ASSOCIATION INTERNATIONALE DE GEODESIE

BUREAU GRAVIMETRIQUE INTERNATIONAL

BULLETIN D'INFORMATION

N° 73

Décembre 1993

18, Avenue Edouard Belin
31055 TOULOUSE CEDEX
FRANCE

INFORMATIONS FOR CONTRIBUTORS

Contributors should follow as closely as possible the rules below :

Manuscripts should be typed (double-spaced) in Prestige-Elite characters (IBM-type), on one side of plain paper 21 cm x 29,7 cm, with a 2 cm margin on the left and right hand sides as well as on the bottom, and with a 3 cm margin at the top (as indicated by the frame drawn on this page).

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

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

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

Footnotes. Because footnotes are distracting, they should be avoided as much as possible.

Mathematics. For papers with complicated notation, a list of symbols and their definitions should be provided as an appendix. All characters that are available on standard typewriters should be typed in equations as well as test. Symbols that must be handwritten should be identified by notes in the margin. Ample space (1.9 cm above and below) should be allowed around equations so that type can be marked for the printer. Where an accent or underscore has been used to designate a special type face (e.g., boldface for vectors, script for transforms, sans serif for tensors), the type should be specified by a note in a margin. Bars cannot be set over superscripts or extended over more than one character. Therefore angle brackets are preferable to accents over characters. Care should be taken to distinguish between the letter 0 and zero, the letter l and the number one, kappa and k, mu and the letter u, nu and v, eta and n, also subscripts and superscripts should be clearly noted and easily distinguished. Unusual symbols should be avoided.

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

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

Tables. Tables are numbered serially with Arabic numerals, in the order of their citation in text. Each table should have a title, and each column, including the first, should have a heading. Column headings should be arranged to that their relation to the data is clear.

Footnotes for the tables should appear below the final double rule and should be indicated by a, b, c, etc. Each table should be arranged to that their relation to the data is clear.

Illustrations. Original drawings of sharply focused glossy prints should be supplied, with two clear Xerox copies of each for the reviewers. Maximum size for figure copy is (25.4 x 40.6 cm). After reduction to printed page size, the smallest lettering or symbol on a figure should not be less than 0.1 cm high ; the largest should not exceed 0.3 cm. All figures should be cited in text and numbered in the order of citation. Figure legends should be submitted together on one or more sheets, not separately with the figures.

Mailing. Typescripts should be packaged in stout padded or stiff containers ; figure copy should be protected with stiff cardboard.

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BUREAU GRAVIMETRIQUE INTERNATIONAL

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Table of Contents

Bulletin d'Information n° 73

Announcement

Meeting of the INTERNATIONAL GRAVITY COMMISSION
and
the INTERNATIONAL COMMISSION FOR THE GEOID
PROGRAMS and CONVENORS
GRAZ, Austria, Sept. 11-17, 1994

Sept. 11	13.00 - 18.00	**BGI Directing Board Meeting**
Sept. 12	09.00 - 13.00	**IGC Technical Reports**
	15.00 - 18.00	**Progress in Gravity Instrumentation** Convenor : Prof. J. Faller JILA Univ. of Colorado Campus Box 440 Boulder, Co. 80309 - USA Fax : +1 3034925235
Sept. 13	09.00 - 13.00	**Intercomparison Campaigns** Convenor : Prof. I. Marson DINMA, Univ. Trieste Via Valerio 10 34127 Trieste - Italy Fax : +39 40 6763497 E-Mail : marson@univ.trieste.it
	15.00 - 18.00	**Standards, Networks, Data Bases and Software** Convenor : Dr. G. Boedecker Deutsches Geod. Forschungsinstitut Bayer Akademie der Wissenschaften DGFI, Abt. 1 - Marstallplatz 8 D-8000 München 22 - Germany Fax : +49 89 23031240
Sept. 14	09.00 - 13.00	**Space and Airborne Gravity and Gradiometry** Convenor : Prof. R. Rummel Technische Universität München Institut für Astronomische und Physikalische Geodäsie Arcistrasse 21 D-8000 München 22 - Germany Fax : +49 89 21053178
	15.00 - 18.00	**Geophysical Inversion of Gravity and Geoid** Convenor : Dr. P. Holota Res. Inst. of Geod. Topogr. and Cart. CS-250 66 Zdiby 98 Praha-Vychod - Czech Republic Fax : +42 2 686 7056
Sept. 15	09.00 - 13.00	**Sightseeing**

	15.00 - 18.00	**Altimetry** Convenor : Prof. F. Sanso Politecnico di Milano Ambientale e del Rilevamento Piazza L. da Vinci 32 20133 Milano - Italy Fax : +39 2 23996530
Sept. 16	09.00 - 13.00	**International Projects and Advanced Techniques** Convenor : Dr. M.G. Sideris University of Calgary Dept. of Geomatics Engineering 2500 University Drive N.W. Calgary, Alberta, Canada T2N 1N4 Fax : +1 403 2841980 E-mail : sideris@acs.ucalgary.ca
	15.00 - 18.00	**ICG Technical session**
Sept. 17	09.00 - 13.00	**The Geoid in Europe** Convenor : Dr. M. Vermeer Finnish Geodetic Institut Ilmalankatu 1A SF - 00240 Helsinki - Finland Fax : +358 0 414946 and National Survey and Cadastres Rentemstervej 8 DK-2400 Copenhagen N.V. Denmark Fax : +45 358 7500054
	15.00 - 18.00	**Poster Presentation**

PART I

INTERNAL MATTERS

GENERAL INFORMATIONS

1. HOW TO OBTAIN THE BULLETIN
2. HOW TO REQUEST DATA
3. USUAL SERVICES B.G.I. CAN PROVIDE
4. PROVIDING DATA TO B.G.I.

1. HOW TO OBTAIN THE BULLETIN

The Bulletin d'Information of the Bureau Gravimétrique International is issued twice a year, generally at the end of June and end of December.

The Bulletin contains general informations on the community, on the Bureau itself. It informs about the data available, about new data sets...

It also contains contributing papers in the field of gravimetry, which are of technical character. More scientifically oriented contributions should better be submitted to appropriate existing journals.

Communications presented at general meeting, workshops, symposia, dealing with gravimetry (e.g. IGC, S.S.G.'s,...) are published in the Bulletin when appropriate - at least by abstract.

Once every four years, a special issue contains the National Reports as presented at the International Gravity Commission meeting. Other special issues may also appear (once every two years) which contain the full catalogue of the holdings.

About three hundred individuals and institutions presently receive the Bulletin.

You may :

- either request a given bulletin, by its number (72 have been issued as June 30,1993, but numbers 2,16, 18,19 are out of print).

- or subscribe for regularly receiving the two bulletins per year plus the special issues.

Requests should be sent to:

Mrs. Nicole LESTIEU
CNES/BGI
18, Avenue Edouard Belin
31055 TOULOUSE CEDEX - FRANCE

Bulletins are sent on an exchange basis (free of charge) to individuals, institutions which currently provide informations, data to the Bureau. For other cases, the price of each issue is 70 FF.

2. HOW TO REQUEST DATA

2.1. Stations descriptions Diagrams for Reference, Base Stations (including IGSN 71's)

Request them by number, area, country, city name or any combination of these.

When we have no diagram for a given request, but have the knowledge that it exists in another center, we shall in most cases forward the request to this center or/and tell the inquiring person to contact the center.

Do not wait until the last moment (e.g. when you depart for a cruise) for asking us the information you need: station diagrams can only reach you by mail, in many cases.

2.2. G-Value at Base Stations

Treated as above.

2.3. Mean Anomalies, Mean Geoid Heights, Mean Values of Topography

The geographic area must be specified (polygon). According to the data set required, the request may be forwarded in some cases to the agency which computed the set.

2.4. Gravity Maps

Request them by number (from the catalogue), area, country, type (free-air, Bouguer...), scale, author, or any combination of these.

Whenever available in stock, copies will be sent without extra charges (with respect to usual cost - see § 3.3.2.). If not, two procedures can be used:

- we can make (poor quality) black and white (or ozalide-type) copies at low cost,

- color copies can be made (at high cost) if the user wishes so (after we obtain the authorization of the editor).

The cost will depend on the map, type of work, size, etc... In both cases, the user will also be asked to send his request to the editor of the map before we proceed to copying.

2.5. Gravity Measurements

BGI is now using the ORACLE Data Base Management System. One implication is that data are stored in only one format (though different for land and marine data), and that archive files do not exist anymore.

There are two distinct formats for land or sea gravity data, respectively EOL and EOS.

