BGI independently will compare the two files of data.

d. Data common to both files plus data unique to the DMAAC file can be entered into the BGI data bank according to the DMAAC adjustment to IGSN71.

e. Data unique to the BGI file will be adjusted to the IGSN71 by DMAAC and retransmitted to BGI.

2. Continuing exchange and processing.

a. DMAAC will provide, at periodic intervals, data newly acquired and/or newly evaluated to BGI.

b. BGI will transmit newly acquired gravity data to DMAAC. If in the form of original documents, DMAAC will duplicate same and return the originals to BGI. The new data will be processed by DMAAC, adjusted to IGSN71 and eventually, evaluated. Periodically, the adjusted and/or evaluated data will be sent on magnetic tape to BGI.

c. At a convenient time, older BGI data in raw (not automated) form will be shipped in increments to DMAAC for processing, adjustment, evaluation, and retransmitted to BGI in automated form.

3. Miscellaneous items.

a. BGI is authorized to transmit and receive gravity data shipments via the APO at the US Embassy in Paris.

b. BGI will notify DMAAC when gravity data donors place releasability instructions on gravity data donated to BGI. DMAAC will contact the donor to obtain necessary releases to handle such data.

MEETING of the DIRECTING BOARD
of the BUREAU GRAVIMETRIQUE INTERNATIONAL

Paris, 25 March 1980

Attendees:	G. BALMINO	Director BGI, Member
	G. BOEDECKER	Subcommission Western Europe
	J. BOULANGER	Member
	A. COMOLET-TIRMAN	Secr. IGC
	J.C. HUSSON	CNES
	J.P. LEPRÊTRE	BRGM
	R.K. McCONNELL	WG I & II
	C. MORELLI	President IGC, Member
	I. NAKAGAWA	Member
	M. OGIER	BRGM
	J.G. TANNER	President Sec. III IAG, Member
	W. TORGE	Secretary Sec. III IAG, Member
	U.A. UOTILA	Member
	L.E. WILCOX	WG I & II

After a short introduction by MORELLI, reports of the Working Groups were given by the chairmen and discussed.

TANNER reports about WG I, that a $20^0 \times 20^0$ index of the presently existing 800 000 point gravity values in the BGI data base is in process. A compact index will be published in the Bulletin d'Information. 1.5 million gravity stations have been provided by DMAAC, the meshing and/or comparison of BGI and DMAAC data will be done by both BGI and DMAAC. In case of duplicate or inconsistent data the DMAAC-file recently evaluated will be regarded as most up to date and therefore supersede the current BGI-file.

Concerning the requesting of data from member countries or other donors, according to a report by Wilcox the details should be as simple as possible. Avoiding any specification of format the essential data are considered to comprise position, elevation, observed gravity value, reference systems (if needed). Additional data may be terrain corrections, instruments quality indicators etc. After adoption of these principles by the Directing Board they will be published in the Bulletin d'Information, and they will become the basis of the appeal for further gravity data supply.

A second report prepared by Wilcox concerns the principles of data evaluation, which should be followed by WG I. According to this report, which was adopted by WG I, DB and IGC should adopt standards to be pursued as goals for gravity observations of all member countries. These recommendations ask for normal survey type gravity observations accuracy of $\pm 0.1 \text{ mGal}$ ($1 \text{ mGal} \approx 10^{-5} \text{ ms}^{-2}$). Ancillary information such as elevation, position etc. should provide for a free air anomaly accuracy of $\pm 1 \text{ mGal}$, including systematic effects. New absolute gravity measurements should seek an accuracy of $\pm 0.01 \text{ mGal}$.

A third report by Wilcox which was circulated, described the data processing methodology applied by DMAAC to the gravity data transferred to BGI.

TANNER pointed out, that the appeal of BGI to national agencies requesting data for the World Gravity Anomaly Map Series (WGAMS) did not yet bring about any success. The appeal will be published in the Bulletin d'Information in June 1980 and the director BGI will remind the national agencies again, asking for an answer.

Marine gravimetry still yields cross over inconsistencies from different sources amounting to tens of mGal, sometimes even 100 ... 200 mGal. WG I decided to review the procedures in use and perform a few tests. Then it will decide whether to recommend a subgroup or a special study group within section III to deal with this problem.

TANNER then reports on a small subgroup of WG I, the deliberations of which were recorded by McConnell and circulated during the meeting. The first point of this report concerns the indices of BGI data holdings. A detailed $20^{\circ} \times 20^{\circ}$ index should be prepared for internal use mainly, whereas a station density index of degree squares should be published in the Bulletin d'Information in 1980. The second point concerns the melding of BGI and DMAAC data, which was already mentioned above. BGI will prepare draft instructions for data submission to and data retrieval from BGI. This will include scheduled (low cost) charges for various services offered by BGI. The director BGI will keep flexibility in handling the charges. The data holdings of BGI will also comprise the originally supplied data. Concerning altimetry, data files for the computation of gravity anomaly and geoid height should be maintained as a low priority task. For marine gravimetry the importance of calibrating the gravimeters to $5 \cdot 10^{-4}$ or better is stressed. In order to test procedures for the combination of altimetry and marine gravity data DMAAC will supply BGI and EPB (Earth Physics Branch, Ottawa) with satellite altimetry data of the Indian Ocean.

After MORELLI expressed his thanks for Tanners WG I report, BALMINO comments on the charges for the services of BGI. It is not intended to charge the full costs of maps etc. but rather the expenses directly associated with the service in particular materials as magnetic tapes etc. For donors of data and in other cases special arrangements may be made.

MORELLI gratefully acknowledges the support of agencies such as GRGS and DMAAC. No objections are made to Balmino's cost-philosophy. The above mentioned low priority in BGI for altimetry, which is only intended to support the activities of BGI and working groups, is approved by the audience. The agreement about technical details of the BGI - DMAAC gravity data exchange, as outlined by Tanner and as fixed in a draft "Summary of Informal DMAAC - BGI Gravity Data Exchange and Processing Agreement" of January 1980, is approved by the audience too. Tanners report is accepted.

MORELLI announces, that Tanner wants to resign from presiding WG I and that Tanner proposed McConnell as the successor. McConnell is accepted as new chairman of DB - WG I.

UOTILA reports on the subjects of WG II: The IGSN71 station descriptions were prepared by EPB from the material sent to them and transferred to BGI. The descriptions for the U.S. stations are still missing but they shall be submitted to EPB in the near future. No global

readjustment of IGSN71 will be made but regional adjustments may be registered by EPB. The IGSN71-values shall not be changed, but references shall assure access to sources of new values. The new regional coordinators are requested to collect data of regional adjustments and transfer the information to EPB and WG II. According to an IAG 1979 resolution the Honkasalo-correction of the tidal effect shall no longer be applied as has been the case e.g. in IGSN71. WG II recommends, that no new list of IGSN71 station gravity values be published, because this may cause confusion. Instead, a correction formula and a table will be published in the Bulletin d'Information in 1980 and in the Bulletin Geodesique for the correction of IGSN71-values.

UOTILA recalls the proposals of Levallois and Boulanger for a global net of permanent absolute gravity stations. In order to coordinate this work, WG II will first prepare the criteria for the selection of sites of such stations on the basis of the proposals of the U.S. base stations committee. These criteria will be sent to the IGC and via IGC to the regional coordinators, which in turn will select the station sites, with the help of scientists in the region and submit their proposals to WG II. WG II then will coordinate the proposals and pass them to the IGC.

Concerning the regional subcommissions which were established at the IUGG/IAG meeting 1979 in Canberra it was stated, that so far no coordinator has been appointed for India and the Arab countries. Khosler, director of the Survey of India, should be asked whether he would recommend Arour as one possible coordinator of that area. For Eastern Europe and USSR Boulanger agreed to act as a regional coordinator. WG II also discussed, that the regional coordinators could support WG II in some more items such as the IGSN71 station description updating.

In the WG II session Boulanger had presented results of absolute measurements in Moskow, Novosibirsk and Potsdam in the years 1975 - 1980, which consistently show gravity changes of about $30 \mu\text{Gal}$. Furthermore the scheduled French absolute gravity sites for the base net as also for the secular gravity changes monitoring net had been presented. A simultaneous intercomparison of the absolute apparatus' of the USSR, Italy, U.S. and Japan was proposed to take place in Sevres in September 1981. MORELLI states, that the WG II report of Uotila be accepted without objections or discussion.

BOULANGER reports about the business of WG III, that the data acquisition for preparing the anomaly maps of WGAMS (World Gravity Anomaly Map Series) remains difficult. UOTILA recalls, that originally first priority of WG III was put on mean anomalies and that WG III should give guidance to BGI in this matter. BOULANGER sees the mean anomaly computation as the task of BGI and therefore did not undertake any steps in this direction but solely was concerned with anomaly maps. Three sheets are accomplished, three more sheets are underwork, thus representing about half of the area to be covered by the USSR national committee. The whole work will be accomplished 1981/82, at which moment a first example will be issued. TANNER stresses, that one important goal of the WGAMS-project was to bring together as many land and marine gravity data worldwide as possible and that all data should be filed in BGI. He points out, that most important is a sufficient data input flow. The best evaluation and e.g. the computation of mean anomalies will be no problem. He offers the support of WG I to set up the mechanism for e.g. digitizing the maps. BOULANGER continues, that the maps partly are constructed by inclusion of other maps

by hand and that the WGAMS maps at first will serve for geophysical purposes and partly may have improper accuracy for geodesy. These maps afterwards may serve for the derivation of mean anomalies. MORELLI suggests new mutual information during the absolute gravity apparatus intercomparison campaign in Paris September 1981.

The question is discussed among MORELLI, TANNER, UOTILA and BALMINO, whether it will be necessary to set up a new working group for mean anomaly computation. After a suggestion of WILCOX to cooperate with SSG 5.62 it was decided, that the presidents of Sections III and V shall find a solution for this problem.

After opening the discussion about BGI-business by MORELLI, BALMINO reports on the present status of the BGI-move to Toulouse: During a two years transition phase the BGI will work in Paris as also in Toulouse. In June 1980 one scientist together with library, maps etc. moves from Paris to Toulouse, where the main activities will take place. The necessary acquisition of new personnel will be supported by IGN with one data engineer and two technicians as also eventually by the transfer of one position by the ministry of cultural affairs. It is not yet completely clear, what activities will remain in Paris, but Mme Coron and Mme Bouvet probably continue working until 1981/82. Also the work done by BRGM will continue. Concerning the finances, FAGS transmitted a first rate for 1980 of its support amounting to 1500.- \$. Due to the good conditions in Toulouse, the financial situation will be less critical in future.

Going through the still open questions of this BGI-meeting it was agreed, that the presidents of Sections III and V should seek for a solution for the manner, in which satellite altimetry should be treated by the IGC.

The time required for sessions of the IGC-bodies during the IAG Tokyo 1982 meeting was compiled as follows: IGC: 2 x 1/2 d, WGI: 3 x 1/2 d, WG II: 2 x 1/2 d, WG III: 1 x 1/2 d, SSG 3.40: 4 x 1/2 d.

BOULANGER proposes, that for the Paris 1981 intercomparison be invited Japan, U.S., USSR, Sakuma and Italy. TORGE suggests, that during the Tokyo 1982 meeting there should be a symposium of Section III dealing with absolute gravity measurements including in particular the intercomparison results. TANNER adds, that also marine gravity deserves special interest. It was agreed to discuss both these topics in one day meetings in Section III.

TANNER reports on the impact of the adoption of the new geodetic reference system GRS 80, which includes a slight change of the equatorial radius and therefore of the normal gravity formula. It was agreed, that GRS 80 should be used according to the IAG-resolution. If BGI only stores the (absolute) observed gravity values, it will be no problem to refer to any reference system. The new GRS 80 will be published in a regular issue of Bulletin Geodesique in 1981.

TANNER suggests a new sequence during DB-meetings in order to improve coordination: First a DB-meeting, then WG-meetings, at last a DB-meeting again. This proposal was accepted.

G. BOEDECKER, recorder

MEETING OF THE EXECUTIVE COMMITTEE
OF THE INTERNATIONAL GRAVITY COMMISSION

Paris, 25 March 1980

Attendees:	G. BALMINO	Director BGI
	G. BOEDECKER	SC Western Europe
	J. BOULANGER	BGI-DB
	A. COMOLET-TIRMAN	Secretary ICC, Member
	I.C. HUSSON	CNES
	J.P. LEPRETRE	BRGM
	R.U. McCONNELL	WGI II
	C. MORELLI	President IGC, Member
	I. NAKAGAWA	BGI-DB
	M. OGIER	BRGM
	J.G. TANNER	President Sec. III
	W. TORGE	Vice-President IGC, Member
	U.A. UOTILA	BGI-DB
	L.E. WILCOX	WG I&II

MORELLI reports the conclusions of the IGC-meeting in Canberra 1979 to establish the following new regional coordinators for the support of the work of the BGI: REILLY for Southwest-Pacific, STRANGE for North-America, TANNER for Central and South America, NAKAGAWA for Northeast Pacific and COKER for Africa. (Remark: This list was continued by BOULANGER for Eastern Europe and USSR and BOEDECKER for Western Europe at the DB-Meeting, Paris, 25 March 1980).

Some of the duties of those regional coordinators will be 1. to provide the DB with a list of addresses of national agencies and scientists for correspondence, 2. to be involved in the updating of IGSN71 station obscriptions, 3. to inform WG II about new adjustments in the region, 4. to select proper sites for the global permanent absolute stations. This report was accepted by the audience.

On a question of TANNER, MORELLI adds, the coordinators should have all freedom to support the work of IGC by various activities. Some major tasks should be fixed, however. NAKAGAWA and BOEDECKER briefly reported their proposals for the activities of the regional coordinators. MORELLI and TANNER suggest to use the proposal of REILLY as a basis for the terms of reference concerning the regional coordinators. This proposal shall be generalized and completed by ...e) To undertake in consultation with the president of the IGC other activities as required in pursuit of the objectives of the commission. Those guidelines then will be sent by MORELLI to the regional coordinators, who are presidents of their respective subcommissions. The names of the members of the subcommissions shall be reported by June 1st. It is the own affair of the subcommissions to find sponsors and to organize the work to be done.

The next future meetings of the IGC will be held in Tokyo 1982 and in Toulouse.

G.Boedecker, recorder

Meeting of BGI Working Group N° 2

1. Bureau Gravimétrique International (BGI) Working Group N° 2 (WG2) met in Paris at the BGI offices on 25 March 1980.

Attendees included :

- U. UOTILA, USA, Convenor
- W. TORGE, W. Germany, member
- K. McCONNELL, Canada, member
- L. WILCOX, USA, member
- C. MORELLI, Italy, ex-officio member
- M. OGIER, France, guest
- Y. BOULANGER, USSR, guest
- I. NAKAGAWA, Japan, guest
- G. BOEDECKER, W. Germany, guest

2. Convenor UOTILA noted that the President of the International Gravimetric Commission (IGC) assigned certain additional responsibilities to WG2 at the Canberra assembly of the IAG. The new tasks include coordination of new absolute gravity measurements and new regional gravity base net adjustments, and coordination of the work of new IGC sub-commissions pertinent to new absolute measurements, new regional adjustments, and IGSN 71 improvements and extensions. These tasks are in addition to the original charter of WG2 to maintain the IGSN 71, to maintain and coordinate distribution of IGSN 71 principal facts and station descriptions, and to coordinate all international gravity standards work.
3. R.K. McCONNELL reported that the USA remains the major area for which IGSN 71 station descriptions have not been completed. He does not have the basic information from appropriate USA agencies that he needs to compile the descriptions. WG2 requested that I attempt to locate the necessary IGSN71 station description information within the USA and arrange to have the material shipped to McCONNELL so that the IGSN 71 station description project can be completed. McCONNELL reported that compilation of the USA data may not be completed for a year or so after he received the necessary input because of the pressure of high-priority projects at EPB. WG2 suggested that descriptions for the primary stations be done first, leaving the excenter descriptions for completion later. However, due to the possibility that some primary stations may have been destroyed, the final decision in this matter was left to the discretion of McCONNELL.
4. There was an extended discussion of the problem of how to coordinate new regional gravity base network adjustments. Although some held the opinion that WG2 should do a review of local adjustments, others held that a formal review of work done by responsible agencies is not really necessary. As a compromise, it was decided that WG2 will prepare and disseminate through the BGI a document that describes all new gravity base network adjustments, and recommends how each ought to be used. The document will contain a comprehensive reference list and recommend that the appropriate local agency be contacted for additional details where required. WG2 also decided to annotate IGSN 71 station descriptions and/or values, where appropriate, to indicate the existence of a value determined through a local adjustment.

5. C. MORELLI suggested that WG2 recommend base network adjustments to new absolute stations be postponed until there are enough absolute stations within a country or region to firmly establish datum and, especially, scale over the whole gravity range within the country or region. This suggestion was adopted by WG2.
6. Y. BOULANGER reported that his absolute measurements in Australia suggest that scale problems on the order of 35 μ Gal may exist within that country. It is thought that these problems may be related to the age of the Australian calibration line. When a sufficient number of new absolute sites have been established in Australia to firmly establish the scale conditions, a new base net adjustment there may be beneficial.
7. The WG2 noted that the IGC Sub-Commissions were not completely established at the Canberra IAG Assembly. At Canberra, the following Sub-Commissions and Regional coordinators were appointed by the President of the IGC, C. MORELLI.

Americas : W. STRANGE and J. TANNER
Africa : O. COKER
NW Pacific : I. NAKAGAWA
SW Pacific : I. REILLY

After discussion, C. MORELLI made the following additional appointments :

W. Europe : G. BOEDECKER
E. Europe and USSR : Y. BOULANGER

In addition, U. UOTILA will correspond with the Director of the Survey of India and request he nominate an individual to serve as Regional Coordinator for a Sub-Commission for Southern Asia and the Middle East. Each Regional Coordinator will be asked to assemble an appropriate group of specialists to serve on the Sub-Commission. The first major task for the Sub-Commission will be to select sites for new absolute measurements to establish a global absolute gravity station network. Initially, about 10 stations with world-wide distribution is desired. The recommendations of the Sub-Commission in this matter will be passed to WG2 for consideration. WG2 will prepare a final set of recommendations for submission to the IGC. Additional functions of the Sub-Commissions are to keep WG2 informed about new regional gravity base network adjustments, to compile a list of responsible correspondents and agencies in each country that can be contacted on gravity related matters and to perform any pertinent tasks requested by WG2. For the latter tasks, WG2 will contact the Regional Coordinators via the IGC. C. MORELLI will correspond with the Regional Coordinators of the Sub-Commissions to inform them of their responsibilities.

8. WG2 noted that the US Gravity Coordinating Committee is preparing criteria for selection of primary absolute base station sites in the U.S. The results of this work will be considered by WG2 and amended or amplified as necessary. Then WG2 will prepare site selection guidelines for submission to the Regional Coordinators.

9. With respect to removing the Honkasalo Correction from IGSN 71 values, WG2 decided to publish appropriate formulas/tables and instructions in Bulletin Géodésique and/or the Bulletin d'Information. This will avoid having two sets of IGSN 71 values in circulation. A December 1980 publication data is anticipated.
10. Y. BOULANGER reported results of repeated absolute measurements at Moscow, Novosibirsk, and Potsdam over the period 1975-1980. These measurements suggest a quasi-periodic variation in gravity with a period of about five years and a magnitude of a few 10's of μGal . His results are generally in agreement with those of Sakuma at Sèvres - which also suggest a small periodic variation of gravity. However, BOULANGER also reported that he has been unable so far to detect any significant gravity change in the Southern Hemisphere. In the future, it may be necessary to specify an epoch for absolute measurements whose accuracy is in the 10 μGal range, but additional studies are needed to confirm whether gravity changes are universal or local in nature. Since the maximum periodic variation appears to be on the order of 50 μGal , IGSN 71 which has an indicated accuracy of 100 μGal is not affected.
11. M. OGIER reported that the French BRGM is planning to use a new absolute gravity measuring apparatus to make repeated measurements at Orléans, Reims, and Nancy in order to observe time changes in gravity. Three or four measurements will be made at each station per year. The expected accuracy will be 7 to 10 μGal . WG2 noted that these measurements will help determine whether gravity time changes are universal or local.
12. Y. BOULANGER has requested that all existing absolute apparatus be brought to Sèvres in October of 1981 to make simultaneous comparison measurements. WG2 will assist in coordinating this project. It is hoped that at least the following instruments will participate : Hammond (USA), French, Sakuma, Italian, USSR.
13. The next meeting of WG2 is scheduled for 26-28 May at Ottawa. The agenda will include a discussion of the gravimeter measurements made along the European Calibration Line in 1979, base stations for marine gravity, accuracy requirements for international gravity standards, and progress reports on other work underway.

L.E. WILCOX
Recorder

Eighth Meeting of the
INTERNATIONAL GRAVITY COMMISSION
Paris, 12 to 16 September 1978

- C -

PRECISE TIDAL CORRECTIONS

FOR HIGH PRECISION GRAVITY MEASUREMENTS

by

B. DUCARME*, C. POITEVIN**, J. LOODTS**

SUMMARY

For very precise tidal gravity corrections it is necessary to take into account the observed amplitude factors (δ) and phase differences (α) for the main diurnal and semi-diurnal components. The global method using a fixed factor $\delta = 1.16$ or $\delta = 1.20$ gives tidal predictions with errors that can reach 50 nm s^{-2} (5 microgals). From the results of the Trans European Tidal Gravity Profiles (1970-1973) isolines have been computed for δ and α in Western Europe. They can insure in continental areas a precision better than one per cent on the predicted tides (errors less than 10 nm s^{-2}). An application has been made on the belgian gravity network.

* Observatoire Royal de Belgique - Chargé de Recherches au FNRS

** Institut Géographique National - La Cambre, Bruxelles.

1. THE TIDAL PERTURBATIONS

The tidal corrections can be computed either by a direct evaluation of the global effect of the Moon and the Sun using the ephemeris positions, either from the development of the tidal potential into a sum of harmonic constituents or tidal waves. The first approach has the same accuracy as the second one as long as one does not take into account the perturbations introduced by the physical properties of the Earth.

The static response of the Earth to the tidal potential increases the amplitudes of the gravimetric tides and give static values of the δ factor (ratio of observed amplitudes to the theoretical ones)

$$\delta = 1.16$$

The global approach as well as the tidal development allows to introduce a constant scale factor.

As a matter of fact such a static response is only true for the long period part of the tidal spectrum. A first major perturbation comes from the resonance effect of the liquid core of the Earth [Melchior, 1978, ch 6] which affects the δ factors of the diurnal waves. According to the model Molodensky I the theoretical δ values for the two major diurnal constituents O_1 and K_1 are respectively

$$\delta(O_1) = 1.159$$

$$\delta(K_1) = 1.137$$

This amplitude modulation is well observed.

However the largest perturbations are coming from the oceanic tides. They can produce unmodelled residual on the M_2 frequency as large as 80 nm s^{-2} at the tip of Cornwall. At Brussels this effect is still 20 nm s^{-2} with a phase lead of 64° .

To evaluate these "indirect effects" we can model the oceanic tides influence by computing the attraction of the water masses and the loading effect. Unhappily for the time being the cotidal charts of the World Ocean are still contradictory and for coastal regions the contribution of the nearest water masses is very difficult to model. In the near future direct altimetry from satellites will help to solve these problems. Nevertheless for some parts of Western Europe including Benelux, France, Germany and Great Britain such calculations have been carried out by various authors [Bower 1970, Gerstenecker, Groten 1976, Moens 1977, Baker 1977, Souriau 1978].

Another way is to carry out tidal observations with gravity meters in such a way that a sufficient coverage of a definite area is insured. The main constituents of the tidal development are directly multiplied by the observed δ factors and affected by the observed phase differences α in order to synthetize a "true" tidal signal.

We shall now deal with two questions

- Which error can we expect when using a fixed δ factor 1.16 or 1.20.
- Which precision can we reach now using the extensive tidal measurements performed between 1970 and 1973 under the name "Trans European Tidal Gravity Profiles" (TEP).

2. TIDAL CORRECTIONS WITH A FIXED FACTOR

If we consider the gravimetric tides as a sum of sinusoidal waves, we can write:

$$W_T = \delta A \cos(\omega t + \alpha)$$

A: theoretical amplitude

δ : amplitude factor

α phase difference

We can consider errors Δ on the amplitude factors and ϵ on the phase difference under the form

$$W_O = (\delta + \Delta) A \cos(\omega t + \alpha + \epsilon)$$

The resulting error will be

$$W_O - W_T = -2(\delta + \Delta) A \sin \frac{\epsilon}{2} (\sin \omega t + \alpha) : \text{phase contribution} \\ + \Delta A \cos(\omega t + \alpha) : \text{amplitude contribution}$$

The residuals will present spurious tidal waves with magnitudes proportional to the wave itself, and to the phase shift or amplitude error.

For M_2 in Brussels we have

$$A = 31.5 \text{ nm s}^{-2} \\ \delta = 1.19 \\ \alpha = 2^\circ 8$$

The maximum discrepancy with respect to a static tide ($\delta=1.16$) will be

$$\begin{array}{ll} \text{amplitude contribution} & 9 \text{ nm s}^{-2} \\ \text{and phase contribution} & 18 \text{ nm s}^{-2} \end{array}$$

which is equivalent to a residual vector with an amplitude of 20 nm s^{-2} and a phase difference of 64° .

The RMS on one tidal correction associated to it is thus 10 nm s^{-2} .

Generally for a given oceanic basin all diurnal waves on one hand and all semi-diurnal waves on the other have very similar corange and cophase lines and their indirect effects will show a close relationship.

In Western Europe for example the main semi-diurnal waves (N_2 , M_2 , S_2 , K_2) have δ factors higher than the static response, close to 1.20 and their phase differences are positive (fig. 4, 5 and Melchior & alii 1976). The diurnal components O_1 , P_1 and K_1 are close to the Molodensky model with very small phase differences (fig. 2, 3 and Melchior & alii 1976). This is due to the fact that Atlantic Ocean and North Sea have predominantly semi-diurnal tides.

We can thus roughly extrapolate the data on M_2 to all the semi-diurnal spectrum (at least 37 per cent of the maximum tidal amplitude at a latitude of 50 degrees) and those on O_1 to all the diurnal band which can amount 63 per cent of the phenomenon.

The real tidal behaviour is quite complicate . The diurnal tides disappear when the declination of the corresponding celestial body goes through zero. The 14 days cycle linked to the Moon phases modulates the tidal amplitude by a factor of two.

We can now answer the question: in the global method which amplitude factor is the most suitable: 1.20 or 1.16?

Before all one must point out that 1.20 is certainly wrong for long period waves an these are very important for absolute gravity measurements. For gravimetric survey however this part of the spectrum is quite negligible except for transcontinental ties involving big latitude changes.

Some results based on the theoretical considerations of this paragraph are shown in Table 1. More realistic data are obtained when we compare tides calculated with the fixed amplitude factors to the best available tidal prediction available for Brussels (table 2). The results shown on figure 1 are self explanatory. The residuals obtained with a constant factor 1.16 never exceed $\pm 32 \text{ nm s}^{-2}$ while those computed for a factor 1.20 fluctuate between $+ 80$ and -30 nm s^{-2} with a modulation linked to the equinoxial minimum of the diurnal waves.

If we now consider two measurements made at times T_1 and T_2 , the associated tidal effect is

$$\delta A \cos(\omega T_2 + \alpha) - \delta A \cos(\omega T_1 + \alpha) = -2 \delta A \sin \omega \frac{\Delta T}{2} \sin (\omega T + \alpha)$$

with

$$\Delta T = T_2 - T_1$$

$$T = \frac{T_1 + T_2}{2}$$

When performing two measurements separated by half the period of a given tidal wave we may introduce an error equal to twice its amplitude.

These considerations are valid for the residual vectors due to an improper modelling of the tidal effect.

3. THE OBSERVED TIDAL FACTORS

We present here the isolines for the amplitude factors δ and phase differences α for the M_2 and O_1 waves. They are based upon the results obtained in more than 70 earth tides recording stations in Western Europe from Faeroe Islands to Tihany and from Tromsø to Granada. Most of the data were gathered during the Trans european Tidal Gravity profiles [Melchior & alii 1976] . As a matter of fact the density of the stations was only sufficient in Germany, Benelux, France, Northern Italy and South of England. We decided thus to produce maps covering an area comprised between 5 degrees West and 20 degrees East and between 40 and 60 degrees latitude North.

To avoid resonance effects in the model static solution were imposed on 30 degrees East and 30 degrees North.

The first step in producing isolines is to construct a Digital Terrain Model (DTM) [Loodts, 1977] which determines the values of the parameter δ or α at each summit of a square grid covering the whole area (15°W to 30°E and 30°N to 60°N). The dimensions of the grid can be locally adjusted as a function of the local density of entry points (observed values). This possibility leads to a kind of variable grid Digital Terrain Model (DTM).

At every summit the plane tangent to the surface is least square adjusted from the values of the neighbouring entry points. The number of points considered for this adjustment is determined from criteria of local isotropy and their influence is weighted according to a function of the distance to the summit.

The isolines are then considered as the boundaries between two structures [Loodts, 1978]. It is a problem of structural stability and morphogenesis [Thom, 1972]. The model produces two solutions that should coincide if the surface described is sufficiently continuous. It happens effectively for the tidal factors (see fig. 8).

From a practical point of view coastal stations or small islands where the nearest water masses have a predominant influence, produce instability in the model. For example the influence of the very low δ factors observed at Helgoland perturbed the results in the Netherlands. It's the reason why we discarded Helgoland and Oostende as entry points.

Figure 9 shows the location of 45 stations. Some 30 others are situated outside of the fixed limits. On the following maps dashed areas indicates a lack of observational points. Figures 2 and 3 give the results for the O_1 component. These maps are very smooth everywhere. The only remarkable features are low value in Scandinavia and a bump over Austria. This anomaly is due to the station Graz only and is thus questionable.

Figures 4 and 5 give the results for M_2 . The topography of the $\delta(M_2)$ map is smooth except in the British Islands, specially in Cornwalls ($\delta(M_2) = 1.40$ in Redruth). The surface is dipping to the North-East. It is a consequence of the very low δ factors observed along the atlantic coast of Norway. The behaviour of the phase difference α is very similar with very high positive values on British Islands and negative ones over Norway. The influence of the Bay of Biscaye produces very high positive phases in the North of Spain and South-West of France.

To evaluate the precision of the model we can look at the RMS obtained from the differences between the observed values at the entry points and the values interpolated from the Digital Terrain Model for the same points (table 3). However the precision is much better on the continental area of the central part as seen from the isolines maps of the residuals for M_2 (fig. 6,7). These residuals do generally not exceed 0.5 degree in phase and 0.5 per cent in amplitude. Some discrepancies appear in Normandy with residuals higher than 1 degree and 1.5 per cent. In the South-West

of France we find large residuals on the phase only. These areas require more observational data. The British Islands are also very difficult to model due to the influence of the Irish Sea, the North Sea and the Channel.

The digital Terrain Model is thus allowing interpolation of the tidal parameters in continental areas with a precision of 0.5 per cent for δ and 0.5 degree for α .

The corresponding errors in the tidal predictions will be

$$\approx 5 \text{ nm s}^{-2} \quad \text{for the amplitude}$$

$$\approx 9 \text{ nm s}^{-2} \quad \text{for the phase}$$

or a maximum total effect of $\pm 10 \text{ nm s}^{-2}$.

Thus the microgal precision can now be achieved for the tidal corrections to be applied on absolute gravity measurements.

4. APPLICATION TO THE FIRST ORDER BELGIAN NETWORK

To investigate the influence of the tidal corrections in a gravity network we have chosen the new First Order Belgian Gravity Network established during a fifteen days campaign. From the Digital Terrain Model (DTM) we have computed the best δ and α values for the 42 stations of the network.

For comparison purposes we reduced the data assuming four different tidal models:

- 1- fixed tidal factor ($\delta = 1.20$),
coordinates ϕ, λ of Brussels
- 2- observed tidal factors at Brussels,
coordinates ϕ, λ of Brussels
- 3- observed tidal factors at Brussels,
individual coordinates for the stations
- 4- tidal factors computed from the DTM, individual coordinates for the stations.

The long period tides were not taken into account.

Table 4 shows the effects on the Δg values for three lines crossing the country.

- line A: maximum changes in the observed tidal factors from Oostende to Walferdange.
- line B: maximum latitude effect
- line C: maximum longitude effect

TABLE 1: Maximum residuals with respect to a tidal model

	Diurnals (nm s ⁻²)	Semi-diurnals (nm s ⁻²)	Total (nm s ⁻²)
Maximum Theoretical Amplitude ($\phi=50^\circ$)	1150	700	1850
Residuals for $\delta = 1.16$	-	40	40
Residuals for $\delta = 1.20$	46	34	80

Model: $\delta = 1.16$ for diurnals
 $\alpha = 0$

$\delta = 1.19$ for semi-diurnals
 $\alpha = 2^\circ 8$

(1 $\mu\text{gal} = 10 \text{ nm s}^{-2}$)

TABLE 2

TIDAL MODEL FOR BRUSSELS STATION

GROUP	NAME	A	δ	α
1 - 62	Q1	115	1.180	-0.2
63 - 88	Q1	388	1.180	-0.2
89 - 110	M1	30	1.155	-0.2
111 - 120	P1	157	1.150	-0.2
121 - 123	S1	3	1.150	-0.2
124 - 143	K1	530	1.150	-0.2
144 - 165	J1	39	1.150	-0.2
166 - 197	OO1	28	1.150	-0.2
198 - 236	2N2	23	1.180	3.0
237 - 260	N2	87	1.170	3.0
261 - 286	M2	353	1.187	2.8
287 - 300	L2	9	1.170	2.5
301 - 309	S2	178	1.200	2.0
310 - 347	K2	57	1.200	2.0
348 - 363	M3	6	1.080	0.0

It is clear that models 3 and 4 are equivalent for such a local network. The results are affected mainly by the introduction of realistic tidal factors at the base station (model 2) and for line C by the use of the true coordinates of the station. This effect is less pronounced on line B as the tidal parameters are only slowly changing with latitude.

The cumulated error between the poorest model (number 1) and the best one (number 4) does not exceed 100 nm s^{-2} . The procedure here developed thus allows to reduce the tidal correction error from $10 \text{ } \mu\text{gal}$ to $1 \text{ } \mu\text{gal}$ which is now desirable considering the high performances of LCR gravimeters.

TABLE 3: R.M.S. error on the Digital Terrain Model computed from the differences at the entry points.

	Amplitude factor δ	Phase difference α
O_1	.006	0°30
K_1	.008	0°70
M_2	.012	0°70
S_2	.010	0°75

TABLE 4a

[Δg in $10 \times \text{nm. sec}^{-2}$]

LINE A *****	TIDAL MODEL *****			
	1	2	3	4
OOSTENDE	-2 167.1	-2 166.3	-2 165.8	-2 164.8
LOPPEM	-16 691.4	-16 694.1	-16 691.8	-16 692.8
ZWIJNAARDE	-37 559.0	-37 559.0	-37 557.2	-37 558.7
UCCLE	-24 093.1	-24 093.3	-24 093.7	-24 094.0
LOUVAIN-LA-NEUVE	-16 502.6	-16 503.8	-16 504.4	-16 504.5
CHAMPION	-74 469.3	-74 469.6	-74 470.1	-74 469.7
HUMAIN	-50 643.8	-50 645.4	-50 646.8	-50 646.5
BASTOGNE	31 071.2	31 070.4	31 070.1	31 070.3
WALFERDANGE				
TOTAL	-191 055.1	-191 061.1	-191 059.7	-191 060.7

TABLE 4b

 $(\Delta g \text{ in } 10 \times \text{nm. sec}^{-2})$

LINE B

TIDAL MODEL

	1	2	3	4
ZWANFVEN	-22 396.7	-22 396.6	-22 396.5	-22 396.3
LUMMEN	-77 632.7	-77 634.0	-77 635.7	-77 635.3
WANZE	-80 599.2	-80 599.6	-80 601.3	-80 601.4
HUMAIN	-40 340.1	-40 339.5	-40 339.5	-40 339.1
ST HUBERT	-8 951.7	-8 953.6	-8 952.8	-8 953.2
NEUFCHATEAU				
TOTAL	-229 920.4	-229 923.3	-229 925.8	-229 925.3

LINE C

TIDAL MODEL

	1	2	3	4
THIEULAIN	-6 440.4	-6 439.1	-6 438.9	-6 439.6
HOVES	-20 071.5	-20 072.1	-20 071.5	-20 072.5
LOUVAIN-LA-NEUVE	21 129.0	21 130.3	21 130.6	21 131.4
LINCENT	-15 217.1	-15 214.3	-15 211.7	-15 212.1
LIERS	-51 616.1	-51 615.2	-51 613.5	-51 613.6
KETTENIS				
TOTAL	-72 216.1	-72 210.4	-72 205.0	-72 206.4

APPENDIX

I, like to take this opportunity for rising again the problem of the Honkasalo correction.

Everyone does agree to correct absolute gravity measurements reduced using a tidal prediction including the Mo So term or constant tidal effect.

On the other hand the Working Group on Data Analysis in Tidal Research appointed by the International Commission for Earth Tides (IAG, section V) proposed at its first meeting at Bonn in march 1978 that the constant term Mo So should not be considered in synthesizing theoretical tides for tidal analysis. We should like to ask the opinion of International Gravity Commission on the following point: should we continue to include in gravity tides predictions a term that will be subtracted later on for the final reduction of absolute gravity measurements and that will generally disappear in relative measurements?

We have shown that in any case the precise tidal predictions should use the potential development that is the easiest way to take into account the perturbations of the static response of the Earth.

In this method the elimination of Mo So is quite natural. In the gravity tides calculated from the ephemeris positions of the Moon and the Sun, one can also easily subtract this term.