EOL
LAND DATA FORMAT
RECORD DESCRIPTION
126 characters

Col.			
	1-8	B.G.I. source number	(8 char.)
	9-16	Latitude (unit : 0.00001 degree)	(8 char.)
	17-25	Longitude (unit : 0.00001 degree)	(9 char.)
	26-27	Accuracy of position	(2 char.)
		The site of the gravity measurements is defined in a circle of radius R	
		0 = no information	
		1 - R <= 5 Meters	
		2 = 5 < R <= 20 M (approximately 0'01)	
		3 = 20 < R <= 100 M	
		4 = 100 < R <= 200 M (approximately 0'1)	
		5 = 200 < R <= 500 M	
		6 = 500 < R <= 1000 M	
		7 = 1000 < R <= 2000 M (approximately 1')	
		8 = 2000 < R <= 5000 M	
		9 = 5000 M < R	
		10...	
	28-29	System of positioning	(2 char.)
		0 = no information	
		1 = topographical map	
		2 = trigonometric positioning	
		3 = satellite	
	30	Type of observation	(1 char.)
		1 = current observation of detail or other observations of a 3rd or 4th order network	
		2 = observation of a 2nd order national network	
		3 = observation of a 1st order national network	
		4 = observation being part of a nation calibration line	
		5 = coastal ordinary observation (Harbour, Bay, Sea-side...)	
		6 = harbour base station	
	31-38	Elevation of the station (unit : centimeter)	(8 char.)
	39-40	Elevation type	(2 char.)
		1 = Land	
		2 = Subsurface	
		3 = Lake surface (above sea level)	
		4 = Lake bottom (above sea level)	
		5 = Lake bottom (below sea level)	
		6 = Lake surface (above sea level with lake bottom below sea level)	
		7 = Lake surface (below sea level)	
		8 = Lake bottom (surface below sea level)	
		9 = Ice cap (bottom below sea level)	
		10 = Ice cap (bottom above sea level)	
		11 = Ice cap (no information about ice thickness)	
	41-42	Accuracy of elevation	(2 char.)
		0 = no information	
		1 = E <= 0.02 M	
		2 = .02 < E <= 0.1 M	
		3 = .1 < E <= 1	
		4 = 1 < E <= 2	
		5 = 2 < E <= 5	
		6 = 5 < E <= 10	
		7 = 10 < E <= 20	
		8 = 20 < E <= 50	
		9 = 50 < E <= 100	
		10 = E superior to 100 M	
	43-44	Determination of the elevation	(2 char.)
		0 = no information	
		1 = geometrical levelling (bench mark)	
		2 = barometrical levelling	
		3 = trigonometric levelling	
		4 = data obtained from topographical map	
		5 = data directly appreciated from the mean sea level	
		6 = data measured by the depression of the horizon	
		7 = satellite	
	45-52	Supplemental elevation (unit : centimeter)	(8 char.)
	53-61	Observed gravity (unit : microgal)	(9 char.)

62-67	Free air anomaly (0.01 mgal)	(6 char.)
68-73	Bouguer anomaly (0.01 mgal)	(6 char.)
	Simple Bouguer anomaly with a mean density of 2.67. No terrain correction	
74-76	Estimation standard deviation free-air anomaly (0.1 mgal)	(3 char.)
77-79	Estimation standard deviation bouguer anomaly (0.1 mgal)	(3 char.)
80-85	Terrain correction (0.01 mgal)	(6 char.)
	computed according to the next mentioned radius & density	
86-87	Information about terrain correction	(2 char.)
	0 = no topographic correction	
	1 = tc computed for a radius of 5 km (zone H)	
	2 = tc computed for a radius of 30 km (zone L)	
	3 = tc computed for a radius of 100 km (zone N)	
	4 = tc computed for a radius of 167 km (zone 02)	
	11 = tc computed from 1 km to 167 km	
	12 = tc computed from 2.5 km to 167 km	
	13 = tc computed from 5.2 km to 167 km	
	14 =tc (unknown radius)	
	15 = tc computed to zone M (22 km)	
	16 = tc computed to zone G	
	17 = tc computed to zone K (18.8 km)	
	25 = tc computed to 48.6 km on a curved Earth	
	26 = tc computed to 64. km on a curved Earth	
88-91	Density used for terrain correction	(4 char.)
92-93	Accuracy of gravity	(2 char.)
	0 = no information	
	1 = E <= 0.01 mgal	
	2 = .01 < E <= 0.05 mgal	
	3 = .05 < E <= 0.1 mgal	
	4 = 0.1 < E <= 0.5 mgal	
	5 = 0.5 < E <= 1. mgal	
	6 = 1. < E <= 3. mgal	
	7 = 3. < E <= 5. mgal	
	8 = 5. < E <= 10 mgal	
	9 = 10. < E <= 15. mgal	
	10 = 15. < E <= 20. mgal	
	11 = 20. < E mgal	
94-99	Correction of observed gravity (unit : microgal)	(6 char.)
100-105	Reference station	(6 char.)
	This station is the base station (BGI number) to which the concerned station is referred	

106-108	Apparatus used for the measurement of G 0.. no information 1.. pendulum apparatus before 1960 2.. latest pendulum apparatus (after 1960) 3.. gravimeters for ground measurements in which the variations of G are equilibrated of detected using the following methods : 30 = torsion balance (Thyssen...) 31 = elastic rod 32 = bifilar system 34 = Boliden (Sweden) 4.. Metal spring gravimeters for ground measurements 41 = Frost 42 = Askania (GS-4-9-11-12), Graf 43 = Gulf, Hoyt (helical spring) 44 = North American 45 = Western 47 = Lacoste-Romberg 48 = Lacoste-Romberg, Model D (microgravimeter) 5.. Quartz spring gravimeter for ground measurements 51 = Norgaard 52 = GAE-3 53 = Worden ordinary 54 = Worden (additional thermostat 55 = Worden worldwide 56 = Cak 57 = Canadian gravity meter, sharpe 58 = GAG-2 59 = SCINTREX CG2 6.. Gravimeters for under water measurements (at the bottom of the sea or of a lake) 60 = Gulf 62 = Western 63 = North American 64 = Lacoste-Romberg	(3 char.)
109-111	**Country code** (BGI)	(3 char.)
112	**Confidentiality** 0 = without restriction .....1 = with authorization 2 = classified	(1 char.)
113	**Validity** 0 = no validation 1 = good 2 = doubtful 3 = lapsed	(1 char.)
114-120	Numbering of the station (original)	(7 char.)
121-126	Sequence number	(6 char.)

EOS
SEA DATA FORMAT
RECORD DESCRIPTION
146 characters

Col.			
	1-8	B.G.I. source number	(8 char.)
	9-16	**Latitude** (unit : 0.00001 degree)	(8 char.)
	17-25	**Longitude** (unit : 0.00001 degree)	(9 char.)
	26-27	Accuracy of position	(2 char.)
		The site of the gravity measurements is defined in a circle of radius R	
		0 = no information	
		1 - R <= 5 Meters	
		2 = 5 < R <= 20 M (approximately 0'01)	
		3 = 20 < R <= 100 M	
		4 = 100 < R <= 200 M (approximately 0'1)	
		5 = 200 < R <= 500 M	
		6 = 500 < R <= 1000 M	
		7 = 1000 < R <= 2000 M (approximately 1')	
		8 = 2000 < R <= 5000 M	
		9 = 5000 M < R	
		10...	
	28-29	System of positioning	(2 char.)
		0 = no information	
		1 = Decca	
		2 = visual observation	
		3 = radar	
		4 = loran A	
		5 = loran C	
		6 = omega or VLF	
		7 = satellite	
		8 = solar/stellar (with sextant)	
	30	Type of observation	(1 char.)
		1 = individual observation at sea	
		2 = mean observation at sea obtained from a continuous recording	
	31-38	**Elevation of the station** (unit : centimeter)	(8 char.)
	39-40	Elevation type	(2 char.)
		1 = ocean surface	
		2 = ocean submerged	
		3 = ocean bottom	
	41-42	Accuracy of elevation	(2 char.)
		0 = no information	
		1 = E <= 0.02 Meter	
		2 = .02 < E <= 0.1 M	
		3 = .1 < E <= 1	
		4 = 1 < E <= 2	
		5 = 2 < E <= 5	
		6 = 5 < E <= 10	
		7 = 10 < E <= 20	
		8 = 20 < E <= 50	
		9 = 50 < E <= 100	
		10 = E superior to 100 Meters	
	43-44	Determination of the elevation	(2 char.)
		0 = no information	
		1 = depth obtained with a cable (meters)	
		2 = manometer depth	
		3 = corrected acoustic depth (corrected from Mathew's tables, 1939)	
		4 = acoustic depth without correction obtained with sound speed 1500 M/sec. (or 820 fathom/sec)	
		5 = acoustic depth obtained with sound speed 1463 M/sec (800 fathom/sec)	
		6 = depth interpolated on a magnetic record	
		7 = depth interpolated on a chart	
	45-52	Supplemental elevation	(8 char.)
	53-61	**Observed gravity** (unit : microgal)	(9 char.)
	62-67	**Free air anomaly** (0.01 mgal)	(6 char.)
	68-73	**Bouguer anomaly** (0.01 mgal)	(6 char.)
		Simple Bouguer anomaly with a mean density of 2.67. No terrain correction	
	74-76	Estimation standard deviation free-air anomaly (0.1 mgal)	(3 char.)