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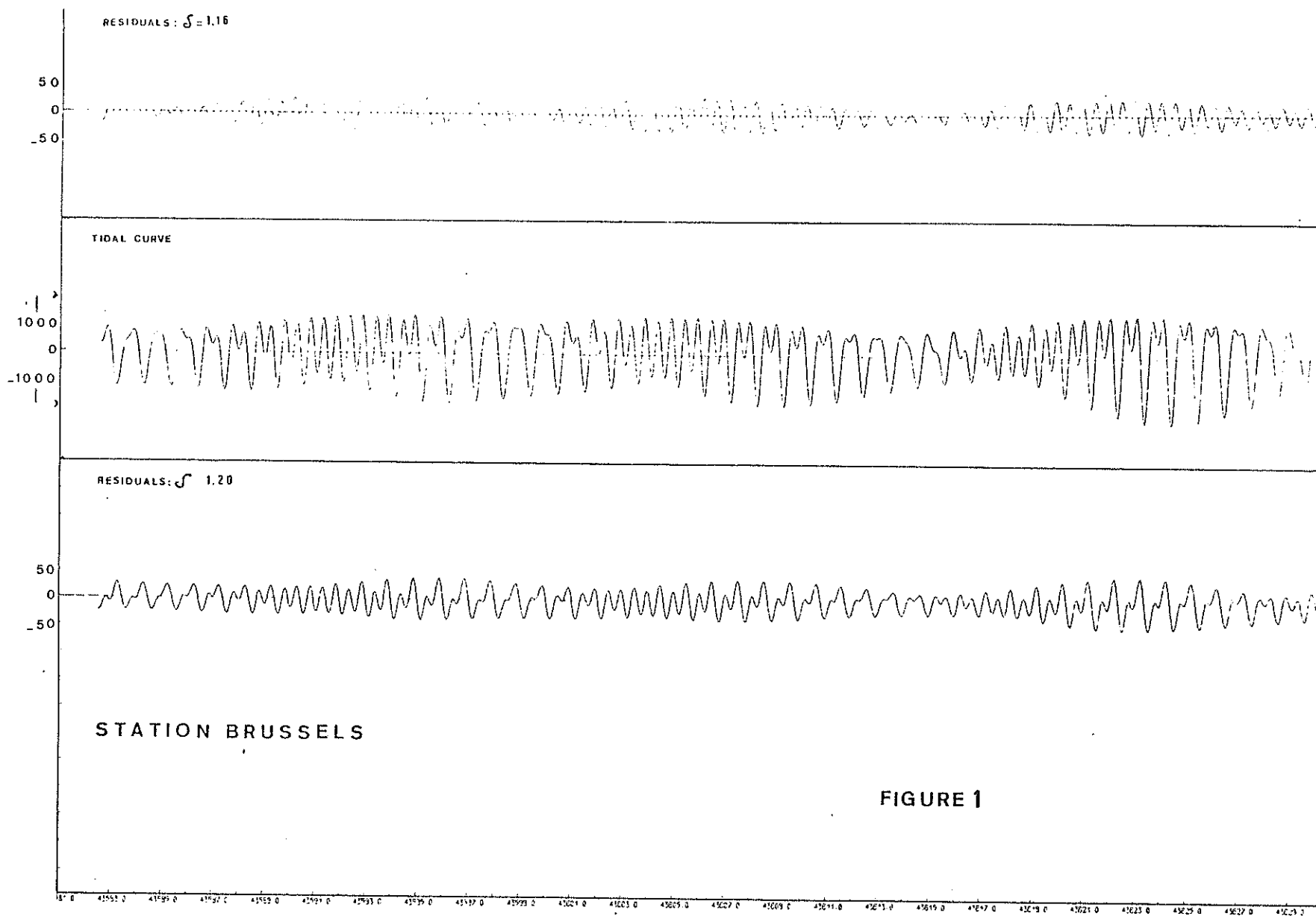


FIGURE 1

EPOQUE INITIALE 78 3 15 0

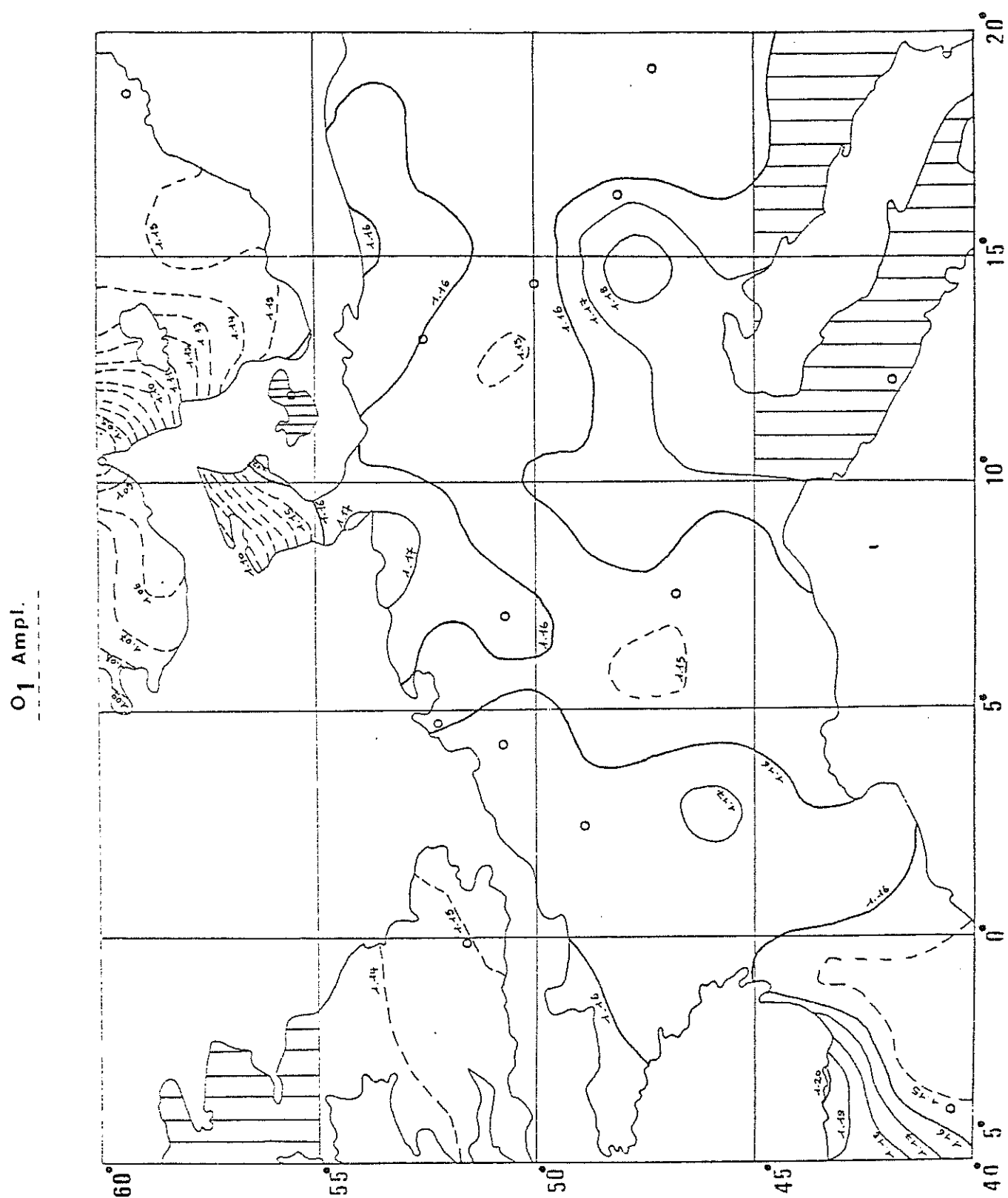


Fig. 2: O₁ amplitude factor

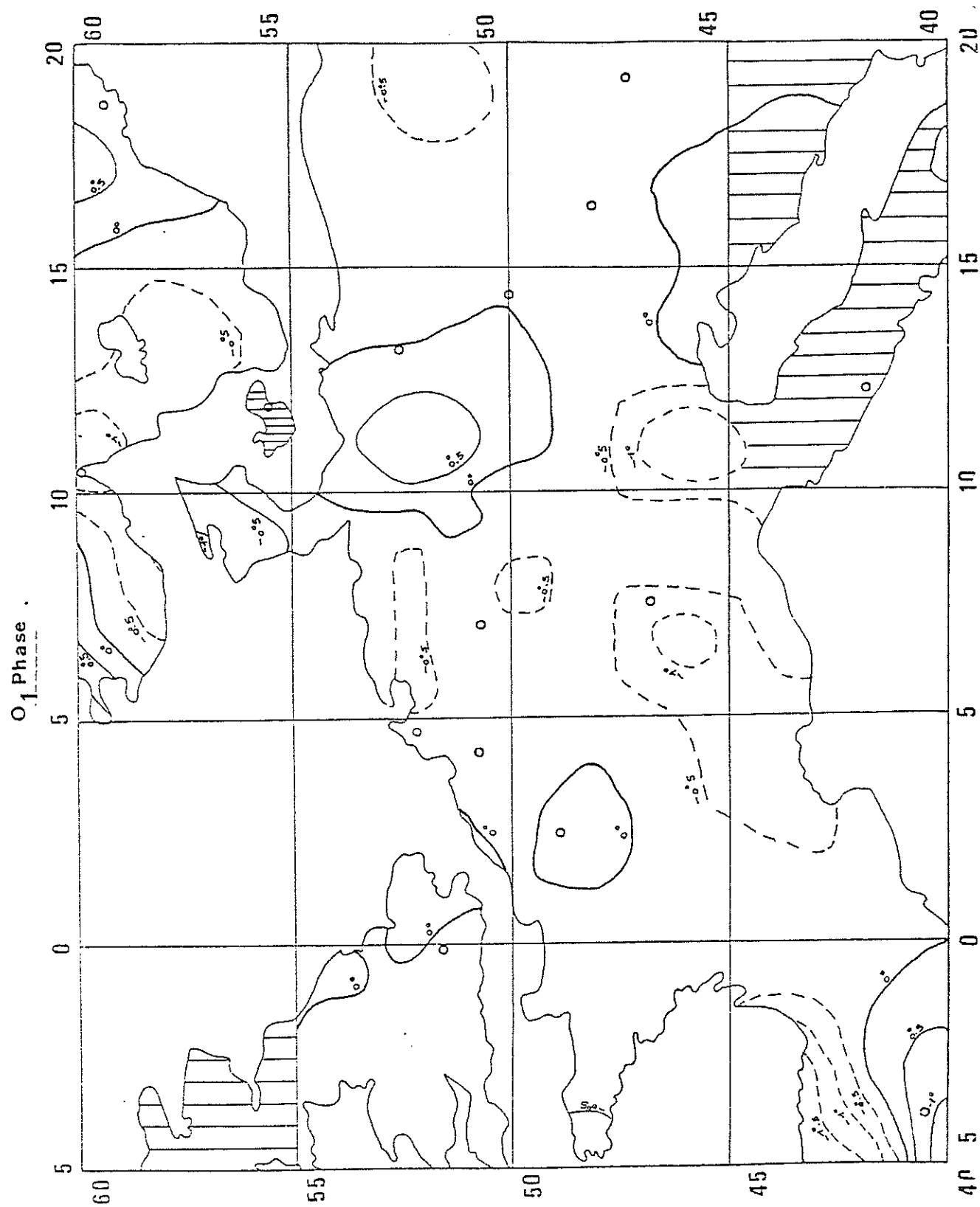


Fig. 3: O₁ phase difference

M₂ Ampl.