77-79	Estimation standard deviation bouguer anomaly (0.1 mgal)	(3 char.)
80-85	**Terrain correction** (0.01 mgal) *computed according to the next mentioned radius & density*	(6 char.)
86-87	Information about terrain correction 0 = no topographic correction 1 = tc computed for a radius of 5 km (zone H) 2 = tc computed for a radius of 30 km (zone L) 3 = tc computed for a radius of 100 km (zone N) 4 = tc computed for a radius of 167 km (zone 02) 11 = tc computed from 1 km to 167 km 12 = tc computed from 2.5 km to 167 km 13 = tc computed from 5.2 km to 167 km 14 =tc (unknown radius) 15 = tc computed to zone M (22 km) 16 = tc computed to zone G 17 = tc computed to zone K (18.8 km) 25 = tc computed to 48.6 km on a curved Earth 26 = tc computed to 64. km on a curved Earth	(2 char.)
88-91	Density used for terrain correction	(4 char.)
92-93	Mathew's zone *when the depth is not corrected depth, this information is necessary. For example : zone 50 for the Eastern Mediterranean Sea*	(2 char.)
94-95	Accuracy of gravity 0 = no information 1 = E <= 0.01 mgal 2 = .01 < E <= 0.05 mgal 3 = .05 < E <= 0.1 mgal 4 = 0.1 < E <= 0.5 mgal 5 = 0.5 < E <= 1. mgal 6 = 1. < E <= 3. mgal 7 = 3. < E <= 5. mgal 8 = 5. < E <= 10. mgal 9 = 10. < E <= 15. mgal 10 = 15 < E <= 20. mgal 11 = 20. < E mgal	(2 char.)
96-101	Correction of observed gravity (unit : microgal)	(6 char.)
102-110	Date of observation *in Julian day - 2 400 000 (unit : 1/10 000 of day)*	(9 char.)
111-113	Velocity of the ship (0.1 knot)	(3 char.)
114-118	Eötvös correction (0.1 mgal)	(5 char.)
119-121	**Country code** (BGI)	(3 char.)
122	**Confidentiality** 0 = without restriction 1 = with authorization 2 = classified	(1 char.)
123	**Validity** 0 = no validation 1 = good 2 = doubtful 3 = lapsed	(1 char.)
124-130	Numbering of the station (original)	(7 char.)
131-136	**Sequence number**	(6 char.)
137-139	**Leg number**	(3 char.)
140-145	**Reference station**	(6 char.)

Whenever given, the theoretical gravity (γ_0), free-air anomaly (FA), Bouguer anomaly (BO) are computed in the 1967 geodetic reference system.

The approximation of the closed form of the 1967 gravity formula is used for theoretical gravity at sea level :

$$\gamma_0 = 978031.85 \times [1 + 0.005278895 * \sin^2(\phi) + 0.000023462 * \sin^4(\phi)], \text{ mgals}$$

where ϕ is the geographic latitude.

The formulas used in computing FA and BO are summarized below.

Formulas used in computing free-air and Bouguer anomalies

Symbols used :

g	*: observed value of gravity*
γ	*: theoretical value of gravity (on the ellipsoid)*
Γ	*: vertical gradient of gravity (approximated by 0.3086 mgal/meter)*
H	*: elevation of the physical surface of the land, lake or glacier (H = o at sea surface), positive upward*
D_1	*: depth of water, or ice, positive downward*
D_2	*: depth of a gravimeter measuring in a mine, in a lake, or in an ocean, counted from the surface , positive downward*
G	*: gravitational constant* $(667.2\ 10^{-13}\ m^3\ kg^{-1}\ s^{-2}) \Rightarrow k = 2\ \pi\ G$
ρ_c	*: mean density of the Earth's crust (taken as* $2670\ kg\ m^{-3}$*)*
ρ_w^f	*: density of fresh water* $(1000\ kg\ m^{-3})$
ρ_w^s	*: density of salted water* $(1027\ kg\ m^{-3})$
ρ_i	*: density of ice* $(917\ kg\ m^{-3})$
FA	*: free-air anomaly*
BO	*: Bouguer anomaly*

Formulas :

* *FA : The principle is to compare the gravity of the Earth at its surface with the normal gravity, which first requires in some cases to derive the surface value from the measured value. Then, and until now, FA is the difference between this Earth's gravity value reduced to the geoid and the normal gravity* γ_0 *computed on the reference ellipsoid (classical concept). The more modern concept* *, *in which the gravity anomaly is the difference between the gravity at the surface point and the normal (ellipsoidal) gravity on the telluroid corresponding point may be adopted in the future depending on other major changes in the BGI data base and data management system.*

* *BO : The basic principle is to remove from the surface gravity the gravitational attraction of one (or several) infinite plate (s) with density depending on where the plate is with respect to the geoid. The conventional computation of BO assumes that parts below the geoid are to be filled with crustal material of density* ρ_c *and that the parts above the geoid have the density of the existing material (which is removed).*

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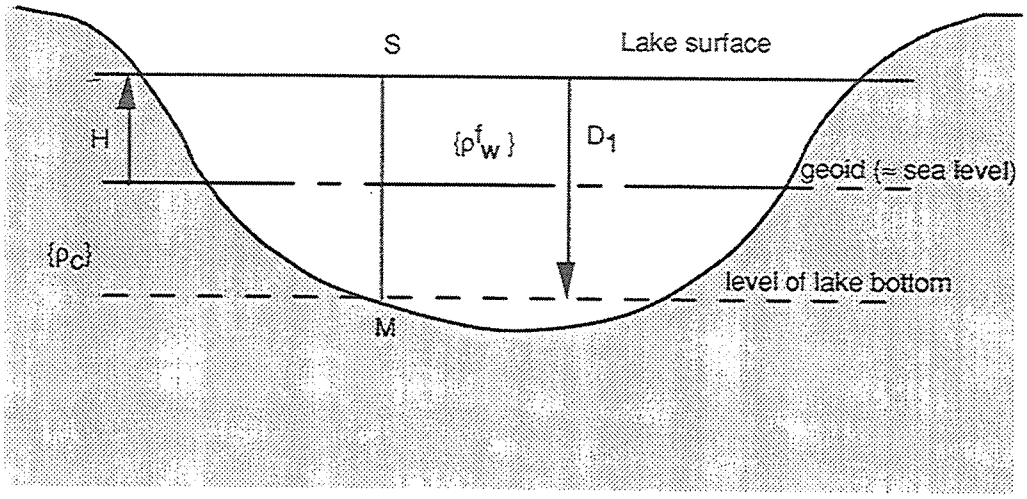
* cf. "On the definition and numerical computation of free air gravity anomalies", by H.G. Wenzel. Bulletin d'Information, BGI, n° 64, pp. 23-40, June 1989.

For example, if a measurement g_M is taken at the bottom of a lake, with the bottom being below sea level, we have :



$$g_S = g_M + 2\,k\,\rho_w^f\,D_1 - \Gamma D_1$$
$$\Rightarrow FA = g_S + \Gamma H - \gamma_0$$

Removing the (actual or virtual) topographic masses as said above, we find :

$$\begin{aligned}\delta g_s &= g_s - k\,\rho_w^f\,D_1 + k\,\rho_c(D_1 - H)\\ &= g_s - k\,\rho_w^f\,[H + (D_1 - H)] + k\,\rho_c\,(D_1 - H)\\ &= g_s - k\,\rho_w^f\,H + k\,(\rho_c - \rho_w^f)(D_1 - H)\end{aligned}$$

$$\Rightarrow \quad BO = \delta g_s + \Gamma\,H - \gamma_o$$

The table below covers most frequent cases. It is an update of the list of formulas published before.

It may be noted that, although some formulas look different, they give the same results. For instance BO (C) and BO (D) are identical since :

$$\begin{aligned}-k\,\rho_i H + k(\rho_c - \rho_i)(D_1 - H) &\equiv -k\,\rho_i(H - D_1 + D_1) - k(\rho_c - \rho_i)(H - D_1)\\ &\equiv -k\,\rho_i\,D_1 - k\,\rho_c(H - D_1)\end{aligned}$$

Similarly, BO (6), BO (7) and BO (8) are identical.

Elev. Type	Situation	Formulas
1	Land Observation-surface	$FA = g + \Gamma H - \gamma_0$
		$BO = FA - k\,\rho_c H$
2	Land Observation-subsurface	$FA = g + 2\,k\,\rho_c D_2 + \Gamma(H - D_2) - \gamma_0$
		$BO = FA - k\,\rho_c H$
3	Ocean Surface	$FA = g - \gamma_0$
		$BO = FA + k(\rho_c - \rho_w^s) D_1$
4	Ocean submerged	$FA = g + (2\,k\,\rho_w^s - \Gamma) D_2 - \gamma_0$
		$BO = FA + k(\rho_c - \rho_w^s) D_1$
5	Ocean bottom	$FA = g + (2\,k\,\rho_w^s - \Gamma) D_1 - \gamma_0$
		$BO = FA + k(\rho_c - \rho_w^s) D_1$
6	Lake surface above sea level	$FA = g + \Gamma H - \gamma_0$
	with bottom above sea level	$BO = FA - k\,\rho_w^f D_1 - k\,\rho_c (H - D_1)$
7	Lake bottom, above sea level	$FA = g + 2\,k\,\rho_w^f D_1 + \Gamma(H - D_1) - \gamma_0$
		$BO = FA - k\,\rho_w^f D_1 - k\,\rho_c (H - D_1)$
8	Lake bottom, below sea level	$FA = g + 2\,k\,\rho_w^f D_1 + \Gamma(H - D_1) - \gamma_0$
		$BO = FA - k\,\rho_w^f H + k(\rho_c - \rho_w^f)(D_1 - H)$
9	Lake surface above sea level	$FA = g + \Gamma H - \gamma_0$
	with bottom below sea level	$BO = FA - k\,\rho_w^f H + k(\rho_c - \rho_w^f)(D_1 - H)$
A	Lake surface, below sea level (here $H < o$)	$FA = g + \Gamma H - \gamma_0$
		$BO = FA - k\,\rho_c H + k(\rho_c - \rho_w^f) D_1$
B	Lake bottom, with surface below sea level ($H < o$)	$FA = g + (2\,k\,\rho_w^f - \Gamma) D_1 + \Gamma H - \gamma_0$
		$BO = FA - k\,\rho_c H + k(\rho_c - \rho_w^f) D_1$
C	Ice cap surface, with bottom below sea level	$FA = g + \Gamma H - \gamma_0$
		$BO = FA - k\,\rho_i H + k(\rho_c - \rho_i)(D_1 - H)$
D	Ice cap surface, with bottom above sea level	$FA = g + \Gamma H - \gamma_0$
		$BO = FA - k\,\rho_i D_1 - k\,\rho_c (H - D_1)$

2.6 Satellite Altimetry Data

BGI has access to the Geos 3, Seasat and Geosat data bases which are managed by the Groupe de Recherches de Géodésie Spatiale (GRGS). These data are now in the public domain. ERS1 and TOPEX-POSEIDON data are not.