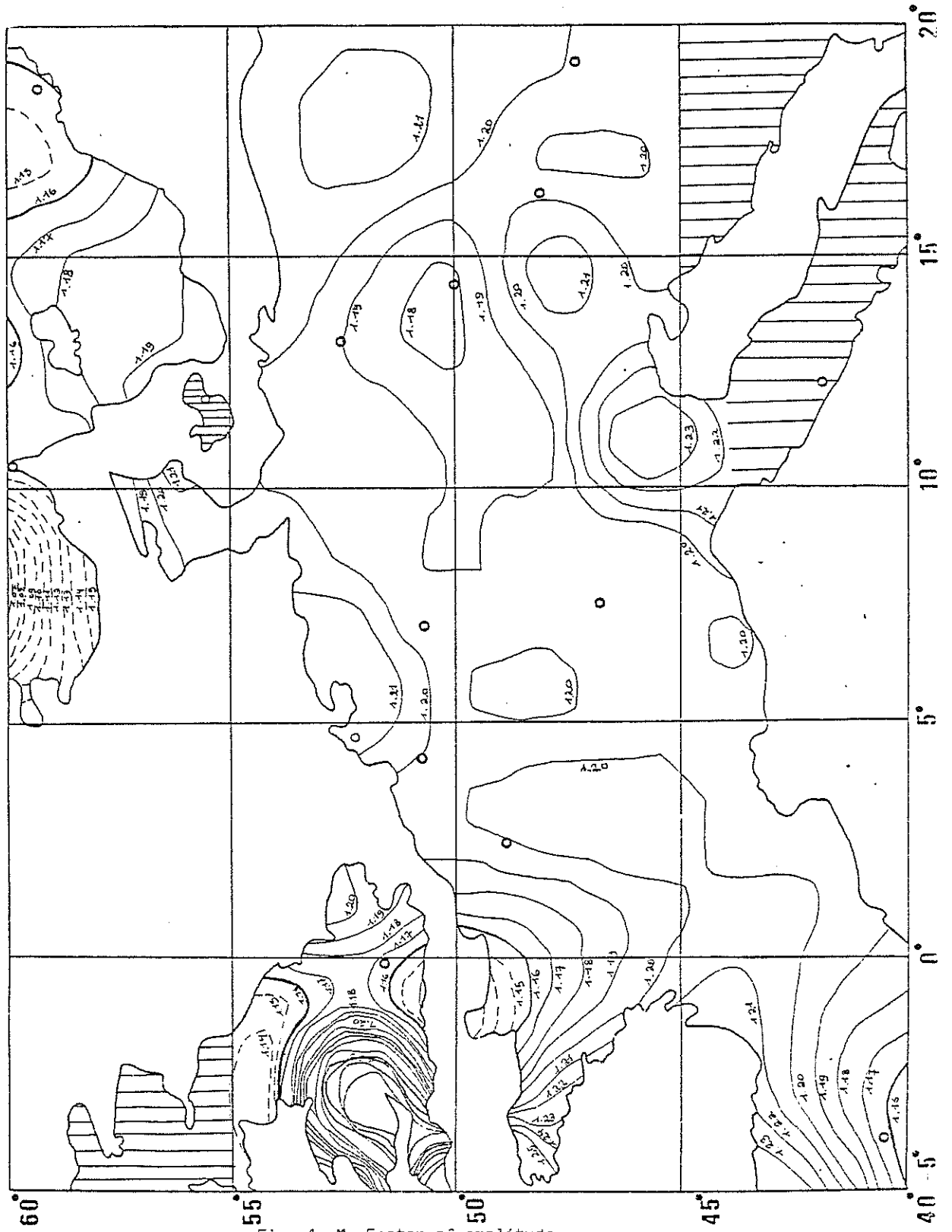


Fig. 4: M₂ Factor of amplitude

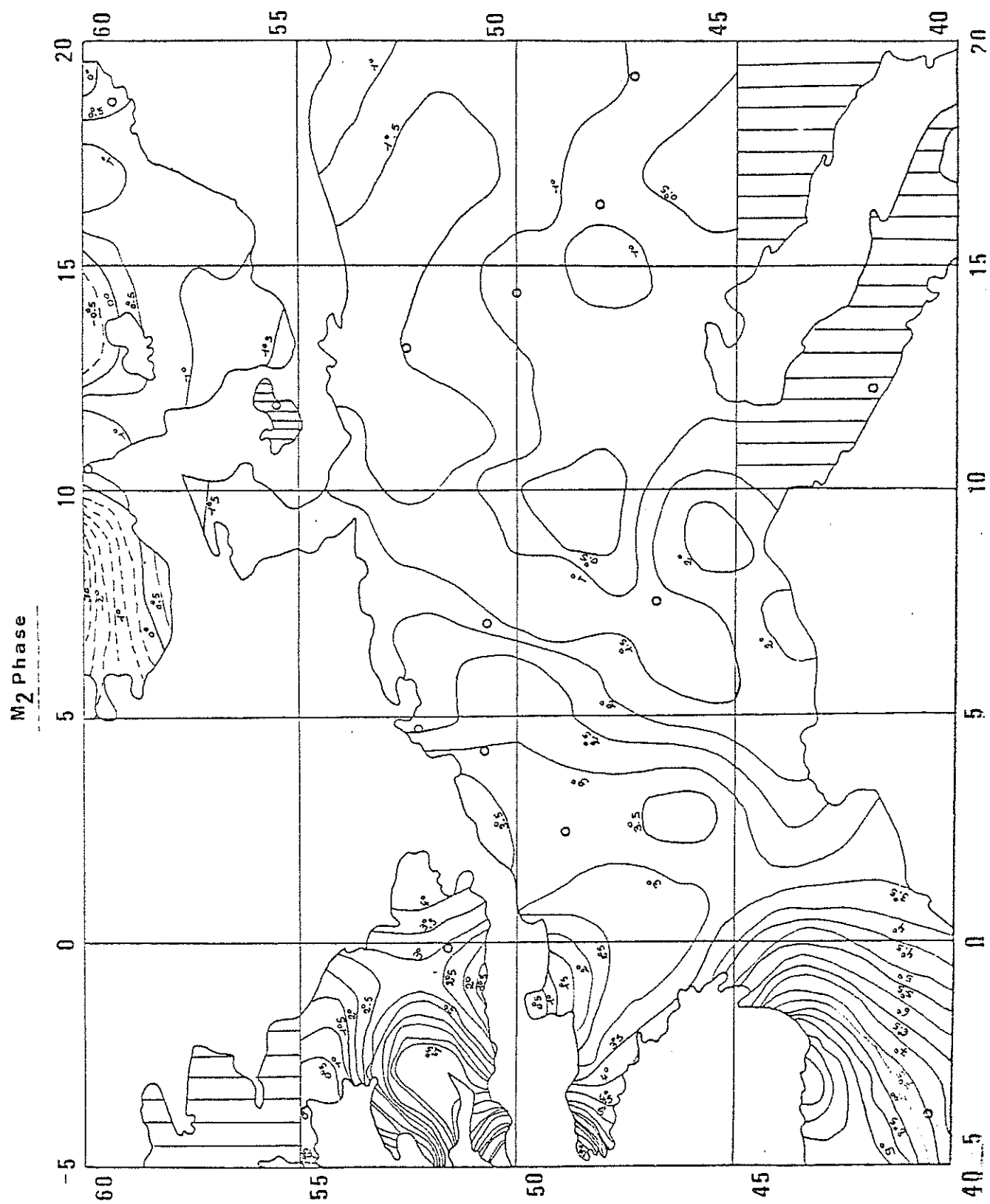


Fig. 5: M₂ Phase difference

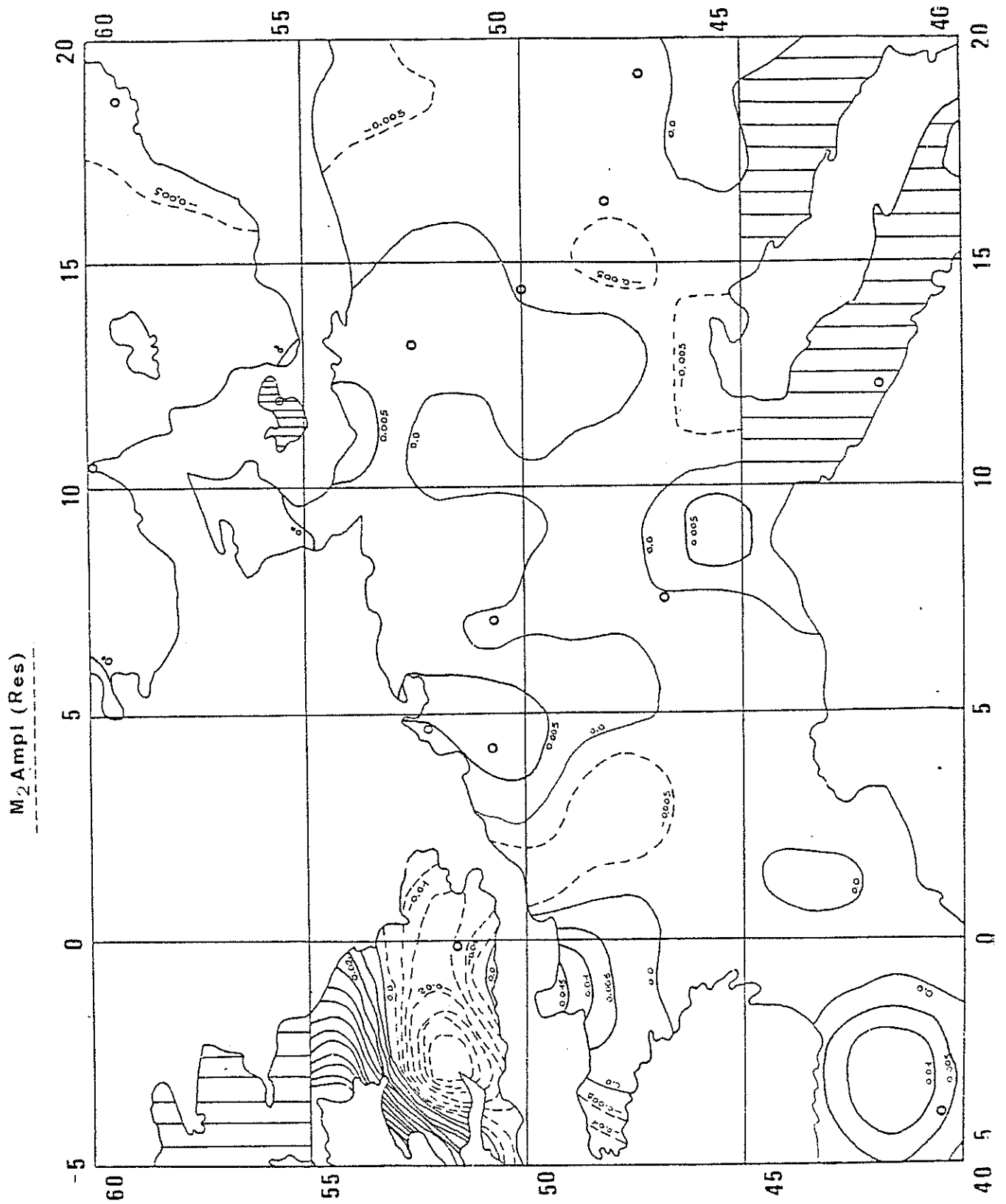


Fig. 8: M_2 residuals factor of amplitude

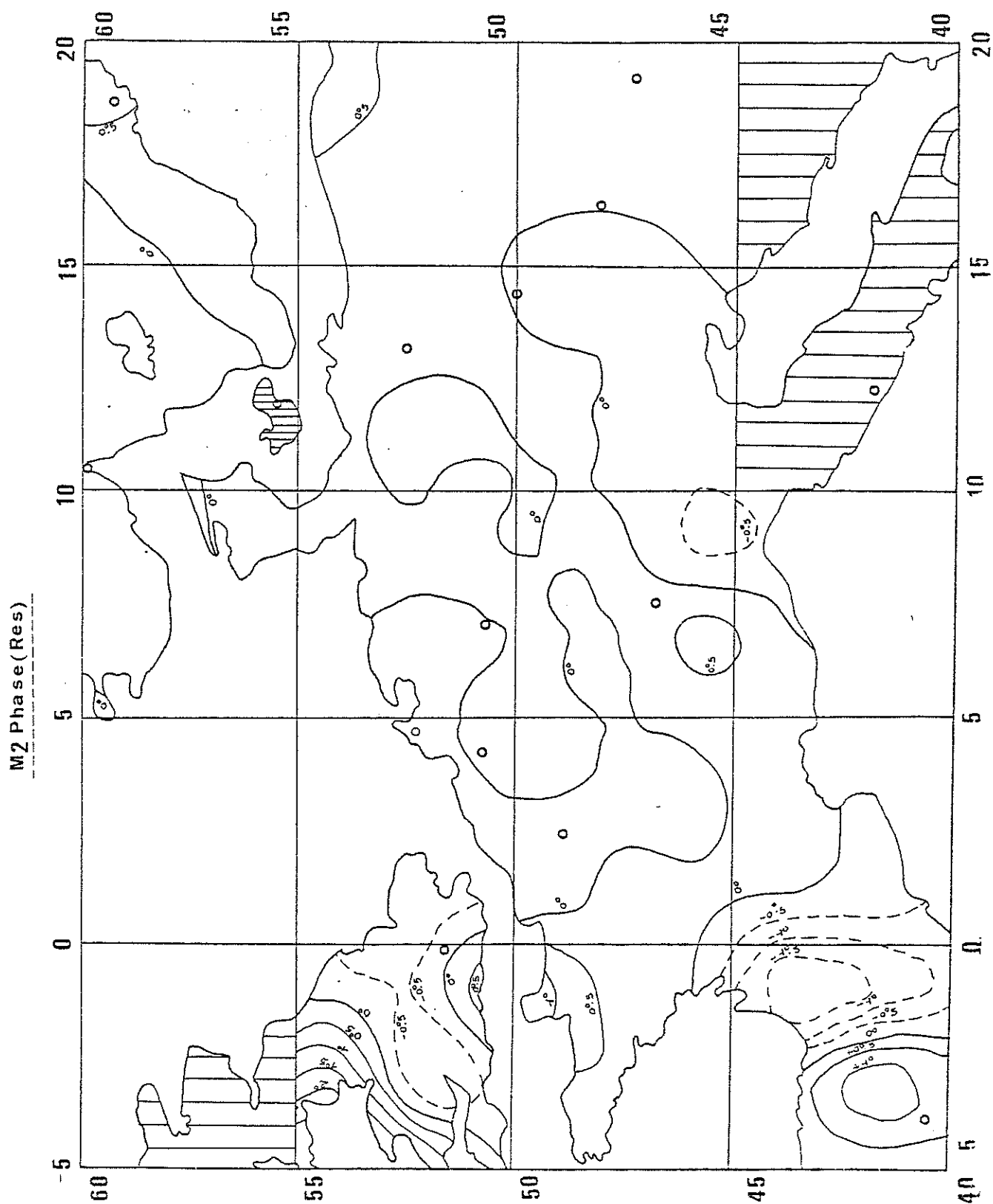
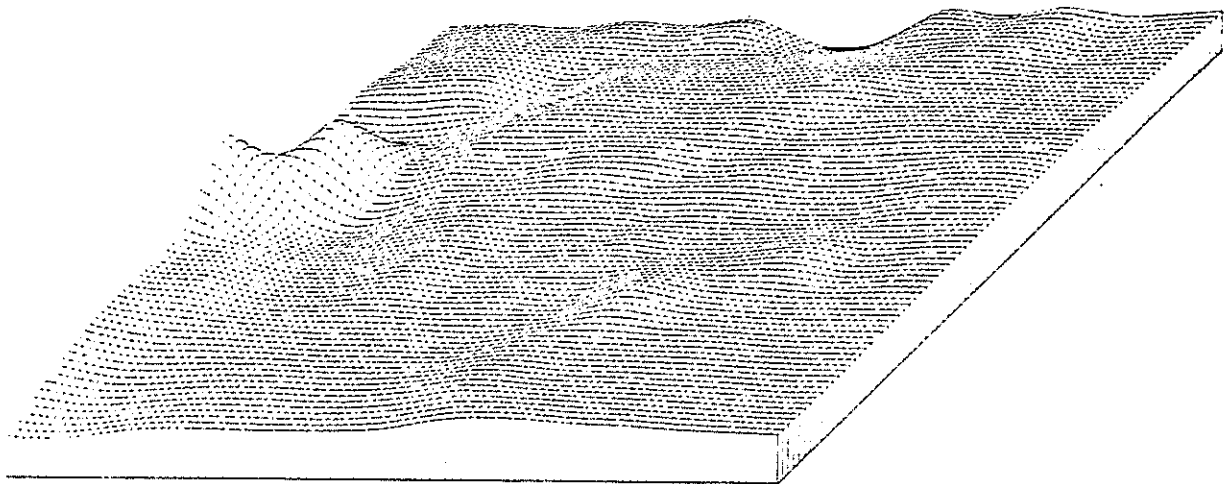
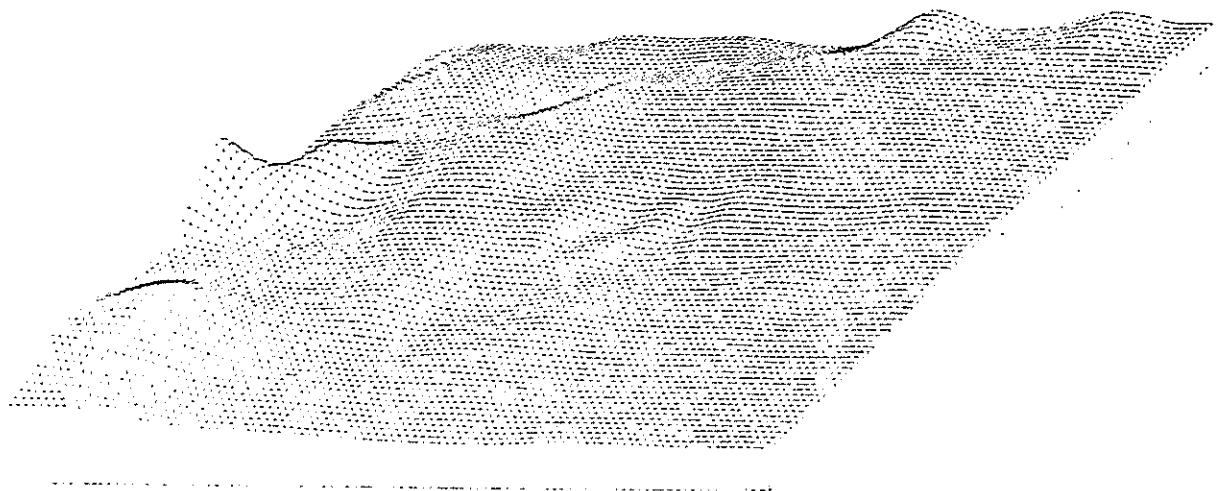


Fig. 7: M_2 residuals phase difference



amplitude m_2



phase m_2

Fig. 8: Tridimensional model

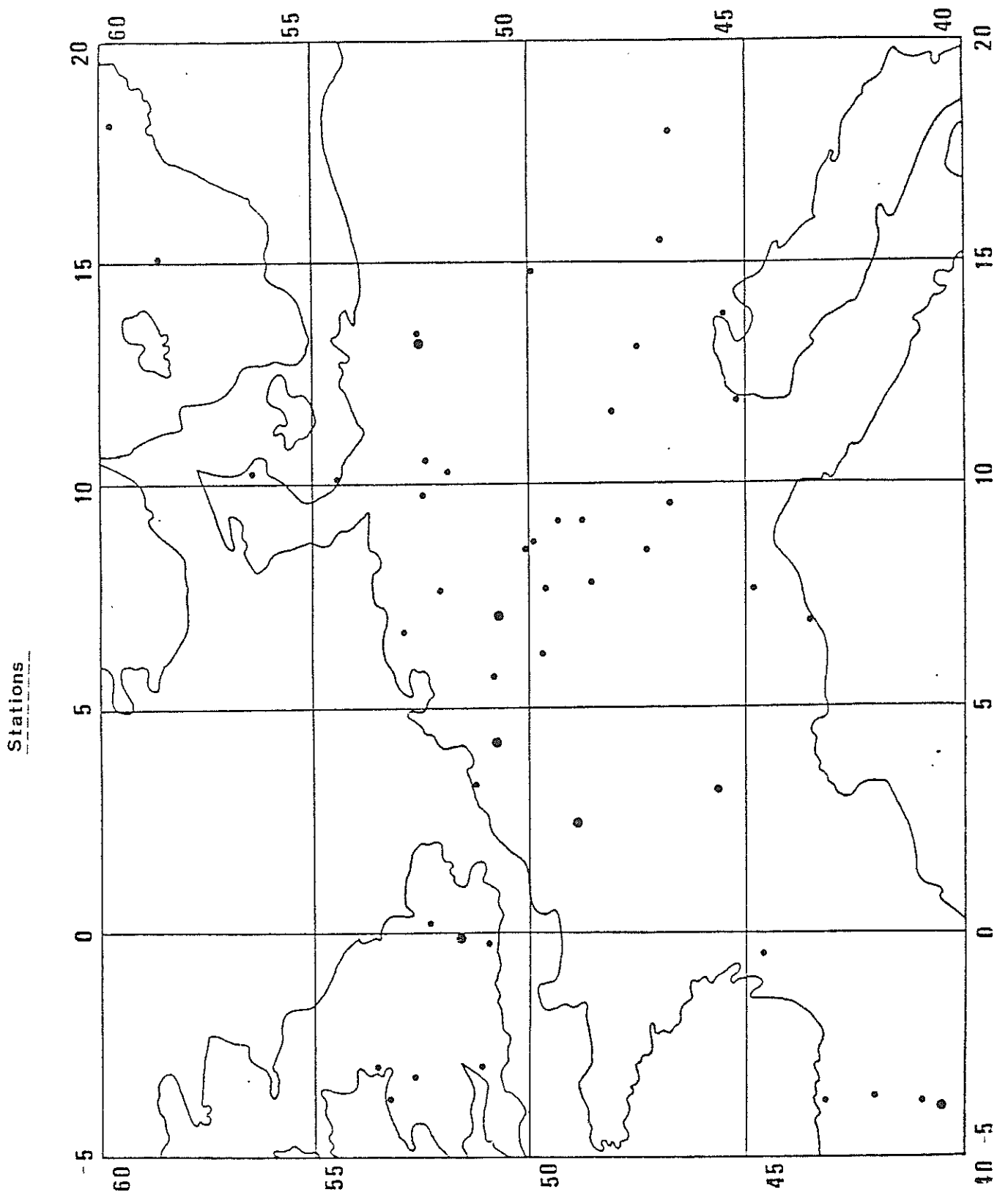


Fig. 9: Tidal stations

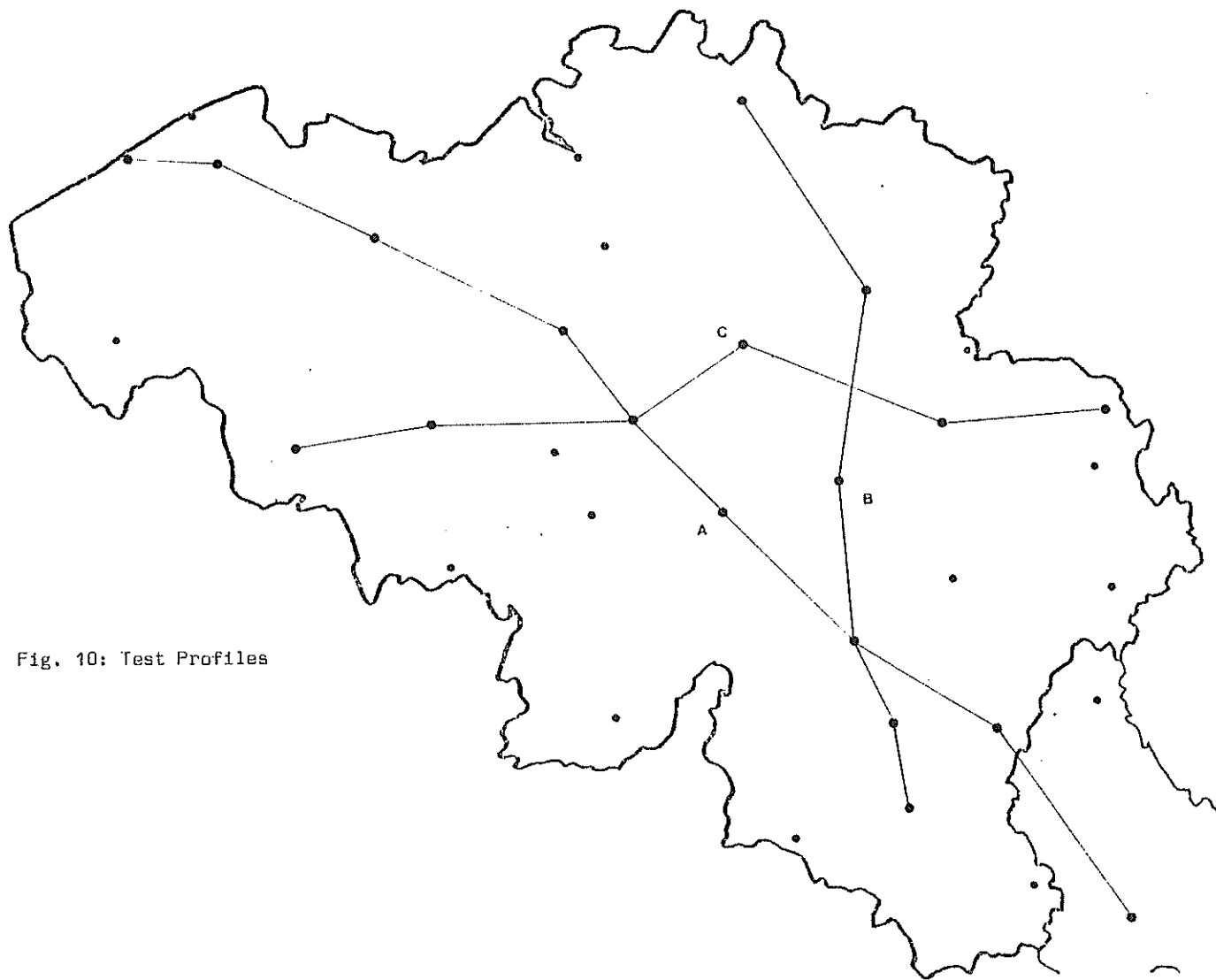


Fig. 10: Test Profiles

Eighth Meeting of the
INTERNATIONAL GRAVITY COMMISSION
Paris, 12 to 16 September 1978

- D -

SENSITIVITY ADJUSTEMENT AND LEVELLING OF
LACOSTE-ROMBERG GRAVIMETERS

by

Michel VAN RUYMBEKE*

Summary

A technique using the electronic output and a digital voltmeter during field measurements allows to work at constant sensitivity without depending upon level readings.

*Observatoire Royal de Belgique

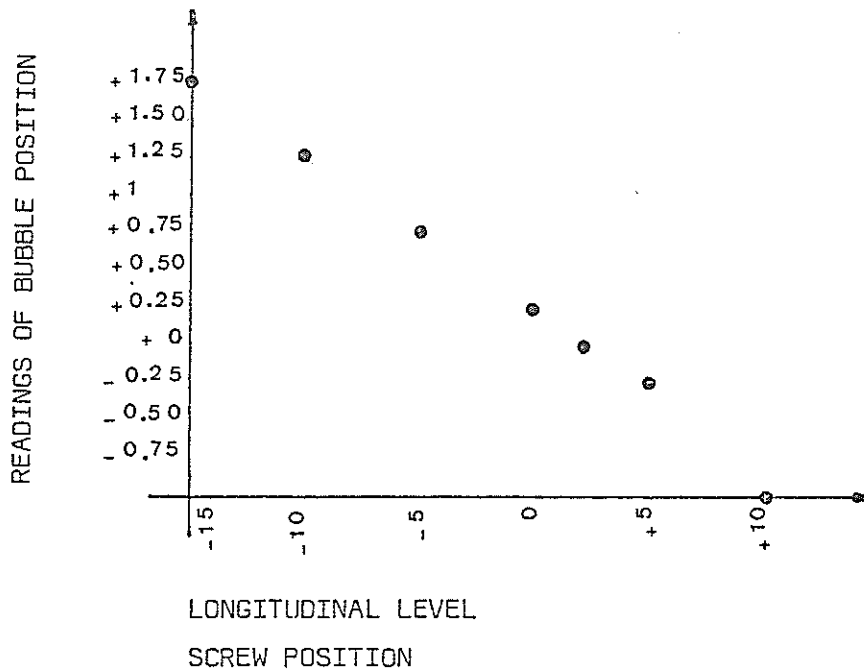


Fig.2: Variations of the bubble position with respect to the rotations of the base plate micrometric screw: 1 division of the micrometric screw is equivalent to 0,1 division of bubble level.

An electronic filter increases the signal to noise ratio.

An equivalent resolution of better than 1 microgal is achieved with the digital voltmeter (in quiet normal conditions).

Before starting for a survey operation values of α and β must be adopted. For what concerns the angle β , we zero the output signal when the beam position is on the reading line proposed by the maker.

One has to keep the signal as close as possible to zero during the following operation.

By slowly changing the longitudinal levelling, we determine the classical parabola which is a function of γ . [Melchior 1978 page 258] and we choose of course the summit of this parabola to define γ .

We have at its summit

$$\gamma = 0$$

$$\alpha = \pi/2 - \beta$$

For this value of the angle α , we estimate the sensitivity of the gravimeter. In our case a standard rotation of 20 units of the micrometer screw gives on the voltmeter a variation of 205 millivolts.

Our working scheme during the field measurements was to check, at every station that a same 20 units rotation of the dial was producing 205 ± 2 millivolts variation in the electronic output. When so, the gravimeter is obviously correctly set with the convenient α , β , γ values.

A difference with respect to this standard output of 205 millivolts indicates the necessity of correcting the longitudinal tilt of the base plate which can be done very accurately with the special micrometric screw.

To achieve such a result we have determined indeed the value of one base-plate screw division in terms of variation of sensitivity for the fixed values of (α, β) .

As an example for gravimeter LCR 336G: 1 division of base plate screw = 2% sensitivity variation or 1/10 bubble level division.

For the cross levelling we search the summit of the parabola. An adjustment within ± 0.2 division of the bubble insures less than 1 microgal difference between the measurement and the exact value of this summit.

With this technique of levelling we achieve a determination of the gravity with a 1 microgal resolution while avoiding any reference to the bubbles during field measurements.

APPENDIX I

This procedure allowed to point out very precisely the effect of diurnal temperature variations on the sensitivity through their influence on bubble positions.