Since January 1, 1987, the following procedure has been applied :

(a) Requests for satellite altimetry derived geoid heights (N), that is : time (julian date), longitude, latitude, N, are processed by BGI. for small areas (smaller than 20° x 20°), and forwarded to GRGS for larger areas.

(b) Requests for the full altimeter measurements records are forwarded to GRGS, or NASA in the case of massive request.

In all cases, the geographical area (polygon) and beginning and end of epoch (if necessary) should be given.

All requests for data must be sent to :

Mr. Gilles BALMA
Bureau Gravimétrique International
18, Avenue E. Belin - 31055 Toulouse Cedex - France

In case of a request made by telephone, it should be followed by a confirmation letter, or telex. Except in particular case (massive data retrieval, holidays...) requests are satisfied within one month following the reception of the written confirmation, or information are given concerning the problems encountered.

If not specified, the data will be written, formatted (EBCDIC) on labeled 9-track tape (s) with a fixed block size, for large amounts of data, or on diskette in the case of small files. The exact physical format will be indicated in each case.

3. USUAL SERVICES BGI CAN PROVIDE

The list below is not restrictive and other services (massive retrieval, special evaluation and products...) may be provided upon request.

The costs of the services listed below are a revision of the charging policy established in 1981 (and revised in 1989) in view of the categories of users : (1) contributors of measurements and scientists, (2) other individuals and private companies.

The prices given below are in french francs. They have been effective on January 1, 1992 and may be revised periodically.

3.1. Charging Policy for Data Contributors and Scientists

For these users and until further notice, - and within the limitation of our in house budget, we shall only charge the incremental cost of the services provided. In all other cases, a different charging policy might be applied.

However, and at the discretion of the Director of B.G.I., some of the services listed below may be provided free of charge upon request, to major data contributors, individuals working in universities, especially students ...

3.1.1. Digital Data Retrieval

. on one of the following media :
** printout ..... 2 F/100 lines*
** diskette..... 25 F per diskette (minimum charge : 50 F-*
** magnetic tape ..... 2 F per 100 records*
+ 100 F per tape - 1600 BPI
(if the tape is not to be returned)

. minimum charge : 100 F

. maximum number of points : 100 000 ; massive data retrieval (in one or several batches) will be processed and charged on a case by case basis.

3.1.2. Data Coverage Plots : in Black and White, with Detailed Indices

. 20°x20° blocks, as shown on the next pages (maps 1 and 2) : 400 F each set.

. For any specified area (rectangular configurations delimited by meridians and parallels) : 1. F per degree square : 100 F minimum charge (at any scales, within a maximum plot size of : 90 cm x 180 cm).

. For area inside polygon : same prices as above, counting the area of the minimum rectangle comprising the polygon.

3.1.3. Data Screening

(Selection of one point per specified unit area, in decimal degrees of latitude and longitude, i.e. selection of first data point encountered in each mesh area).

. 5F/100 points to be screened.

. 100 F minimum charge.

3.1.4. Gridding

(Interpolation at regular intervals Δ in longitude and Δ' in latitude - in decimal degrees) :

. 10 F/($\Delta\Delta'$) per degree square

. minimum charge : 150 F

. maximum area : 40° x 40°

3.1.5. Contour Maps of Bouguer or Free-Air Anomalies

At a specified contour interval Δ (1, 2, 5,... mgal), on a given projection :
10 F/Δ per degree square, plus the cost of gridding (see 3.4) after agreement on grid stepsizes. (at any scale, within a maximum map size for : 90 cm x 180 cm).

. 250 F minimum charge

. maximum area : 40° x 40°

3.1.6. Computation of Mean Gravity Anomalies

(Free-air, Bouguer, isostatic) over Δ xΔ' area : 10F/ΔΔ' per degree square.

. minimum charge : 150 F

. maximum area : 40°x40°

3.2. Charging Policy for Other Individuals or Private Companies

3.2.1. Digital Data Retrieval

..1 F per measurement

. minimum charge : 150 F

3.2.2. Data Coverage Plots, in Black and White, with Detailed Indices

. 2 F per degree square ; 100 F minimum charge. (maximum plot size = 90 cm x 180 cm)

. For area inside polygon : same price as above, counting the area of the smallest rectangle comprising ihe polygon.

3.2.3. Data Screening

. 1 F per screened point

. 250 F minimum charge

3.2.4. Gridding

Same as 31.4.

3.2.5. Contour Maps of Bouguer or Free-Air Anomalies

Same as 3.1.5.

3.2.6. Computation of Mean Gravity Anomalies

Same as 3.1.6.

3.3. Gravity Maps

The pricing policy is the same for all categories of users

3.3.1. Catalogue of all Gravity Maps

Printout : 200 F

Tape 100 F (+ tape price, if not to be returned)

3.2.2. Maps

. Gravity anomaly maps (excluding those listed below) : 100 F each

. Special maps :

Mean Altitude Maps

FRANCE	(1: 600 000)	1948	6 sheets	65 FF the set
WESTERN EUROPE	(1:2 000 000)	1948	1 sheet	55 FF
NORTH AFRICA	(1:2 000 000)	1950	2 sheets	60 FF the set
MADAGASCAR	(1:1 000 000)	1955	3 sheets	55 FF the set
MADAGASCAR	(1:2 000 000)	1956	1 sheet	60 FF

Maps of Gravity Anomalies

NORTHERN FRANCE	Isostatic anomalies	(1:1 000 000)	1954	55 FF
SOUTHERN FRANCE	Isostatic anomalies Airy 50	(1:1 000 000)	1954	55 FF
EUROPE-NORTH AFRICA	Mean Free air anomalies	(1:1 000 000)	1973	90 FF

World Maps of Anomalies (with text)

PARIS-AMSTERDAM	Bouguer anomalies	(1:1 000 000)	1959-60	65 FF
BERLIN-VIENNA	Bouguer anomalies	(1:1 000 000)	1962-63	55 FF
BUDAPEST-OSLO	Bouguer anomalies	(1:1 000 000)	1964-65	65 FF
LAGHOUAT-RABAT	Bouguer anomalies	(1:1 000 000)	1970	65 FF
EUROPE-AFRICA	Bouguer Anomalies	(1:10 000 000)	1975	180 FF with text 120 FF without text
EUROPE-AFRICA	Bouguer anomalies-Airy 30	(1:10 000 000)	1962	65 FF

Charts of Recent Sea Gravity Tracks and Surveys (1:36 000 000)

CRUISES prior to	1970	65 FF
CRUISES	1970-1975	65 FF
CRUISES	1975-1977	65 FF

Miscellaneous

CATALOGUE OF ALL GRAVITY MAPS

listing	200 FF
tape	300 FF

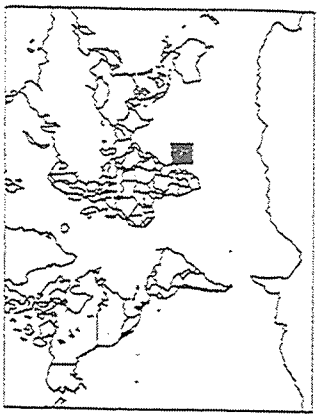
THE UNIFICATION OF THE GRAVITY NETS OF AFRICA

(Vol. 1 and 2)	1979	150 FF

. Black and white copy of maps : 150 F per copy

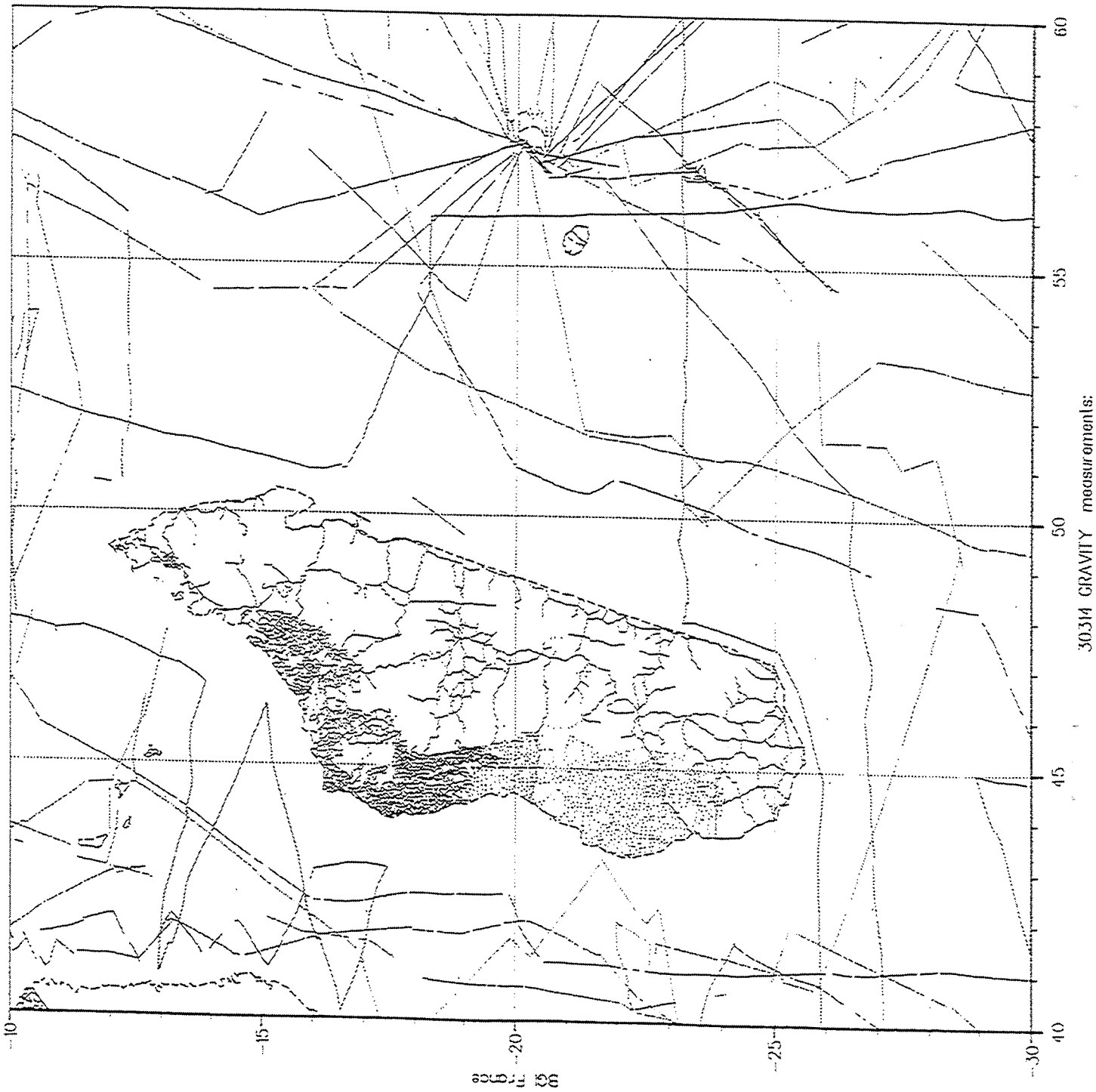
. Colour copy : price according to specifications of request.

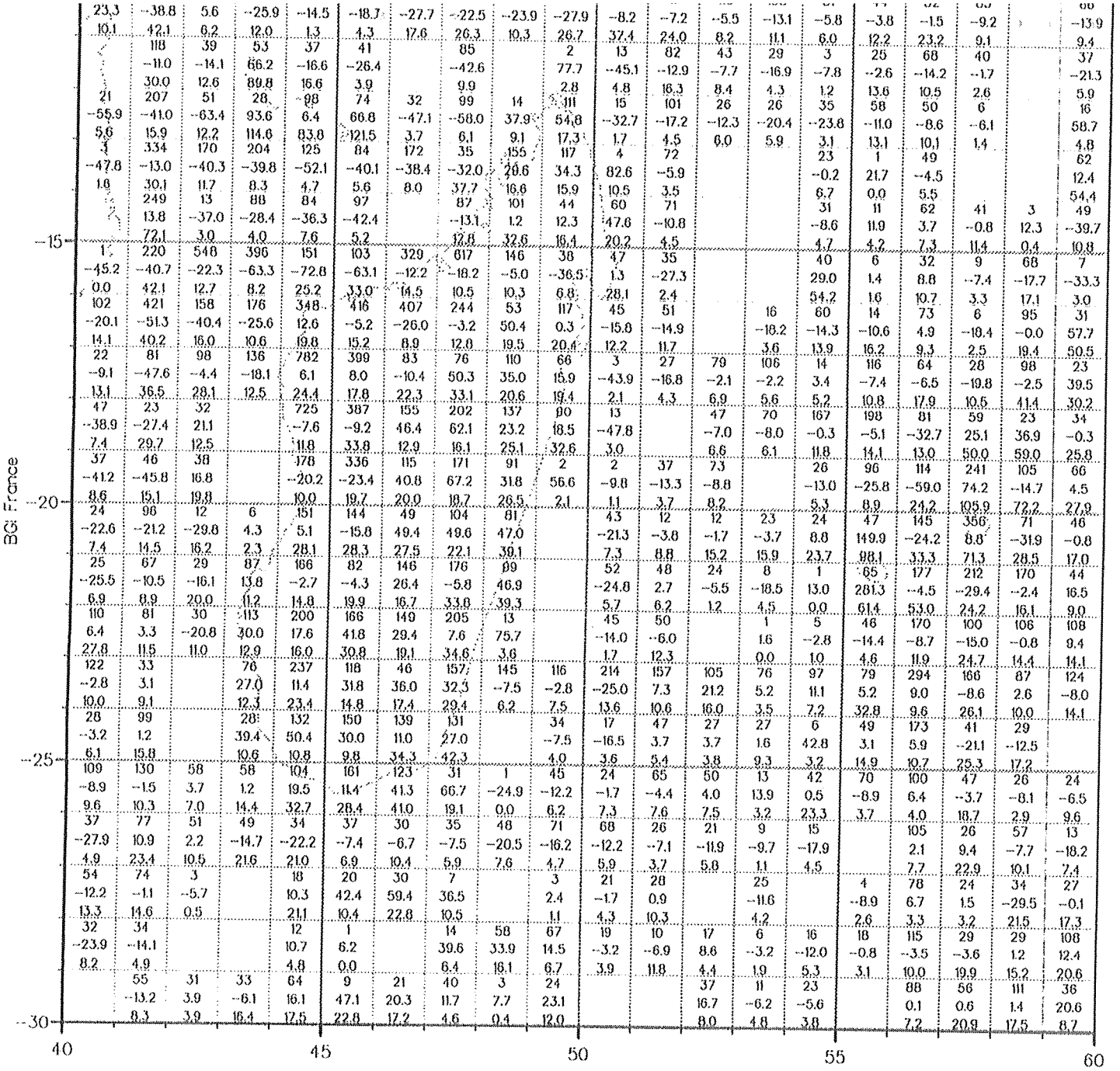
Mailing charges will be added for air-mail parcels when "Air-Mail" is requested)



Map 1. Example of data coverage plot

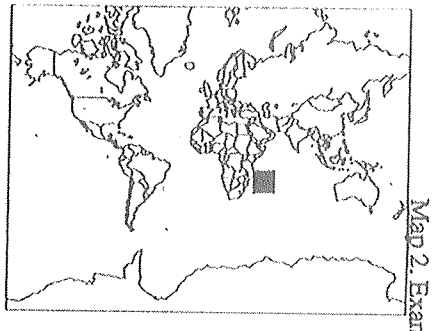
E12





30314 GRAVITY measurements:

19050 marine data 11264 land data



Map 2. Example of detailed index (Data coverage corresponding to Map 1)

BGI GRAVITY DATA

MEAN FREE AIR ANOMALY

1st field : number of points

2nd field : mean value (mgal)

3nd field : Std. Dev. (mgal)

E12

4. PROVIDING DATA TO B.G.I.

4.1. Essential Quantities and 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 instrument 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.

4.2. 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.

---

* 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, or this effect should be provided and clearly explained.

. Isostatic gravity

Please specify type of isostatic anomaly computed.
Example : Airy-Heiskanen, T = 30 km.

. Description of geological setting of each site

4.3. Formats

Actually, any format is acceptable as soon as the essential quantities listed in 4.1. are present, and provided that the contributor gives satisfactory explanations in order to interpret his data properly.

The contributor may use the EOL and/or EOS formats as described above, or if he wishes so, the BGI Official Data Exchange Format established by BRGM in 1976 : "Progress Report for the Creation of a Worldwide Gravimetric Data Bank", published in BGI Bull. Info, n° 39, and recalled in Bulletin n° 50 (pages 112-113).

If magnetifc tapes are used, contributors are kindly asked to use 1600 bpi, unlabelled tapes (if possible), with no password, and formatted records of possibly fixed length and a fixed blocksize, too. Tapes are returned whenever specified, as soon as they are copied

PART II

CONTRIBUTING PAPERS

Nouveau réseau de bases de référence pour le Nord de l'Algérie

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Résumé - Le premier réseau de bases de référence de l'Algérie a été réalisé par Lagrula (1951; 1959). La précision de celui-ci est de l'ordre de 0,2 à 0,3 mgal alors que celle de la base de Bouzaréa est de l'ordre du mgal (Lagrula, 1951; 1959). L'impossibilité de retrouver sur le terrain l'emplacement des stations de ce premier réseau nous a obligés, dans un premier temps, à le réétablir pour la partie nord. Ce nouveau réseau est composé de 74 bases et de 5 stations de remplacement. Sa compensation a été effectuée par la méthode des coefficients auxilaires. La précision des mesures est de 0,06 mgal. Les valeurs de la pesanteur aux stations sont calculées dans le système "IGSN71". La différence entre les valeurs de ce système et celles du système "LAGRULA", calculées à la même station est de +15,2 mgals.