As pointed out in [Ducarme & al, 1976] the bubbles do not only change their length for large temperature variations (3°C) but are also slightly drifting.

Figure 3 shows an example of thermic bubble drift related to temperature T for a constant sensitivity value.

APPENDIX II

Figure 4 shows the variations of the sensitivity as a function of the tilting of the longitudinal level. Obviously the working sensitivity corresponding to the maker proposed reading line 2.5 is at the limit of the instrumental stability.

Figure 5 shows the parabola of the longitudinal level as a function of the chosen reading line. The variations of sensitivity with tilt produce an unsymmetrical response of the instrument.

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Epoch	S MV/ μ gal	T° C°	LL Center displ. 1/10 DIV.	TL Center displacement 1/10 DIV.	LL Length variation 1 DIV.	TL Length variation 1 DIV.
7 8 0 4 2 5						
8h	1 . 0 6	10 . 5				
9h5 0	1 . 0 5	11				
1 1h	1 . 0 5	13				
1 2h5 0	1 . 0 7	14 . 5				
1 4h3 0	1 . 0 5	13				
1 5h5 0	1 . 0 6	17 . 5				
1 7h3 0	1 . 0 6	15				
7 8 0 4 2 8						
7h5 0	1 . 0 7	9				
9h5 0	1 . 0 6	12 . 5				
1 1h	1 . 0 6	12 . 5				
1 3h1 0	1 . 0 7	14 . 5				
1 5h2 0	1 . 0 7	13 . 5				
1 6h5 0	1 . 0 5	13				
1 9h1 0	1 . 0 8	8				

OPERATORS 780425 DUCARME 780428 VAN RUYMBEKE

FIGURE 3

S = Sensitivity of the gravimeter
T° = Air temperature near the gravimeter
LL = Longitudinal level
TL = Cross level
div = One division of the bubble level.

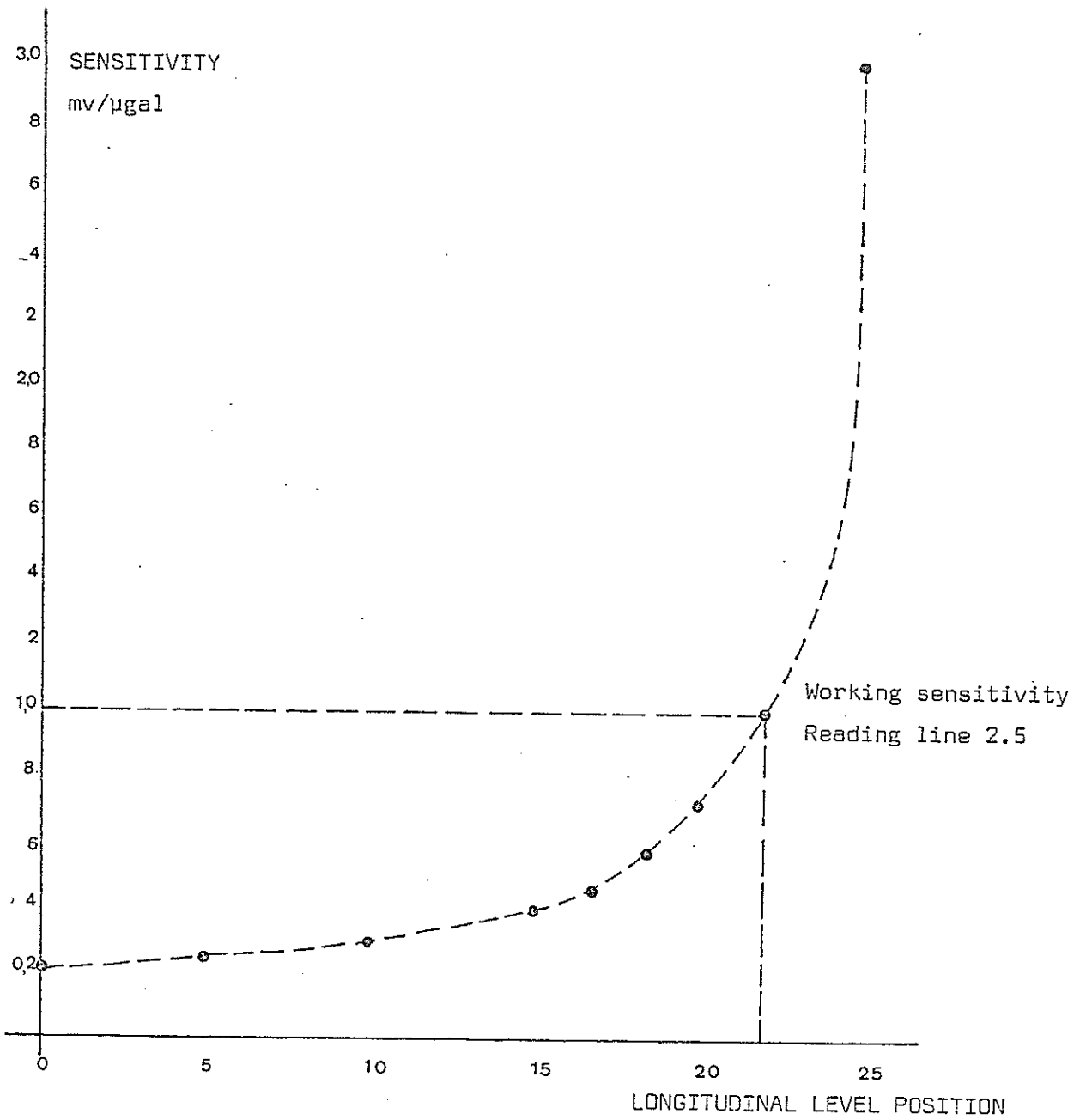


Fig. 4

ELECTRONIC
OUTPUT

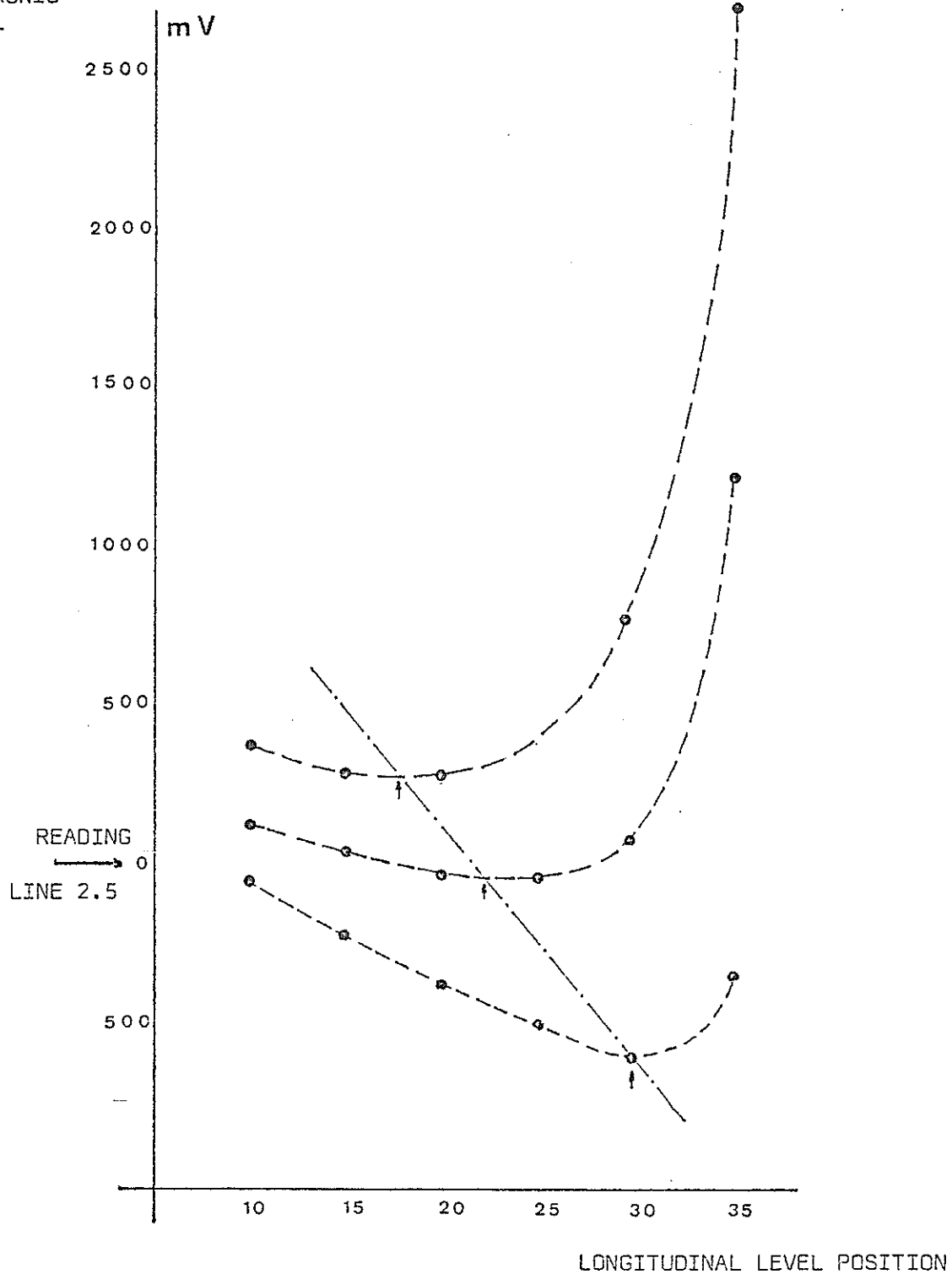


Fig. 5

- E -

INTERNATIONAL TIES BETWEEN FRANCE AND
THE EUROPEAN ADJACENT COUNTRIES

LIAISONS GRAVIMETRIQUES ENTRE LA FRANCE
ET LES PAYS EUROPEENS LIMITROPHES

par

M. OGIER

Avril 1980

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RESUME

Ce travail résume les liaisons réalisées en 1978-79 entre la France et les pays européens frontaliers afin d'améliorer la connection des réseau gravimétriques européens, de définir la formule de passage Carte Gravimétrique de la France IGSN 71 et d'essayer de mieux préciser la valeur de la pesanteur à l'Observatoire de Toulouse.

Les mesures ont été effectuées tant sur des stations IGSN 71 qu'en des stations absolues afin d'évaluer la précision de la table d'étalonnage du gravimètre utilisée par rapport au système IGSN 71 et par rapport aux mesures absolues.

La nouvelle valeur de la pesanteur obtenue pour Toulouse est assurée avec une précision de 0,03 mGal compte-tenu de l'imprécision de l'étalonnage. Cette valeur est la suivante :

980 427,74 mGal, valeur brute L & R G 225 identique à la
valeur IGSN 71 ;
980 427,48 mGal, valeur calée sur les stations absolues
italiennes.

SUMMARY

We present the ties undertaken in 1978 and 1979 between France and the european adjacent countries in order to define with accuracy the connection between the French and the European gravity networks. An attempt was made to give a more accurate relative value of the gravity at Toulouse Observatory wich was with Sevres A the Basic Station of the French gravity system.

The gravity has been measured in both IGSN 71 and absolute stations in order to investigate the accuracy of the Scale Table of the used gravity-meter.

A new gravity value has been computed for Toulouse but with an accuracy no more greeter than 0.03 mGal because of the errors in the calibration measurements. The new value is as following :

980 427.74 mGal, raw Lacoste & Romberg value, exactly
the same than the IGSN 71 one ;

980 427.48 mGal, wich is the adjusted value in regard of
the italian absolute measurements.

INTRODUCTION

Le système gravimétrique français est basé sur deux stations fondamentales Paris A et Toulouse Observatoire. La première de ces stations a été définie par de nombreuses liaisons relatives avec POTZDAM et d'autres stations pendulaires européennes, alors que la seconde a toujours été établie par des liaisons avec Paris en utilisant des appareils étalonnés sur l'E.C.L. Les réseaux de bases établis sur ces deux stations fondamentales bien qu'ayant permis la réalisation d'une couverture gravimétrique détaillée de la France (C.G.F.), ne sont plus compatibles avec la précision des gravimètres modernes et doivent être complètement révisés. Les campagnes de liaisons effectuées de 1977 à 1979 étaient destinées à mieux connaître la précision de l'actuel réseau français, à établir sa connection avec les réseaux étrangers, à calculer la formule de conversion CGF - IGSN et à définir les modalités de restructuration. Les travaux se sont déroulés de la manière suivante :

- réactualisation de la Base Gravimétrique Paris-Toulouse-Pic du Midi de Bigorre (M. OGIER 1977) ;
- recompensation à partir de ces données du réseau de premier ordre français (J.J. LEVALLOIS 1977, inédit) ;
- liaisons France-Europe et Turin-Toulouse (M. OGIER 1978, inédit) ;
- liaisons CGF - IGSN 71 (M. OGIER 1979 inédit).

La méthode de travail utilisée dans toutes ces campagnes est celle des boucles se refermant sur elles-mêmes à des intervalles de temps variables et définis en fonction de la dérive diurne des appareils utilisés. Cette méthode permet de répartir l'écart à la fermeture au prorata du nombre d'heure de trajet entre les différentes stations. Les corrections

luni-solaires ont été calculées selon la méthode de CARTWRIGHT et TAYLER (1973). Les corrections de HONKASALO, de pression et de température n'ont pas été effectuées. Dans tous les cas la dérive nocturne a été corrigée par une double mesure soir/matin en deux stations identiques espacées de plusieurs kilomètres.

1. FERMETURES

L'étude comportait deux grandes boucles principales sur lesquelles se greffaient de nombreuses boucles annexes qui permettaient en tout moment de contrôler la dérive diurne du gravimètre. L'itinéraire général fut le suivant :

1ère boucle : ORLEANS, TARARE (Lyon), ARLES, TOULOUSE, SOUILLAC, ORLEANS (4 jours).

2ème boucle : ORLEANS, SEVRES, BRUXELLES, WIESBADEN, KARLSRUHE, STRASBOURG, STUTTGART, ALTKIRCH, ZURICH, GENEVE, TURIN, ARLES, TOULOUSE, ORLEANS (10 jours).

L'écart à la fermeture a été de 11 μGal sur la première boucle et de 10 μGal sur la seconde. L'étude des écarts aux fermetures des boucles secondaires (tableau 1) montre que la dérive diurne moyenne est de 9 μGal tantôt positive, tantôt négative. L'excellente fermeture d'ensemble est donc dûe finalement à l'absence de dérive systématique et à une compensation statistique des faibles dérives de transport pour l'appareil utilisé (Lacoste & Romberg G 225).

Boucle	Durée des trajets (en heures)	Ecart à la fermeture (en μGal)
ARLES	13	- 9
PARIS	3	- 3
CAMBRAI	5	- 2
BRUXELLES	6	- 3
BRUXELLES	1	+ 5
KARLSRUHE	1	+ 6
ALTKIRSCH	5	+ 1
BONNEVILLE	9	+ 10
BONNEVILLE	7	+ 9
TURIN	2	- 6
TURIN	12,5	+ 26
SQUILLAC	10	+ 26
SQUILLAC	3,5	- 6
		Ecart moyen 9 μGal

TABLEAU 1 : écarts aux fermetures (dérive diurne)

2. ETALONNAGE DE L'APPAREIL

La comparaison des valeurs Lacoste et Romberg et IGSN 71 pour 5 stations européennes et 12 stations françaises (tableau 2) permet de mettre en évidence un écart significatif entre les deux types de réseau. Les stations européennes, pour des raisons inconnues, montrent des écarts importants six fois plus élevés en moyenne que les stations françaises. L'écart moyen est de 0,113 mGal (ou 0,082 mGal si l'on élimine Genève J dont l'environnement a probablement été modifié) pour les 5 stations européennes contre seulement 0,017 mGal pour les 12 stations françaises. L'étude de la répartition des écarts en fonction de la valeur de g ne permet pas de mettre en évidence aucune erreur systématique du coefficient d'étalonnage.

TABLEAU 2 : comparaison valeurs Lacoste et Romberg et IGSN 71.

Référence IGSN 71	Stations	Valeurs L.R. G 225	Valeurs IGSN 71 en mGal**	Ecart en mGal
<u>STATIONS EUROPEENNES (1978)</u>				
180 82A	SEVRES A	Valeur de référence	980 925,97	-
216 04A	BRUXELLES A	981 117,186	981 117,32	- 0,134
180 98C	KARLSRUHE	980 942,116	980 942,00	+ 0,116
180 89J	STUTTGART	980 832,820	980 832,87	- 0,050
180 78Q	ZURICH	980 704,739	980 704,71	+ 0,029
	(GEBENSDORF)		Ecart moyen = 0,082	
180 66J	GENEVE	980 574,675 ?	980 574,44	0,235 ?
			Ecart moyen = 0,113	
<u>STATIONS FRANCAISES (1977-1979)</u>				
180 41J	MONTAUBAN	980 491,527	980 491,54	- 0,013
180 40J	AGEN	980 519,360	980 519,41	- 0,050
180 40P	BERGERAC	980 568,511	980 568,55	- 0,039
180 70J	CHATEAURENAULT	980 818,599	980 818,59	+ 0,009
180 60P	CHATELLERAULT	980 767,132	980 767,13	0,002
180 81J	CHARTRES	980 871,575	980 871,60	- 0,025
180 50K	POITIERS K	980 726,880	980 726,83	+ 0,050
180 30P	ST GAUDENS	980 328,82 (G 125)	980 328,82	0,000
180 82B	PARIS A (1968)	980 928,650	980 928,65	0,000
	(1978)	980 928,567		
180 31A	TOULOUSE	980 427,74	980 427,74	0,000
180 31X	CAPENS	980 388,01	980 388,03	- 0,020
180 82K	LE BOURGET	980 935,326 (G 125)	980 935,33	- 0,004
			Ecart moyen = 0,017	

** Les valeurs IGSN 71 sont celles publiées par C. MORELLI et al. (1974).

Les valeurs françaises du réseau IGSN 71 ayant été mesurées à l'aide de quatre gravimètres Lacoste et Romberg opérant simultanément, on s'aperçoit immédiatement que la valeur adoptée n'est autre que la moyenne arithmétique des quatre résultats en valeurs Lacoste et Romberg.

Ces résultats aussi satisfaisants qu'ils apparaissent et s'ils répondent largement aux besoins des géodésiens et des géologues, ne sont néanmoins pas suffisants pour les métrologistes qui recherchent la valeur de la pesanteur avec une précision de quelques 10^{-7} m.s⁻². Pour ces derniers, il est nécessaire de calibrer les gravimètres non plus sur le réseau IGSN 71, mais sur une série de stations absolues. Nous avons réalisé cet étalonnage entre les stations de SEVRES, BRUXELLES, WIESBADEN, et TURIN où L. CANNIZZO, G. CERUTTI et I. MARSON (1978) ont effectué une série de mesures absolues en 1976 et 1977.

Les coefficients d'étalonnage obtenus (tableau 3) montrent d'une part que l'échelle d'étalonnage du gravimètre Lacoste et Romberg utilisé est systématiquement sous estimée de 5 à 8.10^{-4} , et d'autre part que le décalage n'est pas constant. Si les étalonnages sur SEVRES-BRUXELLES et WIESBADEN-TURIN sont assez proches l'un de l'autre (8.10^{-5}), BRUXELLES-WIESBADEN diverge nettement (3.10^{-4}). Une telle divergence n'est pas inhabituelle, et peut être facilement expliquée par une dérive diurne un peu plus importante de l'appareil au cours de cette liaison (2 centièmes de milligal suffiraient). Pour atténuer l'influence de la dérive qui devient particulièrement importante sur les bases d'étalonnage de faible différence de gravité, nous utilisons un coefficient de pondération dont le facteur est incrémenté d'une unité par 100 milliGal.

TABLEAU 3 : étalonnage Lacoste et Romberg G 225 sur stations absolues.