New gravity base-station network in Northern Algeria

Abstract - A first gravity network has been made in the 50's in Northern Algeria by Lagrula (1951; 1959). The accuracy of this network is in the range of 0.2-0.3 mgal while that of the Bouzaréa base is in the range of 1 mgal (Lagrula, 1951; 1959). In the field, the precise location of this base-station network can hardly be recognized now because of the topographic changes. We have therefore realized a new gravity base-station network in that area, that consists of 74 basis and 5 replacement stations. Its compensation has been made using the auxiliary coefficients method. Measurements are given within 0.06 mgals error in the "IGSN71" reference frame. The difference between the values calculated in this system and those using "LAGRULA" system at the same station is +15.2 mgals.

Abridged English version - "LAGRULA" gravity network basis has been determined after direct and indirect connexions with the Bouzaréa base-station (Algiers), which is one of the international basis network (Lagrula, 1951; 1959). This network was realized more than 30 years ago and it is impossible to localize the base stations in the field. This is why we decided to perform a new gravity network. The use of new gravity-meters makes it possible to achieve a better accuracy.

The Bouzaréa base is located in the CRAAG center (Astronomy Observatory of Algiers). Its gravity value is 979912 mgals in the "LAGRULA" reference frame. Its accuracy is about 1 mgal (Lagrula, 1951; 1959). A new value has been calculated from the International Gravity Office, in the "IGSN71" reference frame. It yields 979896.83 mgals (BGI, 1977; 1978).

The new gravity network in Northern Algeria consists of 74 main basis and 5 replacement stations. The choice of these sites has been made to have a regular ring and to be easily recognized. The distance between two basis is almost seventy kilometers in the North of the region and one hundred kilometers in the south (fig.1). The sites are often located next to new and official buildings.

Each base is connected three times to its adjacents. Corrections for the drift and the sun-moon variations have been taken linear. The final gravity measurements in all stations have been determined successively from the Bouzaréa base-station. Twenty-two first connexions have been realized with two gravity-meters, the Wordens 774 and 1112. The second one is new and its standard coefficient is known. Thus, we have determined the standard coefficient of the Worden 774 and we continued working using it. We then calculated all connexion values and ring-squares which are different from zero. These ring-squares are the result of error measurements and their study is a good indicator of accuracy. We made the repartition of the squares on all connexions of each ring with the auxiliary coefficients method before calculating the gravity value in each base-station. This method does not improve the measurements but give more homogeneity to the network.

The accuracy of the result is calculated using the ring-squares by dividing it by the connexion number of each ring. An arithmetic mean is then applied which provides an accuracy of 0.06 mgals.

This new gravity base-station network is essential to realize any gravity survey in the North of Algeria. The accuracy result is good for a second order network. The choice of the base-station sites gives to the network a long-time duration to realize any gravity survey. The gravity values and descriptions of the base-stations are given in annex 1 and 2.

I - INTRODUCTION - Les bases de réference du réseau "LAGRULA" ont été déterminées par des liaisons directes ou indirectes (en passant par d'autres stations du réseau) avec la base de Bouzaréa (Alger), qui, elle même, fait partie du réseau mondial (Lagrula, 1951; 1959). Ce réseau ayant été réalisé il y a plus d'une trentaine d'années, a vu disparaître l'emplacement de ses stations à cause des transformations routières et immobilères. Nous avons pensé qu'il serait plus facile de réaliser un nouveau réseau que d'essayer de retrouver l'emplacement des stations constituant ce premier. De même, l'utilisation de gravimètres plus récents nous a permis d'obtenir une meilleure précision.

II. LA BASE DE BOUZAREA - Elle est située au centre de recherches en Astronomie, Astrophysique et Géophysique (CRAAG, ancien observatoire astronomique d'Alger). Dans le système "LAGRULA", la valeur de la pesanteur à cette base est de 979912 mgals. Sa précision est de l'ordre du mgal (Lagrula, 1951; 1959). Une nouvelle valeur a été calculée par le Bureau Gravimétrique International (BGI) pour cette base, dans le système "IGSN71", elle est de 979896,83 mgals (BGI, 1977; 1978).

III. CHOIX DES STATIONS DU RESEAU - Le nouveau réseau de bases du Nord de l'Algérie est composé de 74 stations principales et de 5 stations de remplacement. L'emplacement de celles-ci a été choisi de façon telle que l'on obtienne le maillage le plus régulier possible, d'accès commode et facile à retrouver. Il est souvent situé à proximité d'édifices neufs, de batiments officiels, d'intersection de nouvelles et grandes routes ainsi que de monuments car ceux-ci ne sont pas susceptibles de disparaître dans un proche avenir. La distance moyenne entre les bases est d'environ soixante-dix kilomètres au Nord et cent kilomètres lorsqu'on se dirige vers le Sud (fig.1). Dans les cas où nous avons douté du bon choix de cet emplacement, nous avons installé une autre base à proximité que nous avons appelé station de remplacement.

IV. CORRECTION DE DERIVE ET DE VARIATION LUNI-SOLAIRE - Chaque base a été reliée à ses voisines par un aller-retour-aller, ce qui nous a permis de déterminer deux valeurs de la liaison entre les deux bases considérées dont nous avons fait la moyenne arithmétique pour déterminer la liaison finale. Pour corriger la dérive (la variation luni-solaire ayant été incluse dans celle-ci), nous avons procédé de la façon suivante:

Soient: Deux bases A et B et
L_{A1}, la lecture faite en A au temps t_1;
L_{B2}, la lecture faite en B au temps t_2, en partant de A;
L_{A3}, La lecture faite en A au temps t_3, en revenant de B;
L_{B4}, la lecture faite en B au temps t_4, en repartant de A.

Pour corriger l'influence de la dérive, nous l'avons supposée linéaire car le temps de fermeture sur la même base n'a jamais dépassé trois heures. Ce qui nous a permis de calculer la dérive en A, qui est (L_{A3}-L_{A1}) pour un temps (t_3-t_1), ensuite nous avons déterminé la lecture en A au temps t_2 (L_{A2}) grâce à la relation suivante: $L_{A2} = L_{A1} + (L_{A3} - L_{A1})\,(t_2 - t_1)/(t_3 - t_1)$.

Nous avons ensuite déterminé la première liaison (L_{B2}-L_{A2}) et de la même façon (L_{B3}-L_{A3}) dont nous avons fait la moyenne pour déterminer la liaison finale entre les bases A et B (L_B-L_A). Si nous supposons connue la pesanteur en A (g_A), alors la pesanteur en B (g_B) est donnée par la relation:
$g_B = g_A + k(L_B - L_A)$,
où k représente le coefficient d'étalonnage du gravimètre utilisé.

V. ACQUISITION DES DONNEES - Les vingt deux premières liaisons ont été effectuées avec deux gravimètres ensemble, les Worden 774 et 1112 dont le dernier était neuf. L'utilisation de ces deux appareils ensemble nous a permis d'étalonner le premier grâce au second (dont la constante était connue) et de contourner le problème de l'inexistance de bases d'étalonnage (leur emplacement ayant disparu). Le reste des liaisons a été établi avec le Worden 774. La détermination du coefficient d'étalonnage de celui-ci s'est faite grâce à la relation: $k_{774} = (k_{1112})(L_{1112})/(L_{774})$,

où L_{1112} et L_{774} sont les liaisons effectuées entre deux mêmes bases avec les deux gravimètres respectivement. Nous avons choisi comme coefficient d'étalonnage du gravimètre Worden 774 la moyenne des vingt deux valeurs de celui-ci ainsi obtenue.

VI. COMPENSATION DU RESEAU - Après avoir déterminé les valeurs des différentes liaisons entre les bases, nous avons obtenu un réseau de mailles formées par ces liaisons. Nous avons alors calculé l'écart de fermeture de chaque maille. Celui-ci serait nul si les valeurs des liaisons, donc des mesures, étaient rigoureusement précises, ce qui n'est pas le cas. Nous pouvons dire que cet écart est un bon indicateur de la précision des mesures. Afin de donner aux résultats une certaine homogénéïté, nous avons compensé le réseau obtenu, avant de déterminer la pesanteur en chaque station. La méthode utilisée est celle des coefficients auxiliaires. Elle présente, sur la méthode de Kirchoff, l'avantage de réduire de moitié le nombre d'équations à résoudre. Avant de l'utiliser, il est nécessaire de prendre certaines précautions:

- L'orientation de la liaison se fait de la base où la lecture est la plus faible à celle où elle est la plus élevée, ainsi toutes les liaisons seront positives.
- On définit un sens conventionnel de rotation pour l'ensemble des mailles et l'on comptera en positif toutes les liaisons orientées dans ce sens et en négatif celles orientées dans le sens contraire. Ainsi les écarts de fermeture prendront un signe.

Soit la maille μ, F_μ est son écart de fermeture et $P_{k\mu}$, le nombre de liaisons qui la composent. $N_{\mu\lambda}$ est le nombre de côtés communs aux mailles λ et μ et L_μ est son coefficient auxiliaire.

Soit $F_\mu = P_{k\mu}L_\mu - \sum_\lambda N_{\mu\lambda}L_\lambda$ (1)

L'application de la relation (1) à l'ensemble des mailles nous permet d'obtenir un système linéaire A.X=B de dimension le nombre de liaisons (dans notre cas quarante sept) où X représente l'ensemble des coefficients auxiliaires. Nous avons résolu ce système avec la méthode de Gauss. Pour déterminer la correction, E_k, à apporter à chaque liaison k nous avons utilisé la relation suivante:

$E_k = - \sum_\alpha \varepsilon_{k\alpha}L_\alpha$ avec

$\varepsilon_{k\alpha}$ = +1 si la liaison k est parcourue dans le sens positif,
-1 si elle est parcourue dans le sens négatif,
0 si elle n'appartient pas à la maille α.

On détermine alors les valeurs compensées des différentes liaisons en utilisant la relation suivante:
$M_i=N_i+E_i$ i Œ [1,47]
où M_i est la liaison corrigée et N_i, la liaison non corrigée.
Nous avons vérifié que tous les écarts de fermeture calculés à partir des liaisons corrigées sont nuls.

VII. PRECISION DES RESULTATS - Pour déterminer la précision des résultats obtenus, nous nous sommes appuyés sur le fait que l'écart de fermeture d'une maille du réseau est le résultat des erreurs commises sur les différentes liaisons qui la composent, donc des différentes mesures effectuées. Nous avons alors calculé le rapport de l'écart de fermeture de chaque maille au nombre de liaisons de celle-ci dont nous avons déterminé une moyenne arithmétique de 0,06 mgal qui est considérée comme la précision du réseau.

VIII. CONCLUSION - Le nouveau réseau de bases de référence que nous avons établi est indispensable à la réalisation de la couverture gravimétrique du Nord de l'Algérie. Il est à remarquer que les stations de ce réseau sont éloignées les unes des autres et ne permettent pas le tracé d'une carte d'anomalies (d'où l'inutilité de donner les coordonnées x,y,z des différentes stations). Nous pensons que la précision des résultats obtenue est acceptable pour un réseau du second ordre. Le choix de l'emplacement des bases du réseau à proximité d'édifices récents lui confère une durée de vie suffisante pour la réalisation de la couverture gravimétrique. La valeur de la pesanteur aux différentes stations, ainsi que la description de leur emplacement exact sur le terrain sont données en annexes 1 et 2.

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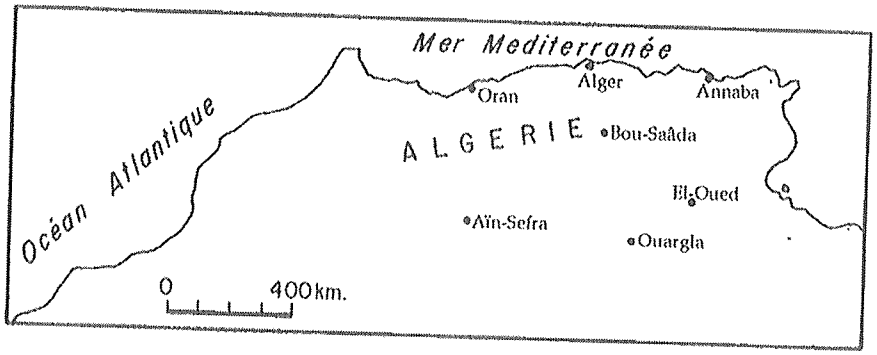

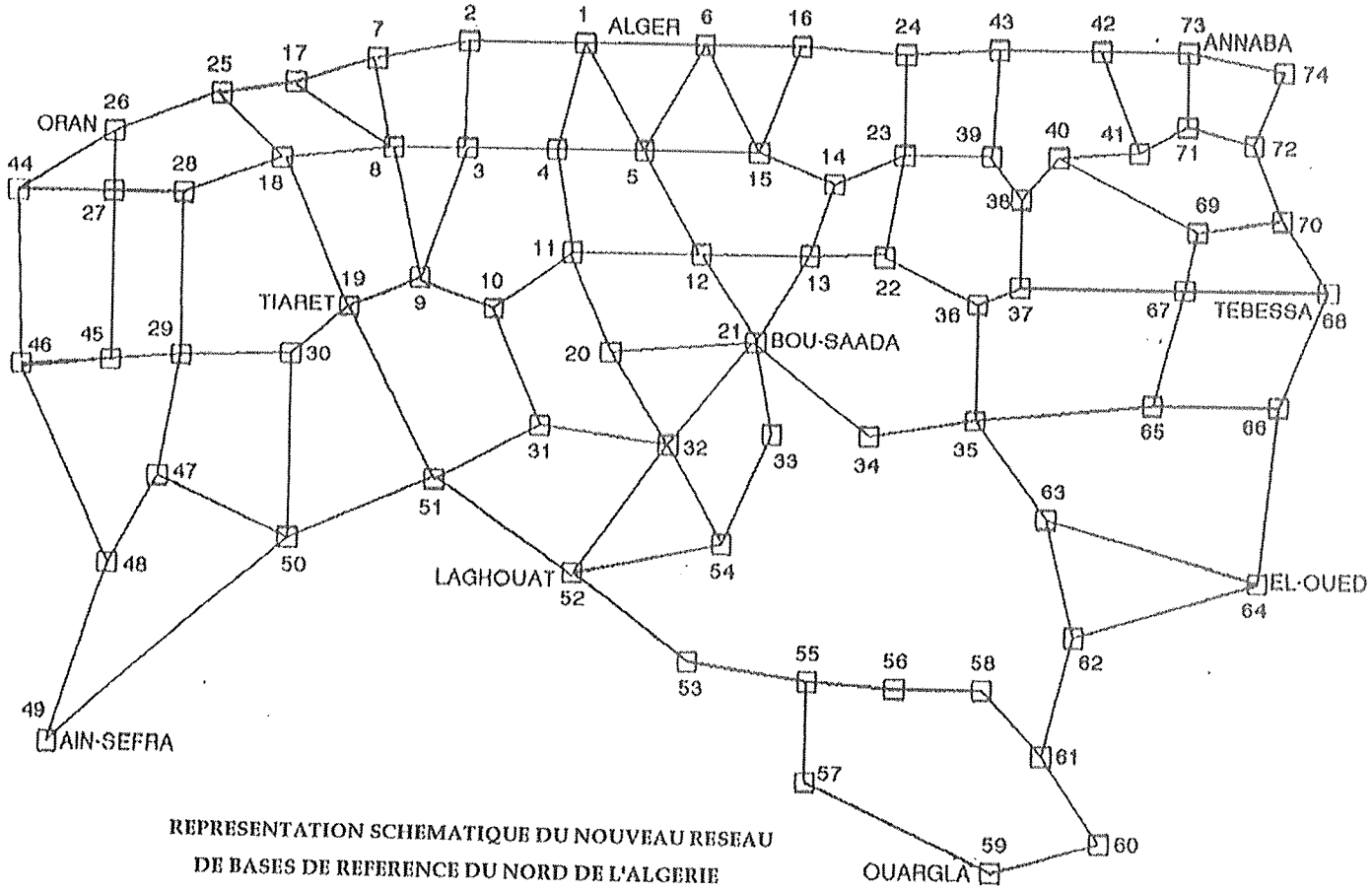

REPRESENTATION SCHEMATIQUE DU NOUVEAU RESEAU
DE BASES DE REFERENCE DU NORD DE L'ALGERIE

Annexe 1: Pesanteur aux différentes stations du nouveau réseau dans le système "IGSN71"

Annex 1: Gravity data of the new network in the "IGSN71" frame

N°	LOCALITE	g_{1971}(mgals)	N°	LOCALITE	g_{1971}(mgals)
01	Bouzaréa	979896.8	40	El-Khroub	979663.0
1R	Dar-El-Beida	979889.4	40R	Constantine	979659.0
02	Cherchell	979926.8	41	Oued-Zenati	979686.5
03	Khemis-Miliana	979769.4	42	El-Hadaïck	979921.7
04	Médéa	979633.2	43	El-Milia	979902.8
05	Bir-Ghbalou	979691.5	44	Tlemcen	979510.2
06	Draâ-Ben-Khedda	979923.8	45	Ras-El-Ma	979376.4
07	Ténès	979915.0	46	El-Aricha	979316.7
08	Chlef	979812.4	47	Bougtob	979358.8
09	Tissemsilt	979517.0	48	Méchria	979280.4
10	Hassi-Feddoul	979527.1	49	Aïn-Sefra-1	979211.3
11	Bougzoul	979578.1	49R	Aïn-Sefra-2	979213.4
12	Aïn-El-Hdjel	979597.2	50	El-Bayadh	979239.6
13	M'sila	979580.2	51	Aflou	979261.2
14	Bordj-Bou-Arreridj	979582.8	52	Laghouat	979395.3
15	M'Chedallah	979746.8	53	Ghardaïa-1	979359.5
16	El-Kseur	979870.7	54	Messaâd	979370.7
17	Khadra	979856.2	55	Berriane	979386.8
18	Relizane	979777.1	56	Guerrara	979425.4
19	Tiaret	979473.0	57	Ghardaïa-2	979321.9
20	Hassi-Bahbah	979479.0	58	El-Alia	979471.8
21	Bou-Saâda	979566.8	59	Ouargla	979385.8
22	Magra	979559.8	60	Hassi-Messaoud-1	979370.7
23	Sétif	979562.4	60R	Hassi-Messaoud-2	979375.0
24	Souk-El-Tnine	979899.9	61	Touggourt-1	979467.8
25	Mostaganem	979798.7	62	Touggourt-2	979511.0
26	Oran	979808.3	63	Biskra-2	979592.2
27	Sidi-Bel-Abbès	979616.0	64	El-Oued	979530.2
28	Mascara	979620.1	65	Khangat-Sidi-Nadji	979586.7
29	Saïda	979472.5	66	Négrine	979531.3
30	Aïn-Kermes	979431.1	67	Khenchela-1	979478.1
31	El-Idrissia	979360.8	67R	Khenchela-2	979479.7
32	Djelfa	979374.8	68	Tebessa	979529.4
33	Aïn-El-Melh	979453.1	69	Aïn-Beïda	979542.5
34	Ouled-Djellal	979597.1	70	El-Aouinet	979629.0
35	Biskra-1	979618.6	71	Guelma	979790.1
36	Aïn-Touta	979478.1	72	Souk-Ahras	979677.9
37	Batna	979477.2	73	Annaba	979925.7
38	Aïn-M'lila	979596.9	74	El-Kalaâ	979911.8
39	Oued-Athmania	979655.2			

Annexe 2: Description de l'emplacement des stations de référence
Annex 2: Description of the location of the reference stations

01-Bouzaréa (CRAAG): Ancien bureau du télescope Foucault. A l'intérieur, devant la porte d'entrée et sur la plaque de marbre.