Stations	Valeurs L.R. - G 225	G absolu (corr. Honkasalo soustraite)
<u>SEVRES-BRUXELLES (2 journées)</u>		
SEVRES A		980 925,970
SEVRES Extérieur	+ 0,263	
BRUXELLES A	+ 190,953	981 117,272
	$\Delta g_r = 191,216$	$\Delta g_a = 191,302$
	$K_1 = \frac{191,302}{191,216} = 1,000\ 45$	
<u>BRUXELLES-WIESBADEN (1 journée)</u>		
BRUXELLES A		981 117,272
KETTENIS	- 70,431	
WIESBADEN	- 9,931	981 036,847
	$\Delta g_r = - 80,362$	$\Delta g_a = 80,425$
	$K_2 = \frac{80,425}{80,362} = 1,000\ 78$	
<u>WIESBADEN-TURIN (5 journées)</u>		
WIESBADEN		981 036,847
KARLSRUHE	- 95,366	
TURIN	- 406,979	980 534,237
	$\Delta g_r = - 502,345$	$\Delta g_a = 502,610$
	$K_3 = \frac{502,610}{502,345} = 1,000\ 53$	
$K_m = \frac{2 K_1 + K_2 + 5 K_3}{8} = 1,000\ 54$		

TABLEAU 4 : établissement de la formule de conversion CGF-IGSN.

Stations	g_{CGF} (mGal)	g_{IGSN} (mGal)	$g_{calculé}$ (mGal)	Différence (mGal)
SEVRES A	980 940,40	980 925,97	980 925,96	0,01
PARIS A	980 943,00	980 928,56	980 928,57	- 0,01
TOULOUSE P11.	980 442,80	980 427,74	980 427,76	- 0,02
LE BOURGET K	980 949,73	980 935,33	980 935,30	0,03
ST GAUDENS P	980 343,98	980 328,82	980 328,82	0,00
MONTAUBAN J	980 506,50	980 491,54	980 491,54	0,00
AGEN J	980 534,30	980 519,41	980 519,37	0,04
BERGERAC P	980 583,39	980 568,55	980 568,52	0,03
CHATEAURENAULT J	980 833,17	980 818,59	980 818,60	- 0,01
CHATELLERAULT P	980 781,77	980 767,13	980 767,14	- 0,01
CHARTRES J	980 886,09	980 871,60	980 871,59	0,01
POITIERS K	980 741,57	980 726,83	980 726,89	- 0,06
CAPENS X	980 403,11	980 388,03	980 388,02	0,01
				Ecart moyen 0,018
$g_{IGSN} = g_{CGF} + 0,001205688 \times g_{CGF} - 1197,15$				

3. ETABLISSEMENT DE LA FORMULE DE CONVERSION CGF-IGSN 71

Cette formule a été établie par la remesure et le calcul dans le système de la Carte Gravimétrique de la France de 13 stations IGSN 71 françaises encore accessibles (tableau 4). Le calcul des coefficients pour g a été effectué à l'ordinateur afin de pouvoir obtenir une précision suffisante. Les coefficients obtenus sont les suivants :

$$\text{ALPHA} = 0,001\ 205\ 688$$

$$\text{BEFOND} = - 1197,15$$

ce qui donne la formule générale suivante :

$$g_{\text{IGSN}} = g_{\text{CGF}} + 0,001\ 205\ 688 \times g_{\text{CGF}} - 1197,15$$

Cette formule permet d'effectuer les conversions avec une précision d'environ 0,02 mGal. Les corrections à apporter seront donc pour la France comprises entre - 14,20 mGal (Dunkerque) et - 16,01 mGal (Pic du Midi de Bigorre).

4. LIAISONS INTERNATIONALES

4.1. Belgique

Nous avons relié la Belgique à la France d'une part, et à l'Allemagne d'autre part. Les bases utilisées sont les suivantes :

SEVRES : station A pilier du laboratoire de A. SAKUMA, pièce n° 1,
(F) appareil posé directement sur la plaque du pilier.

SEVRES 6 : station CANNIZZO-CERUTTI Pilier.

SEVRES Extérieur : station située dans la cours du BIPM, à côté
(F) du chenil.

ARRAS : parvis de l'église St AGNES (cf. schéma).
(F)

CAMBRAI : place de l'église St GERY (cf. schéma).
(F)

BRUXELLES A : pilier de l'Observatoire de UCCLE. Station IGSN
(B) 216-04A. Appareil posé sur le pilier.

BRUXELLES 6 : station extérieure de l'Observatoire d'UCCLE, appareil
(B) sur le sol.

KETTENIS : porche de l'église. Station de premier ordre du nouveau
(B) réseau gravimétrique belge. Appareil posé sur le sol.

WIESBADEN : pilier de la salle K 2 au sous-sol du Hessisches Landes-
(D) vermessungsamt. Appareil posé directement sur le pi-
lier. (station CANNIZZO, CERUTTI).

Les résultats sont résumés dans le tableau n° 5.

TABLEAU 5 : liaisons France-Belgique-Allemagne.

Stations	Δg LR - G 225	Δg corrigé (x km - 0.00054)	g
SEVRES 6			980 925,89
SEVRES A	+ 0,077	+ 0,077	980 925,97 ^{IGSN}
SEVRES extérieur	+ 0,263	+ 0,263	980 926,23 ¹⁸⁵⁰
ARRAS	+ 127,070	+ 127,139	981 053,37
CAMBRAI	- 3,821	- 3,823	981 049,55
BRUXELLES A	+ 67,704	+ 67,741	981 117,29
BRUXELLES 6	- 0,743	- 0,743	981 116,55
KETTENIS	- 69,688	- 69,726	981 046,82
WIESBADEN	- 9,931	- 9,936	981 036,88

4.2. Allemagne fédérale

Outre la liaison avec la Belgique dont nous avons déjà parlé, nous avons relié l'Allemagne avec la France et la Suisse. Les bases utilisées sont les suivantes :

WIESBADEN cf. § 3.1.

KARLSRUHE : n° 16, pilier de la cave séismologie de l'Université de
(D) Karlsruhe. Station réseau premier ordre allemand
(DSGN). Appareil directement posé sur le pilier.

KARLSRUHE : IGSN station 180-98 C. Appareil sur le sol.
(D)

SAVERNE : gare cf. schéma.
(F)

STUTTGART : base IGSN 180-89J. Appareil sur le sol.
(D)

ENSISHEIM : église. cf. schéma.
(F)

ALTKIRCH : cimetière. cf. schéma.

(F)

ZURICH-GEBENS DORF : base IGSN n° 180-78Q. Appareil sur le sol.

(CH)

Les résultats sont résumés dans le tableau 6.

TABLEAU 6 : liaisons Allemagne-France-Suisse.

Stations	Δg LR - G 225	Δg corrigé	g
WIESBADEN			981 036,88
KARLSRUHE DSGN	- 95,366	- 95,417	980 941,46
KARLSRUHE IGSN	+ 0,665	+ 0,665	980 942,13
KARLSRUHE DSGN	- 0,665	- 0,665	980 941,46
SAVERNE	- 9,577	- 9,582	980 931,88
STUTTGART	- 99,061	- 99,114	980 832,77
ENSISHEIM	- 35,225	- 35,244	980 797,52
ZURICH	+ 53,698	+ 53,727	980 851,25
ALTKIRCH	- 73,193	- 73,233	980 776,01

4.3. Suisse

Nous avons relié deux stations helvétiques (Zurich-Gehensdorf et Genève) du réseau IGSN au réseau français. La première liaison a donné d'excellents résultats (cf. tableau 6), mais par contre le seconde est beaucoup plus douteuse car l'environnement de la station de Genève-Cointrin (180-66J) a été récemment modifié.

4.4. Italie

Les liaisons France-Italie ont été menées en deux phases en 1978 et 1979. Nous avons utilisé les stations suivantes :

BELLEGARDE : Cimetière. Cf. schéma.

(F)

BONNEVILLE : gare. Station récemment détruite.

(F)

CHAMONIX : poste de péage du tunnel du Mont Blanc, escalier du

(F) bureau de change (cf. schéma).

TURIN : istituto di Metrologia "G. COLONETTI". Pilier de la salle

(I) E 9 au sous-sol. Appareil sur le pilier.

PINO TORINESE : Osservatorio di Pino Torinese. Ancienne coupole

(I) astronomique. Appareil sur le sol.

LE BOURGET DU LAC : parvis de l'église (cf. schéma).

(F)

ARLES-FOURQUES B : angle du monument aux morts (cf. schéma).

(F)

NICE : église de St Isidore (Banlieue Ouest de Nice). Cf schéma.

(F)

VINTIMIGLIA : douane française de l'autoroute A 8.

(I)

Les résultats sont rassemblés dans le tableau 7.

TABLEAU 7 : liaisons France-Italie.

Stations	Δg LR - G 225	Δg corrigé	g
ALTKIRCH			980 778,01
BELLEGARDE	- 207,967	- 208,079	980 569,93
BONNEVILLE	- 53,864	- 53,893	980 516,04
MONT BLANC	- 245,391	- 245,524	980 270,516
TURIN	+ 263,602	+ 263,744	980 534,26
PINO TORINESE	- 106,007	- 106,064	980 428,20
LE BOURGET	+ 99,030	+ 99,083	980 527,28
TURIN	+ 6,977	+ 6,981	980 534,26
FOURQUES B	- 27,774	- 27,789	980 506,47
NICE	- 14,804	- 14,812	980 491,66
VINTIMIGLIA	+ 37,503	+ 37,523	980 529,18

4.5. Espagne

Nous n'avons pas réellement effectué une liaison France-Espagne, mais implanté une station frontalière sur l'autoroute A 9 au Col du Perthus. La station a été reliée aux bases existantes de CARCASSONNE, ST MARTIN DE CRAUX et ARLES B, cette dernière étant directement reliée à TURIN.

Les résultats sont présentés tableau 8.

TABLEAU 8 : liaisons France-Espagne.

Stations	Δg LR - G 225	Δg corrigé	g
TURIN			980 534,26
ARLES-FOURQUES B	- 27,774	- 27,789	980 506,47
LE PERTHUS	- 177,693	- 177,789	980 328,68
CARCASSONNE	+ 61,018	+ 61,051	980 389,73

5. VALEUR DE LA PESANTEUR A TOULOUSE

Nous avons dans l'introduction expliqué l'importance de la connaissance exacte de la valeur de la pesanteur à la station de Toulouse. Aussi pour affiner cette valeur nous avons outre la liaison avec Turin, réalisé deux autres liaisons avec Sèvres, l'une via Souillac et Orléans, l'autre via Arles et Tarare (Lyon). L'examen des résultats (tableau 9) amène un certain nombre de remarques.

1) La nouvelle valeur de la pesanteur à Toulouse observatoire, pilier de la première salle est de 980 427,48 mGal.

2) La précision de cette valeur est liée plus à l'incertitude sur le coefficient d'étalonnage utilisé ($K_m = 1,000\ 54$) qu'aux écarts entre les différentes liaisons.

3) La liaison Pino Torinese-Toulouse qui nous aurait permis de nous affranchir de cette incertitude sur K_m est inexploitable en raison de l'imprécision sur la mesure absolue (0,1 mGal).

4) La liaison Paris-Toulouse-Pic du Midi de Bigorre effectuée en 1977 à l'aide du gravimètre Lacoste et Romberg modèle G 125 de la DMA (affecté du même coefficient d'étalonnage par rapport aux stations absolues que le G 225) fournit une valeur de g absolument identique pour Toulouse.

TABLEAU 9 : valeur de la pesanteur à Toulouse-Observatoire (Pilier)

Stations	Δg LR - G 225	Δg corrigé	g
TURIN			980 534,26
ARLES B	- 27,774	- 27,789	980 506,47
TOULOUSE Pilier	- 78,957	- 79,000	<u>980 427,47</u>
PINO TORINESE			980 428,12*
TOULOUSE Pilier	- 0,731	- 0,731	980 427,39
SEVRES			980 925,97
TARARE	- 334,042	- 334,222	980 591,75
ARLES B	- 85,213	- 85,259	980 506,49
TOULOUSE Pilier	- 78,972	- 79,015	<u>980 427,48</u>
SEVRES			980 925,97
SOUILLAC	- 365,282	- 365,479	980 560,49
TOULOUSE Pilier	- 132,926	- 132,998	<u>980 427,49</u>
<u>Liaison 1977</u>	<u>Δg LR - G 125</u>		
SEVRES			980 925,97
ORLEANS	- 103,197	- 103,253	980 822,72
RILHAC RANCON	- 218,645	- 218,763	980 603,95
(Limoges)			
SOUILLAC	- 43,500	- 43,523	980 560,43
BLAGNAC	- 118,598	- 118,662	980 441,77
TOULOUSE Pilier			<u>980 427,48</u>
PIC DU MIDI DE BIGORRE	- 699,19	- 699,568	979 727,91

* Valeur provisoire valable à $\pm 100 \mu\text{Gal}$, aimablement fournie par G. CERUTTI.

CONCLUSIONS

La série de liaisons gravimétriques longues distances et de liaisons internationales entreprises par le B.R.G.M. de 1977 à 1979, a permis :

- d'établir la formule précise de passage du système de la Carte Gravimétrique de la France dans le système IGSN 71 ;
- de contrôler la précision du système IGSN 71 en France ;
- de connecter le réseau gravimétrique français à ceux des pays européens frontaliers ;
- de calculer une nouvelle valeur de la pesanteur à Toulouse Observatoire. Cette valeur, est égale à 980 427,48 mGal après calage sur les stations absolues de Sèvres-Bruxelles-Wiesbaden et Turin. Cette valeur sera utilisée jusqu'à réalisation d'une mesure absolue à Toulouse.

Ces études ont permis en outre de contrôler l'état de l'ancien réseau gravimétrique et de jeter les bases d'un nouveau Réseau Gravimétrique Français, le R.G.F. 80 qui sera calé sur des mesures absolues de pesanteur.

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DE BIGORRE.

Liaison 1977.

Rapport B.R.G.M. 77 SGN 431 GPH.

FIG. 1: CROQUIS DES BASES

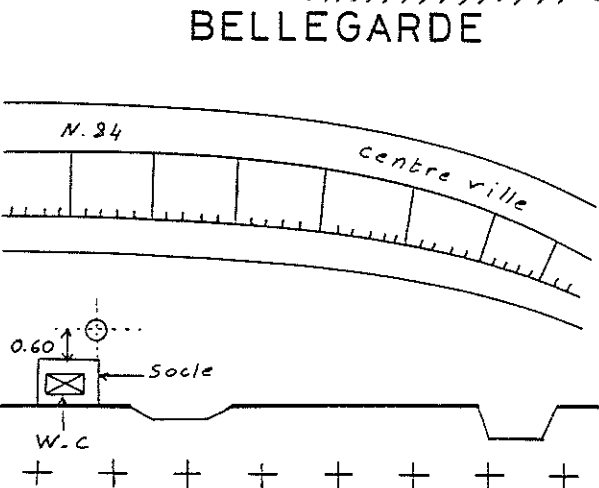
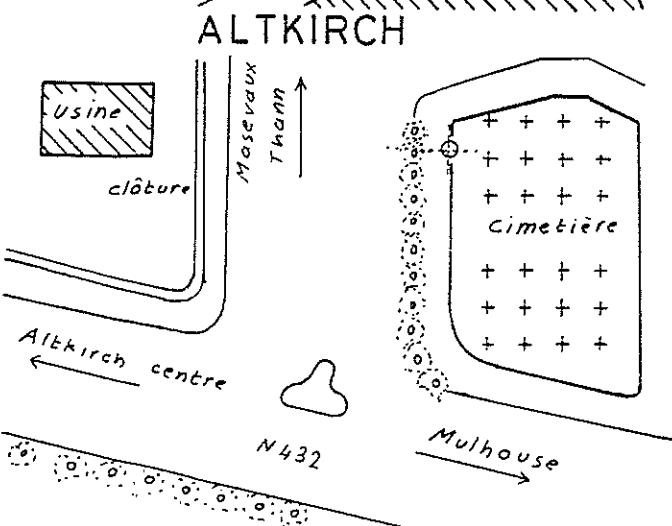
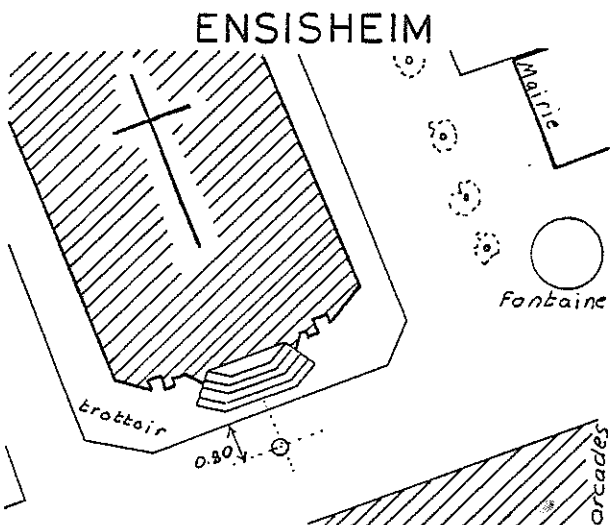
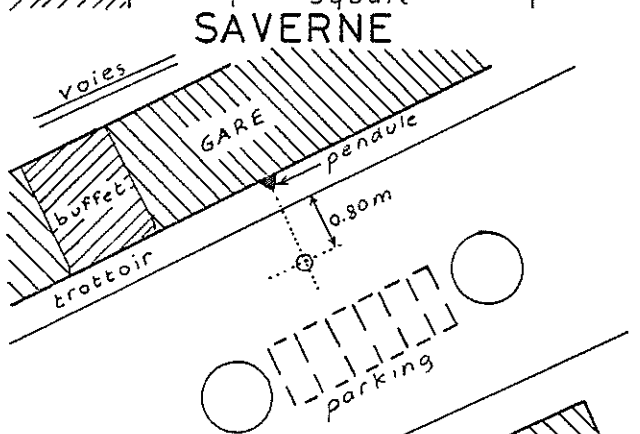
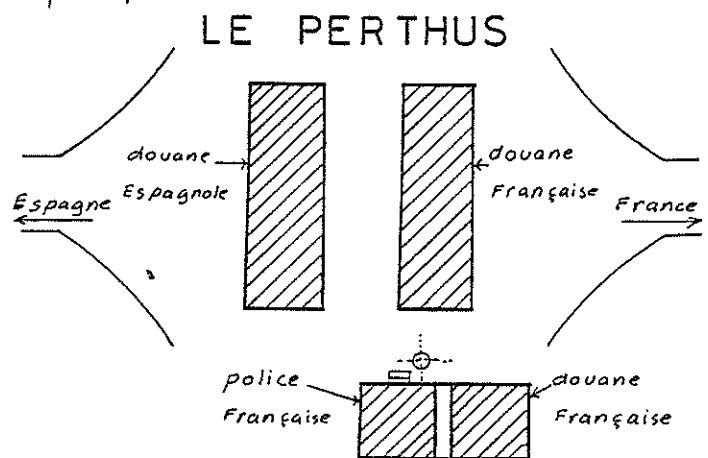
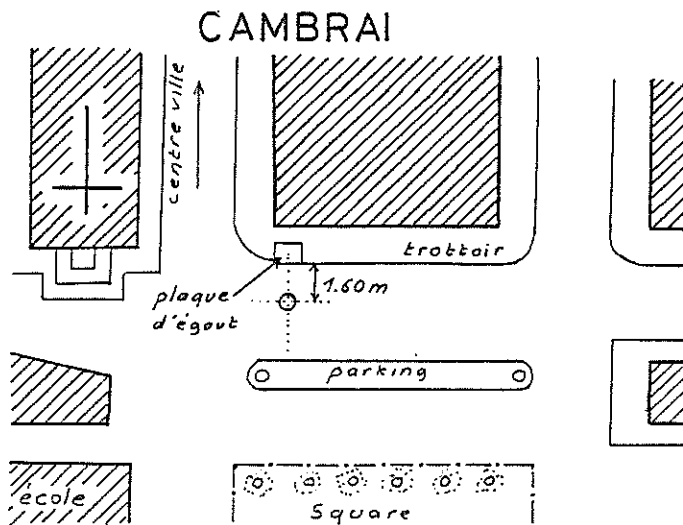
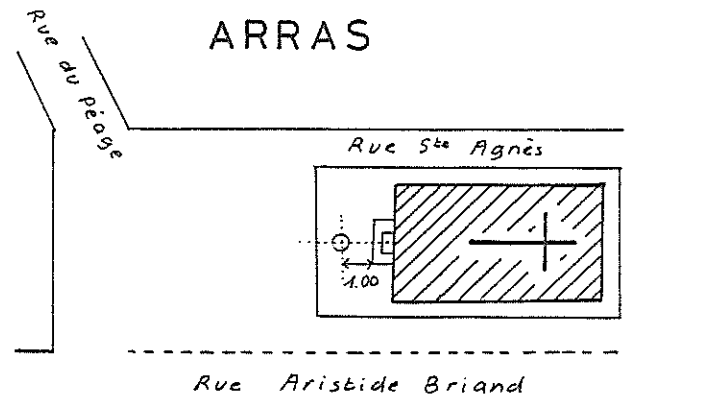
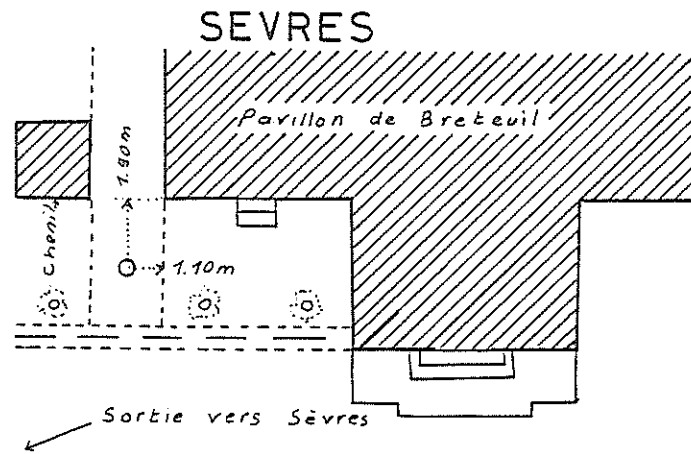
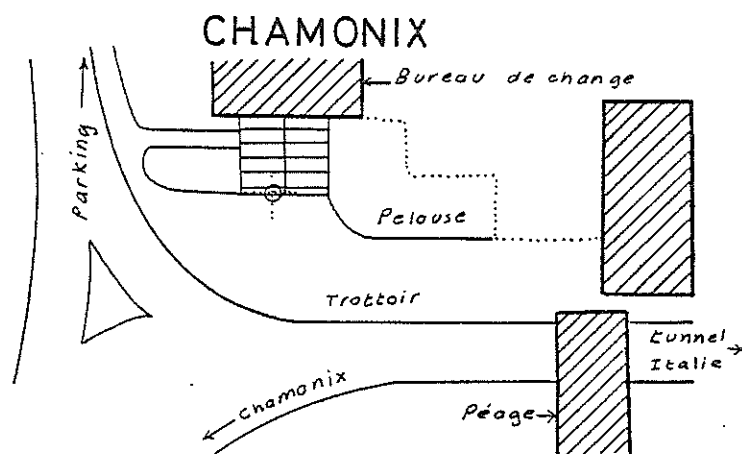
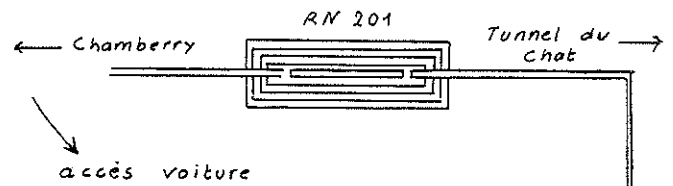
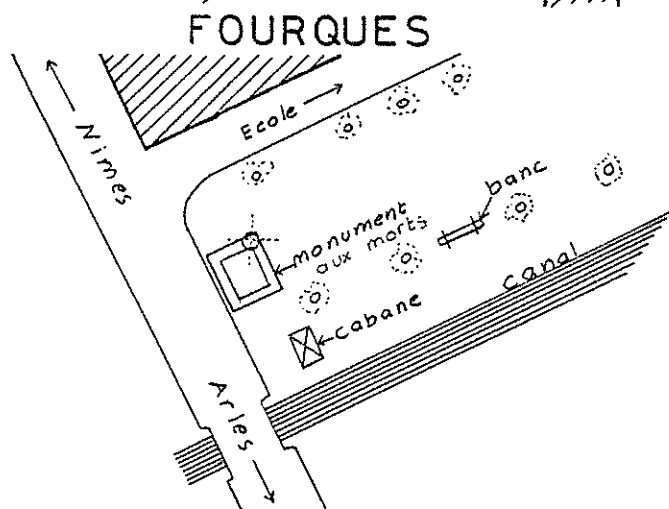
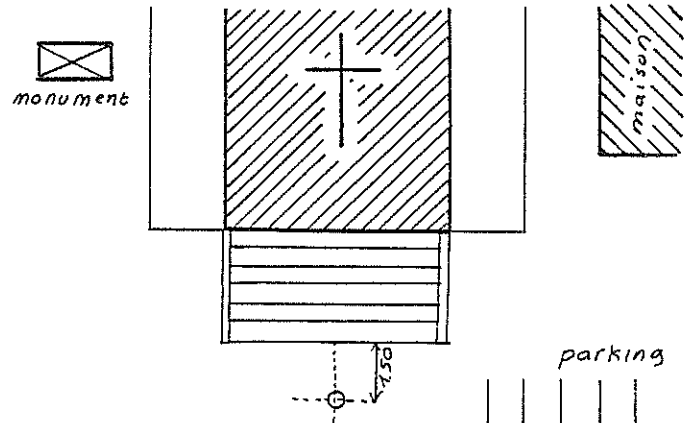
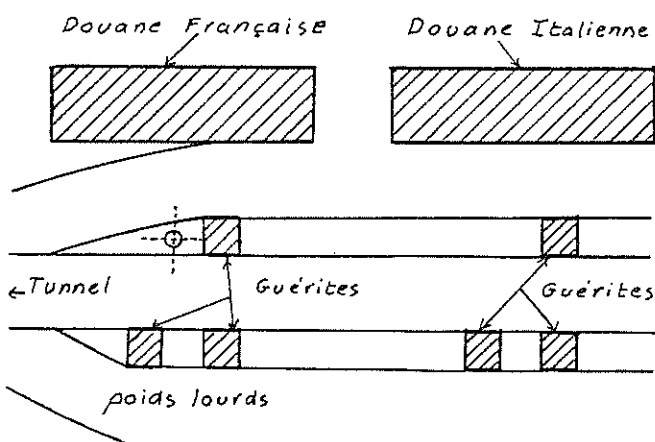
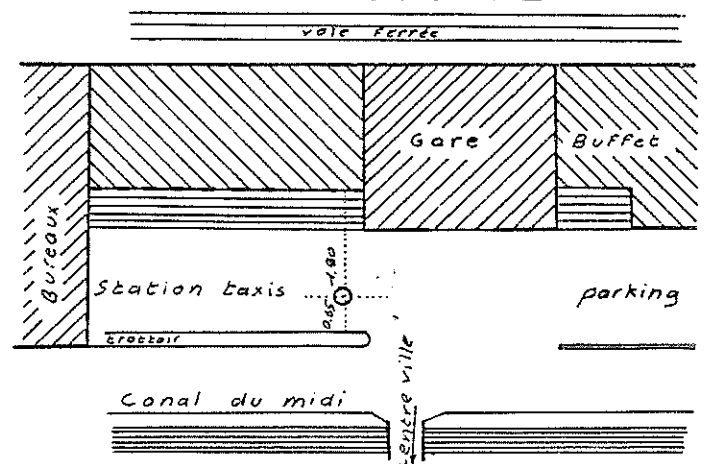
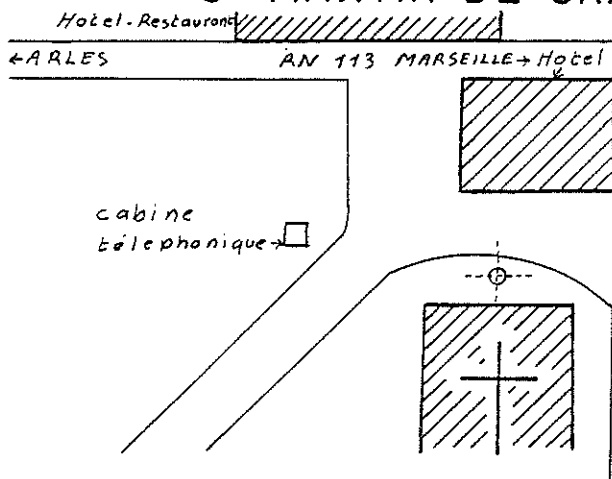
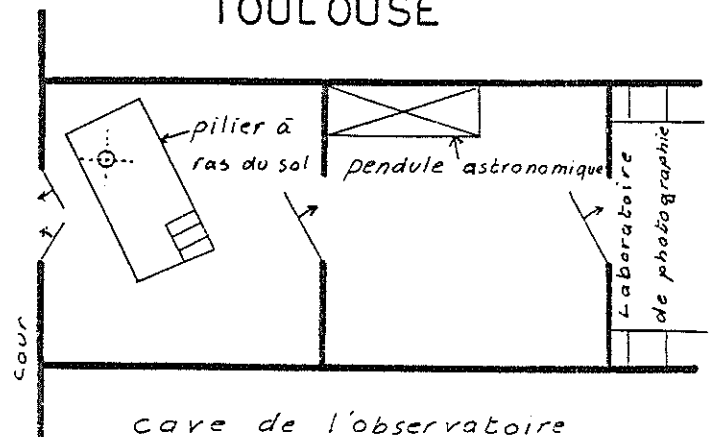


FIG. 2 : CROQUIS DES BASES

**LE BOURGET DU LAC****NICE-ST ISIDORE****VINTIMILLE**

← vers autoroute

CARCASSONNE**ST MARTIN DE CRAU****TOULOUSE**

LISTE des PUBLICATIONS
reçues au
BUREAU GRAVIMETRIQUE INTERNATIONAL
(Juillet à Décembre 1979)

CONCERNANT LES QUESTIONS DE PESANTEUR

LISTE des PUBLICATIONS

- *651 - WENZEL H.G. - "Zur Optimierung von Schwerenetzen".
Sond. : Zeits. für Vermessung. 102, H. 10, S. 452-457, 1977.

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

- 652 - WENZEL H.G. - "Zur Genauigkeit von gravimetrischen Erdzeitenbeobachtungen".
Wissens. Arb. der Lehrs. für Geod. Photogr. & Kartog., Tech. Univ. Hannover, N° 67, 205 S., 1976.

- 653 - HEINEKE U. - "Untersuchungen zur Reduktion und geodätischen Verwendung von Drehwaagemessgrößen".
Wissens. Arb. der Lehrs. für Geod. Photogr. & Kartog., Tech. Univ. Hannover, N° 86, 156 S., 1978.

With a torsion balance certain combinations of the second partial derivatives of the gravity potential can be measured. Near the Earth surface these data include short periodical parts because of the influence of topographic irregularities. For geodetic purposes, such as computing differences of vertical deflections and geoidal heights, a suitable integration of these data is necessary. This operation requires the elimination of the high frequent components, which already in hilly terrain will leads to difficulties.

The purpose of this investigation is the geodetic application of torsion balance measurements with special emphasize to modern evaluation techniques.

Starting with common mathematical models for computing the effect of topographic masses, a rigorous method is developed. For practical use a combined procedure is recommended and its accuracy is discussed. It is shown, that also mathematical smoothing techniques may be applied ; especially the least squares prediction is a very suitable procedure.

For the interpolation of vertical deflections and geoidal height-differences a model is developed, which allows a combined rigorous adjustment of torsion balance data and observed vertical deflections (astrogradiometric levelling).

All the methods are tested in a test area. The results show, that under the given conditions (hilly terrain near a mountain-chain) geoidal height-differences can be determined with a relative accuracy of ± 5 mm/km.

- 654 - RODDE A. - "Simultanbestimmungen der Lotabweichungskomponenten ξ und η mit dem Prismenastrolabium Vb Beobachtungen im 48. Breitengrad im Jahre 1972".
DGK, Reihe B : Angew. Geod. H. N° 199, 102 S., Frankfurt, 1977.

Author reports on his astronomic determinations of longitudes and latitudes performed simultaneously on 19 stations on the profile of the geoid at 48° of latitude, as well as on the calculation of the components ξ and η of the deviation of the vertical.

*Les numéros font suite à ceux indiqués dans le Bull. Inf. N° 45, Décembre 1979.

- 655 - BONATZ M. - "Zur Bedeutung der Erdgezeitenforschung für die Geodäsie".
Mit. Inst. Theor. Geod., Univ. Bonn, N° 41, 13 S, 1976.

As a contribution to the interdisciplinary discussion about the aims and possibilities of earthtide research the relevance of the determination of tidal deformations of the Earth for solving geodetic problems is demonstrated in a general scope. A complex draft on an iterativ solution of the problem is presented.

- 656 - BONATZ M. & Th. WERNER - "Teststation Erpel bein Bonn - Untersuchungen zur Bestimmung von Einflussparametern bei Klinometrischen Gezeitenregistrierungen".
Mit. Inst. Theor. Geod., Univ. Bonn, N° 42, 66 S, 1976.

- 657 - BONATZ M. - "Zum Problem der Bestimmung kleiner vertikaler Schwereunterschiede".
Mit. Inst. Theor. Geod., Univ. Bonn, N° 45, 18 S, 1976.

Measurement of vertical gradients of gravity means always measurement of gravity differences. To apply the possibilities of modern instruments as well as for elimination of "local noise" in gravity along a plumbline due to near disturbing masses it is proposed uniformly to approximate the vertical gradient of gravity by that quotient which appears by a vertical displacement of 1 meter ; the corresponding variation of gravity is called "small vertical gravity difference". For determination of such a gravity difference along the vertical calibration basis of the Earth tide station Bonn four techniques were applied : combined method of measurement and calculation, measurement by an astatized lever arm balance, measurement by gravimeters of typ Askania, measurement by gravimeters of type LaCoste. The results show agreement generally better than 1.5 %. To improve the precision of measurements of small vertical gravity differences by gravimeters some proposals are made. It is pointed out, that it is necessary to solve the problems of possibly occuring systematical instrumental errors depending on movement of the gravimeter and different heights of observation.

- 658 - BONATZ M. & H. WILMES - "Gravimetrisches Gezeitenprofil Bonn - Longyearbyen (Spitzbergen), Hauptpartialtiden für die Stationen Bodö und Tromsö".
Mit. Inst. Theor. Geod., Univ. Bonn, N° 46, 16 S, 1976.

The results of measurements in two additional stations of the gravimetric tide profile Bonn - Spitzbergen are presented. Concerning the results of the earlier observed stations Bonn, Oslo, Bergen and Trondheim see BONATZ M, 1975.

The measurements were carried out with the transformed Askania-Gravimeter BN-02 (GS 12 N° 85a). Relative to the first observation period the electronical part of its capacitive transducer system was improved introducing two active filters in series. ...

- 659 - FISCHER E.U. - "Über den Einfluss von Fehlern in den Mondkoordinaten auf die Integration der Bahnen Künstlicher Erdsatelliten".
Mit. Inst. Theor. Geod. Univ. Bonn, N° 47, 40 S, 1977.

A simple method for taking into account the influence of the sun and the moon on a satellite orbit has been applied by Koch and Morrison (1970) in connection with the simple layer model. The reliability of this procedure is examined for the moon by means of lunar ephemeris. Analytic expressions for the determination of the errors in the orbital elements of a satellite are given for periodically varying errors in the ephemeris of the sun and the moon. Finally an alternate method based on the interpolation of ephemeris with high precision is proposed.

- 660 - BONATZ M. & K. SCHULLER - "Erdgezeitenstation Bonn - Ergebnisse für die Parameter der Hauptpartialtiden und ihre Konfidenzintervalle nach der HYCON methode aus Registrierungen mit elf Gravimetern im Zeitraum 1971-1976". Mit. Inst. Theor. Geod. Univ. Bonn, N° 50, 28 S, 1977.

The registrations of eleven gravimeters (Type : GS 15, LaCoste-Romberg, BN) are analysed by the HYCON-method in order to derive actual tidal parameters of the main tidal frequency bands for the station of BONN. Best unbiased estimates of the amplitude coefficients and phase differences are presented with the associated confidence intervals, based on 95 % statistical security.

- 661 - BONATZ M. & H. WILMES - "Gesamtergebnisse gravimetrischer Gezeiten-registrierungen in der Station Reunion im Indischen Ozean". Mitt. Inst. Theor. Geod., Univ. Bonn, N° 51, 18 S, 1977.

From March 1974 to October 1975 at the Isle of Reunion measurements of the gravimetric tides were performed with an Askania-Gravimeter GS 15. The observed data were analysed according to Chojnicki's method. The relatively small indirect effect of oceanic tides within the parameters of the gravimetric tides as well as the big meteorological perturbation in the S_1 -band is remarkable.

- 662 - SCHULLER K. - "Über die Interpretation der Ergebnisse von Fourieranalysen eindimensionaler diskreter Prozesse im Zeit - und Frequenzbereich". Mit. Inst. Theor. Geod. Univ. Bonn, N° 54, 23 S, 1977.

It is shown how to apply Fourier techniques to periodic and transient processes and how to interpret the subsequent results in the time and frequency domain. Concerning random series, power spectrum estimators are discussed with respect to unbiasedness and consistency. Using the X^2 properties of the power spectrum, confidence intervals are derived.

- 663 - FREEDEN W. - "Stokes" Boundary - Value Problem of Physical Geodesy and its Numerical Computation". Mit. Inst. Theor. Geod., Univ. Bonn, N° 56, 26 S, 1978.

This paper is concerned with the solution of Stokes' boundary-value problem of physical geodesy and its numerical computation only from discretely given boundary data.

In the first part, by use of the concept of Green's functions Stokes' integral formula is developed from Green's identities.

Then a method is used to approximate Stokes' integral representation by a linear combination of values of the integrand at given points and to optimize the accuracy of computation.

The purpose is to explain a simple technique of approximating disturbance potential only from a finite number of given gravity anomalies.

- 664 - WILHEM H. - "Bestimmung elastischer Parameter des Erdinnern durch Erdgezeiten". DGM, Reihe C : Dissert. H. N° 222, 68 S, München, 1976.

- 665 - KNÄBEL F. - Ein Beitrag zur Berechnung der Bewegung eines lateral-gestörten Erdmodells unter dem Einfluss des Gezeitenpotentials".
DGK, Reihe C : Dissert. H. N° 225, 130 S, München, 1976.

Im Rahmen der vorgelegten Arbeit wird die Bewegung eines Erdmodelles mit lateral-gestörter, ansonsten radialsymmetrischer Dichtestruktur unter dem Einfluss des langperiodischen Anteiles des Gezeitenpotentials mittels gewöhnlicher, linearer Differentialgleichungen zweiter Ordnung beschrieben. Grundlage der Erstellung der Bewegungsgleichungen bildet das Konzept der Störungsrechnung. Die den räumlich-zeitlichen Vorgang beschreibenden Größen bestehen demzufolge aus einer sogenannten Grundlösung, die der Bewegung einer rein radialsymmetrischen Erde entspricht, und einer Lösungsstörung, die aus den Dichtestörungen resultiert. Die Grundlösung steht in funktionalem Bezug zur Erregung der Gesamtbewegung, d.h. hier in Bezug zum langperiodischen Anteil des Gezeitenpotentials ; die Lösungsstörung bedient sich zu ihrer Darstellung der Funktionen, die zur Formulierung der lateralen Einlagerungen verwendet werden. Beim hier behandelten Sonderfall beschränkt sich die diesbezügliche mathematische Beschreibung auf die Verwendung Legendrescher Polynome. Als Störkörper werden demnach längenunabhängige, ringförmige Dichtestrukturen oberhalb der radialsymmetrischen Grundstruktur angenommen. Zur Lösung der angegebenen Bewegungsgleichungen bedarfes der numerischen Integration, die sich weitgehend des bei (Alterman et al. 1959) aufgeführten Verfahrens bedienen kann, im Rahmen dieser Abhandlung jedoch nicht durchgeführt wird.

- 666 - HEKIMOGLU S. - "Absolute und relative Erdgezeiten-Analyse mit Schwebungsparametern und spektraler Darstellung des Störsignals".
DGK, Reihe C : Dissert. H. N° 226, 103 S, München, 1976.
- 667 - SCHULLER K. - "Ein Beitrag zur Auswertung von Erdgezeitenregistrierungen".
DGK, Reihe C : Dissert. H. N° 227, 86 S, München, 1976.

- 668 - HEIDENREICH E.D. - "Eine Darstellung des normalen Schwerfeldes über eine Potentialfortsetzung nach unten".
DGK, Reihe C : Dissert. H. N° 229, 68 S, München, 1977.

- 669 - HEIN G. - "Die Berechnung von anomalen vertikalen Schweregradienten hoher Präzision".
DGK, Reihe C : Dissert., H. N° 234, 119 S, München, 1977.

Die vorliegende Arbeit beschäftigt sich mit genauen Methoden zur Berechnung des anomalen vertikalen Schweregradienten auf der Grundlage der Molodensky-Theorie.

- 670 - PREUSSER A. - "Ein dreidimensionales Berechnungsmodell für geodätische Punkt und Geoidbestimmungen".
DGK, Reihe C : Dissert. H. N° 238, 102 S, München, 1977.

Die Bestimmung von Punktfeldern der Erdoberfläche kann als eine Zentrale Aufgabe der Geodäsie angesehen werden. Diese naturgemäss dreidimensionale Problemstellung wurde in der klassischen Geodäsie durch Abspalten des Höhenproblems auf ein zwei dimensionales Problem der Lagebestimmung auf einem Rotationsellipsoid zurückgeführt. Zwar entwickelte Bruns /4/ bereits 1878 eine grundlegende Theorie zur gemeinsamen Berechnung aller drei Koordinaten, doch scheiterte die Verwirklichung eines "Brunsschen Polyeders"

ins besondere an den Schwierigkeiten, Zenitdistanzen über grosse Entfernungen unter Berücksichtigung der Refraktionsanomalien der Luft mit der erforderlichen Genauigkeit messen zu können. So blieb zur Bestimmung der Höhen in erster Linie das Nivellement. Die getrennte Behandlung von Lage- und Höhenproblem war für die damals durchführbaren Messungen durchaus gerechtfertigt korrekturen an den Messungen reichten aus, um die geringe gegenseitige Beeinflussung zwischen Lage und Höhe zu berücksichtigen. Eine Verfälschung der Ergebnisse war dadurch nicht zu befürchten.

...

- 671 - BAYER R. & A. LESQUER - "Les anomalies gravimétriques de la bordure orientale du craton ouest africain : géométrie d'une suture panafricaine". CNRS - USTL, Centre Géol. & Geophys. Montpellier, Rapport d'activité 1977, p. 71-102, 1978.

A Bouguer anomaly map of West Africa including last gravity surveys is given here. The gravity trends on the West African craton are very different from those of the panafrican mobile belt. The limit between the two domains shows positive gravity anomalies which well define a suture zone. We propose that the geometry of the suture is almost the same than the craton margin during the oceanic expansion starting 850 M.y. ago.

According to the suture the Pre-Panafrican subsident basin of Gourma (Mali) has a transverse position. Its associated positive anomaly may be interpreted as a crustal thinning and suggests that the basin is an aulacogene.

The structure associated to suture positive anomalies are very important, their thickness varies on an average from 6 to 20 km ; they often present an upward dipping contact and probably correspond to basic or ultrabasic rocks.

The collision between a rigid block with a complex boundary as assumed by gravity interpretation and a complex rigid-plastic domain may explain the virgation of the structure in Mali and the major NS shear belts parallel to the edge of the craton.

- 676 - BUREAU of MINERAL RESOURCES, GEOLOGY & GEOPHYSICS, Canberra.
BMR Journal of Australian Geology & Geophysics, v. 1, N° 4, Dec. 1976.

- a) DOOLEY J.C. & B.C. BARLOW - "Gravimetry in Australia 1819-1976".
p. 261-271.

The earliest known gravity measurements in Australia were made by French expeditions in 1819 and 1824, using pendulums at Sydney. Later in the 19th century, further pendulum measurements with an accuracy of about 10 mGal were made at various capital cities by observers from Britain, Bavaria, Austria - Hungary, Russia and Italy.

A very early gravity meter was designed and constructed at Sydney University during the last decade of the century, but was used only experimentally. Reasonably accurate gravity meter surveys started about 1947.

The Cambridge pendulums were used in 1950-51 to establish a national network of 59 stations with an accuracy of about 0.8 mGal ; this was supplemented between 1950 and 1959 by gravity meter and pendulum measurements made as part of international surveys, which also helped to relate the Australian datum to the international network.

Meanwhile, surveys, mainly for geophysical prospecting, were made by Government authorities, universities, and private companies ; some of these surveys covered extensive areas and enabled compilation of a preliminary Bouguer anomaly map in 1959.

Early marine gravity surveys included observations in nearby oceans with Vening Meinesz' submarine pendulums, gravity measurements on offshore islands and reefs, and from 1956, underwater gravity meter surveys on the continental shelf.

Two factors stimulated regional gravity coverage in 1959 - firstly the Petroleum Search Subsidy Act, which ensured that exploration data from subsidized surveys were publicly available, and secondly, use of helicopters for reconnaissance gravity coverage of the continent, which was completed in 1973. Gravity data at sea were obtained mainly from reconnaissance marine geophysical surveys carried out under contract to BMR between 1965 and 1973, but include also traverses by international survey vessels and exploration companies.

Gravity meter calibration ranges were established in the main cities in 1960-61. Gravity values at the Cambridge pendulum stations were revised in 1962 using all relevant data, to establish a more accurate control network with standard errors ranging from 0.2 to more than 0.4 mGal for compilation of data from many surveys. These values were superseded by the Isogal Project of 1964-67, which gave values with standard errors of 0.1-0.2 mGal, in which several gravity meters were transported by aircraft along trans-continental east-west traverses. Values at the eastern ends of the traverses, forming part of the Australian Calibration Line (ACL), were established by a U.S. Air Force survey in 1965. The accuracy of the ACL was significantly improved by Soviet pendulum measurements in 1972-74, and joint Soviet-Australian gravity meter measurements in 1973 - a precision of about 0.01 mGal being achieved.

- b) MATHUR S.P. - "Relation of Bouguer anomalies to crustal structure in southwestern and central Australia".
p. 277-286.

An analysis of the gravity field in two largely Precambrian metamorphic rock areas of Australia, one in the southwestern and the other in the central part, indicates that the regional Bouguer anomalies may be explained by models of the crust and upper mantle consistent with the other geophysical and geological observations.

In the southwestern part, the longer wavelength component of the anomalies is consistent with a crust which has been determined by seismic measurements to be greater than normal in thickness and density in the west owing to the presence of a high-velocity basal layer that thins out eastwards. The shorter wavelength components show excellent correlation with the near-surface geology.

In central Australia, where no comparable seismic measurements have been made, the Bouguer anomaly field, which is dominated by large amplitude (up to 150 mGal) and long wavelength (about 150 to 200 km) components, is interpreted in terms of thickness and structure of a two-layer crust. The derived crustal model is based on the concept of folding and faulting that involves the entire crust and upper mantle, and is compatible with the broad aspects of surface geology and structure.

The crustal upwarps in the model, with the intermediate and Mohorovicic discontinuities at depths as shallow as 15 and 27 km, are associated with the Arunta and Musgrave Blocks, where deep crustal rocks are exposed against large thrust faults. The crustal downwarps, with the discontinuities as deep as 31 and 43 km, are associated with basins containing substantial thicknesses of sediments. Depths to these discontinuities are in agreement with those estimated from the only two isolated deep seismic reflection probes in the basin areas.

- c) WELMAN P. - "The gravity field of the Australian basement".
p. 287-290.

The Australian gravity field is analysed to determine whether the basement differs between regions of exposed basement and of covered basement (sedimentary basins). When the thickness of cover is allowed for, there is no systematic change in gravity variability from exposed to covered basement regions and the pattern of density differences is inferred to be similar in the two basement types. With one exception the trends of the gravity anomalies are continuous from covered to exposed basement regions ; therefore geological structure and rock formations in the basement are considered to be continuous between the two kinds of regions. After making allowance for altitude and the effects of cover beds, the covered basement is calculated to have gravity anomalies that average 5 mGal less than the exposed basement. This gravity difference is probably caused by the two kinds of basement not being isostatically balanced relative to each other, rather than the basements having a different average density. No major differences between exposed and covered basement are apparent. It is likely that the two basement types have a similar history of formation, and consequently similar mineral potential.

- d) DOOLEY J.C. - "Variation of crustal mass over the Australian region".
p. 290-296.

Seismic refraction surveys in Australia and nearby marine areas provide data on crustal velocities and layer thicknesses. The averages of these at various places have been used to estimate a density-depth structure. By applying corrections for average elevation and free-air gravity, a crustal mass deficiency (CMD) is calculated for each site ; this characterizes a standard crustal column with zero elevation and zero free-air anomaly, which is considered to be in isostatic equilibrium over a mantle of uniform density 3.32 t/m^3 .

The CMD ranges from about 13 kt/m^2 in the south-west of the continent, to about 21 in parts of Queensland ; marine values range from 15 to 17 kt/m^2 . The variations imply that isostasy on a broad scale is not complete at the base of the crust. As the gravity field indicates that departures from isostasy are comparatively small, compensation occur partly in the mantle.

- e) WELLMAN P. - "Regional variation of gravity, and isostatic equilibrium of the Australian crust".
p. 297-302.

In eastern Australia free-air anomalies and altitudes averaged over $1^\circ \times 1^\circ$ areas show a positive correlation of $+ 0.059 \pm .004 \text{ mGal m}^{-1}$. Isostatic compensation of topography and crustal masses is thought to be mainly at the base of the crust, but partly deeper in the mantle, and to be almost complete for $1^\circ \times 1^\circ$ areas.

In central and western Australia free-air anomalies and altitudes have a zero or slightly negative correlation with a larger scatter ; isostatic compensation is thought to be complete only for $3^{\circ} \times 3^{\circ}$ areas and to be predominantly at the base of the crust. The deeper compensation in eastern Australia is thought to be related in some way to the youth of the crust and the presence of a low velocity zone at about 130 km. Elsewhere in the world Phanerozoic areas have a positive free-air anomaly altitude correlation, and Precambrian areas a negative correlation ; so the different modes of isostatic compensation found in Australia may apply to crust of similar age elsewhere in the world.

In Australia the residual $1^{\circ} \times 1^{\circ}$ area anomalies found by removing altitude, long wavelength and sedimentary effects generally have an amplitude of 30 mGal and a wavelength of 6° ; they are thought to be due to isostatically compensated variations in crustal density. Using these anomalies, variations in crustal thickness are predicted.

- f) SYMONDS P.A. & J.B. WILCOX - "The gravity field of offshore Australia". p. 303-314.

The free-air anomaly field of offshore Australia has been divided into about fifty regional gravity provinces, each of which is characterized by uniformity of trend, free-air anomaly level, or degree of disturbance. These are discussed in relation to structural and/or bathymetric features in each region. The Bouguer anomalies are used as a rough guide to variations in crustal thickness.

On the continental shelf the free-air anomaly provinces generally correlate with the main structural elements. The Precambrian shields are associated mainly with regional gravity lows, and the peripheral mobile belts mainly with gravity ridges. On the northwest and southern margins these mobile belts cut across the continental shelf and appear to be truncated at the shelf-break. On the marginal plateaus and terraces the free-air anomaly pattern largely reflects the relative elevation of basement and the thickness of sediment. The well defined gravity highs on the Lord Howe Island and Tasmanid seamount chains are caused by the combined effects of sea-floor topography and high-density igneous bodies.

Regional positive free-air anomaly values over the broad continental shelves of the Northwest and Southern Margins, and negative values on the adjacent abyssal plains, indicate that slight readjustment of the crust/mantle interface must occur in these regions if isostatic equilibrium is to be attained. However, the well-defined free-air anomaly ridges and troughs which correspond to the top and foot of the continental slope respectively, are largely a "gravity edge effect" caused by abrupt changes in water depth and crustal thickness. This can reach ± 70 mGal over steep slopes, such as that bordering the Tasman Basin. Regional positive free-air anomaly values over the Queensland and Marion Plateaus indicate that slight subsidence of these features is necessary if they are to attain isostatic equilibrium.

The Bouguer anomaly values indicate that the crust thins oceanward except in the Timor Sea area where crustal thickening occurs, probably due to interaction of lithospheric plates along the Inner Banda Arc. Crust of typically oceanic thickness (10 - 15 km) is confined to the lower part of the continental slopes and the abyssal plains, generally oceanward of the 4000 m isobath.

- g) TERRON O., W. ANFILOFF, F.J. MOSS & P. WELLMAN - "A selected bibliography on Australian gravity".
p. 315-319.

This bibliography mainly contains reports of those major surveys used to construct the 1976 1 : 5 million gravity map of Australia. The bibliography is listed in alphabetical order, and the list is numbered consecutively. Figure 1 relates the reference number to the area covered by each report. Most reports give the survey method, logistic information, the gravity meter number and its calibration details, the datum of horizontal coordinates, vertical coordinates and gravity, the accuracy of the reduced position and gravity data. A Bouguer anomaly map, and a description and geological interpretation of this map.

Also included are selected publications on the progress of gravity mapping, on the establishment and refinement of a national gravity reference network of base stations to define datum and scale, and of the use of the mapped gravity anomalies in the definition of geological structure and in geodetic studies.

- h) FRASER A. - "Gravity province and their nomenclature".
p. 350-352.

Gravity features have been defined and named by the various authors who have interpreted the results of land and marine reconnaissance gravity surveys in Australia. In general, two classes of feature have been identified, gravity provinces and gravity units. A gravity province is a region where the gravity field is characterized by uniformity of some property, such as contour trend, gravity level, or degree of contour disturbance, which distinguishes it from neighbouring provinces. A gravity unit is a subdivision of a province. Neighbouring units are again distinguished from each other by differences in contour trend, gravity level, or degree of contour disturbance - but on a smaller scale.

Many gravity features were originally defined from the results of individual reconnaissance surveys in isolated areas and have been shown to be inconsistent with the regional gravity pattern after more extensive coverage has been obtained. Land and marine gravity coverage is now virtually complete, and an attempt has now been made to rationalize gravity province boundaries and names over the whole of Australia and its continental margins. In all, 125 provinces have been defined and named. It is recommended that authors made use of the names when discussing regional gravity features.

- 677 - DOOLEY J.C. - "Implications of Australian seismic and gravity measurements for the structure and composition of the upper mantle".
from : BMR Journal of Australian Geology & Geophysics, v. 2, N° 1, p. 1-5, Canberra, March 1977.

In a previous paper densities of crustal layers were inferred from seismic refraction surveys in Australia and surrounding marine areas. These indicated substantial variations in crustal mass. As the free-air gravity field does not show anomalies corresponding to these, it is inferred that compensating mass variations must occur in the upper mantle. Sub-crustal mantle densities, inferred from P_n velocities, in general do not provide the required mantle mass distribution ; however in some parts of the continent

observed increases in seismic velocity at depths of 60 to 100 km suggest density changes which would lead to approximate compensation at about 130 km depth, corresponding to the top of a low-velocity layer suggested by surface wave studies.

Marine crustal masses are reasonably close to a common value, but the wide variation of P_n velocities implies a corresponding variation of densities which would counteract this compensation if they persisted in depth. It is suggested that the P_n velocities represent comparatively thin layers, and that deeper density changes occur so that compensation takes place at 80 to 100 km, at the top of the sub-oceanic asthenosphere.

The West Australian shield has the highest crustal mass, and also the highest P_n velocity, which implies a further relative increase in mass with depth. If the sub-shield mantle is assumed to consist of refractory peridotite with a relatively low density corresponding to its P_n velocity, the discrepancy in crustal mass with respect to the other areas is reduced with increasing depth, but is still not eliminated at depths less than about 160 km.

This suggests that the sub-shield mantle above this depth has enough strength to support the differential pressure associated with the excess crustal mass. This conclusion is in accordance with other evidence, suggesting that sub-shield or sub-continental mantle differs from sub-oceanic mantle to depths of several hundreds of kilometers, and hence that the return flow compensating for plate-tectonic motions cannot take place at depths of 100 to 200 km, as often supposed.

- 682 - WELLMAN P. - "Gravity evidence for abrupt changes in mean crustal density at the junction of Australian crustal blocks".
from : BMR Journal of Australian Geology & Geophysics, v. 3, N° 2,
p. 153-162, Canberra, June 1978.

The major gravity anomalies in central and western Australia occur as elongate dipoles, either in isolation or in a series. Each dipole is thought to be caused by an abrupt change in mean crustal density at the junction of two crustal blocks and by the associated isostatically compensating masses. Typically one block has along its margin a strip with anomalously high mean crustal density, and the other block has normal density crust covered by several kilometers of low density sediment. The observed anomalies are consistent with the anomalous masses being isostatically compensated by variations in the thickness of the crust, the crustal thickness variations being gradual and extending to about 100 km from the boundaries of the anomalous bodies.

The crustal block boundaries inferred from dipole anomalies correspond in position with the crustal block boundaries inferred from geology, and approximately with the position of block boundaries inferred from changes in the gravity trend pattern. Usually the block with younger basement has high density material along its margin, and the other, older block is covered with sediment ; both these features are likely to be caused by the process that created or emplaced the younger block. The presence of relatively dense material high in the crust along the margins of the younger blocks suggests that younger blocks are not superficial features on a uniform old crust. The dipole anomalies on the Australian Precambrian crust are similar in magnitude and tectonic position to those recognised at Precambrian province boundaries in Canada.

- 683 - MAKRIS J. - "A dynamic model of the Hellenic arc deduced from geophysical data".
from : Tectonophysics, v. 36, p. 339-346, 1976.

Combined gravity and seismic data from Greece and the adjacent areas have been used to explain the high seismicity and tectonic activity of this area. Computed 2-D gravity models revealed that below the Aegean region a large "plume" of hot upper-mantle material is rising, causing strong attenuation of the crust. The hot "plume" extends to the base of the lithosphere and has very probably been mobilized through compressional processes that forced the lithosphere to sink into the asthenosphere. The above model is supported by :

- high heat flow in the Aegean region,
- low velocity of the compressional waves of 7.7 km/sec for the upper mantle ;
- lower density than normal extending to the base of the lithosphere ;
- teleseismic P-wave travel-time residuals of the order of + 2 sec for seismic events recorded at the Greek seismic stations :
- volcanics in the Aegean area with a chemical composition which can be explained by assuming an assimilation of oceanic crust by the upper mantle ;
- deep seismicity (200 km) which has been interpreted by various authors as a Benioff zone.

- 684 - MAKRIS J. & R. VEES - "Crustal structure of the Central Aegean Sea and the Islands of Evia and Crete, Greece, obtained by refractational seismic experiments".
from : J. Geophys. N° 42, p. 329-341, 1977.

In 1973 and 1974 deep seismic sounding experiments were performed in the Aegean area by German and Greek geophysicists, from which two crustal sections were established. The one strikes along the islands of Amorgos-Mikonos-Andros and Evia and the other along Crete, in the E-W direction. The main results obtained are :

Along the Amorgos-Mikonos-Evia section the crust is updipping from 32 km below Evia to 26 km below Amorgos in the southern Aegean Sea.

The crust is of the continental type with $V_{Pg} = 6.0$ km/s for the crystalline basement and 7.7 km/s for the upper mantle.

The average velocity of the crust computed from $P_m P$ - reflections has a value of 6.21 km/s.

The sedimentary cover is very unevenly distributed with maximum thickness at North Evia. The crystalline basement outcrops at the southern part of the island and the Cyclades.

Along Crete the crust is somewhat thicker, than that below South-Evia with 34 km at the western part and about 30 km at the eastern part of the island.

At the western part of the island the nappes have their greatest thickness, the messara basin in the east containing the largest neogene sequences on Crete.

The crustal structure of Crete is also of the average continental type.