01R-Aéroport international d'Alger (station de remplacement): Pavillon des lignes internationales, du côté le plus proche de la tour de contrôle, dans la salle la plus à gauche et devant le pilier central le plus proche de la porte donnant sur la piste d'atterrissage.

02-Cherchell: Au musée de la ville, sur la partie droite de la marche d'escalier.

03-Khemis-Miliana: A l'intersection des routes N4, N14 et N18. En venant de Médéa et à droite du pont se trouvant avant cette intersection.

04-Médéa: A l'intersection des routes N1 et N18, au milieu de la marche supérieure de la stelle érigée sur le terre-plein de la route d'Alger.

05-Bir-Ghbalou: A l'intersection des routes N8 et N18, au milieu du terre-plein circulaire central.

06-Draâ-Ben-Khedda (Tizi-Ouzou): En venant d'Alger, à environ 500 mètres de l'entrée du village et sur la partie droite du trottoir de l'entrée du pont de Oued Sebaou et qui mène vers Sidi-Naâmane.

07-Ténès: Monument du centre ville, sur la partie droite de la marche supérieure.

08-Chlef (ex El-Asnam): A l'intersection des routes N4 et N19, sur la marche supérieure de la stelle érigée à l'occasion du lancement des travaux de reconstruction de cette ville après le séisme du 10/10/1980.

09-Tissemsilt: Au monument du centre ville, sur la partie droite de la marche supérieure.

10-Hassi-Feddoul: Intersection des routes N40 et W77, en allant vers le village, à gauche et sous la plaque indicatrice de direction.

11-Bougzoul: Intersection des routes N40 et N1, sur le terre-plein triangulaire central se trouvant sur la route menant vers Djelfa.

12-Aïn-El-Hdjel: Intersection des routes N8 et N40, en venant de M'sila et sur le terre-plein le plus à droite.

13-M'sila: En venant de Bordj-Bou-Arreridj, on tourne à gauche au rond point central, la station se trouve sur la partie droite de l'entrée du pont de Oued M'sila, qui lui même se trouve sur la route de Barika.

14-Bordj-Bou-Arreridj: A la sortie de la ville, en allant vers M'sila, sous le pont du chemin de fer, à l'entrée et à gauche de celui-ci.

15-M'Chedallah: En allant vers Sétif et Alger, sur la partie droite de l'entrée du pont de Oued Sahel.

16-El-Kseur: En Allant vers Béjaïa, à environ 500 mètres du village, sur la partie droite de l'entrée du pont.

17-Khadra: Monument du centre du village, sur la partie droite de la marche supérieure.

18-Relizane: Intersection des routes N4 et N23, devant le transformateur de la Sonelgaz et sur la partie droite de la marche d'escalier.

19-Tiaret: Au siège de la Wilaya (Préfecture) de Tiaret, devant la porte d'entrée et sur la partie droite.

20-Hassi-Bahbah: Devant la porte d'entrée de l'agence postale, sur la partie gauche de la marche inférieure de l'escalier.

21-Bou-Saâda: Intersection des routes N8 et N46, sur le terre-plein triangulaire central et devant le panneau indicateur de direction.

22-Magra: Après l'intersection des routes N40 et N28, en allant vers Batna et Barika et sur la partie droite de l'entrée de Oued Nakhal.

23-Sétif: Aïn-Fouara, source se trouvant au centre ville, devant le robinet qui se trouve sous la statue vue de face.

24-Souk-El-Tnine: Intersection des routes N9 et N43, à l'extérieur du collège mixte de ce village et contre le pilier droit du portail d'entrée.

25-Mostaganem: Intersection des routes N11 et N23 se trouvant à environ 1500 mètres du centre ville. En venant de Relizane, sur la dalle consolidant les panneaux "sens interdit et obligatoire".

26-Oran: Intersection des routes N4 et N11 se trouvant à environ 2000 mètres du centre ville, sur le terre-plein se trouvant du côté de la ville, sur le trottoir et devant les panneaux "sens interdit et obligatoire".

27-Sidi-Bel-Abbès: Monument se trouvant au centre ville, sur la première marche d'escalier du flambeau se trouvant devant celui-ci.

28-Mascara: Devant la poste qui se trouve au centre ville, sur la marche supérieure et contre le pilier de droite.

29-Saïda: Siège de la Wilaya (Préfecture), contre le pilier droit du portail d'entrée et sur le bord du trottoir.

30-Aïn Kermes: Monument se trouvant hors du village, contre le pilier gauche du portail d'entrée.

31-El-Idrissia: Monument se trouvant à la sortie de la village et sur la route de Djelfa, sur la plateforme supérieure et contre celui-ci.

32-Djelfa: Pont de Oued El Mellah qui se trouve à la sortie de la ville, sur la route d'Alger, sur le bord droit de l'entrée de celui-ci.

33-Aïn-El-Melh: Pont qui se trouve à la sortie du village et sur la route d'Aïn-Rich, sur le bord gauche de l'entrée de celui-ci.

34-Ouled-Djellal: A l'intersection des routes N46 et W60 qui se trouve entre Bou-Saâda et Biskra et à 61 kms de cette dernière, sous le panneau indicateur de direction de Ouled-Djellal.

35-Biskra-1: Lycée du Docteur Saâdane qui se trouve à l'entrée de la ville en venant de Bou-Saâda, à l'extérieur du portail d'entrée et contre le pilier droit.

36-Aïn-Touta: Pont de Oued Tilaton qui se trouve à 500 mètres environ du village. En venant de Barika, sur la partie droite de l'entrée du pont.

37-Batna: A l'entrée du lycée Salah-Eddine-El-Ayoubi, devant le pilier droit et sur la première marche d'escalier.

38-Aïn-M'lila: Monument ayant la forme d'un arc qui se trouve au centre ville, contre le pilier central.

39-Oued-Athmania: Intersection des routes N5 et W17, sur le bord droit de l'entrée du pont de Oued-Seguine qui se trouve à proximité de celle-ci.

40-El-Khroub: Siège de l'APC (Mairie) d'El-Khroub, sur la première marche de l'escalier de droite et contre le pilier droit.

40R-Constantine (Aéroport Aïn-El-Bey, station de remplacement): Devant le pilier droit de l'entrée au salon d'honneur de celui-ci.

41-Oued-Zenati: En venant de ce village, sur la partie gauche de l'entrée du pont portant le même nom.

42-El-Hadaïck: Stelle qui se trouve au centre du village et devant l'intersection des routes N3 et N43, sur la plateforme supérieure et contre le pilier central, du côté qui fait face à la route.

43-El-Milia: En venant de Jijel, sur le bord droit de l'entrée du pont de Oued-El-Kebir qui se trouve avant l'intersection des routes N43 et N27.

44-Tlemcen: Entrée du lycée Malika Hamidou, sur la partie droite de la quatrième marche d'escalier et contre la rampe.

45-Ras-El-Ma: Monument qui se trouve au centre du village, au milieu de la marche et du côté nord-est.

46-El-Aricha: Intersection des routes N22 et N13, contre l'arête centrale du mur nord qui supporte les panneaux indicateurs de direction de Sidi-Bellabes et Tlemcen.

47-Bougtob: Monument qui se trouve au centre du village, au milieu de la marche supérieure.

48-Mechria: Intersection des routes N6 et N22, devant le montant droit du panneau indicateur de direction de Tlemcen, El-Aricha et Mekmen-Ben-Amar.

49-Aïn-Sefra-1: En venant de Mechria, intersection des routes N6 et celle menant au centre ville et qui se trouve à environ 1500 mètres de celui-ci, au milieu du terre-plein et devant le poteau d'éclairage public.

49R-Aïn-Sefra-2 (station de remplacement): Monument qui se trouve au centre ville, au milieu de la dalle et contre la partie centrale de celui-ci.

50-El-Bayadh: Atlas-Hôtel, contre le pilier droit du portail d'entrée et sur le trottoir.

51-Aflou: Mosquée du centre ville, portant le chiffre "1902" au dessus de la porte d'entrée, contre le pilier droit de cette dernière.

52-Laghouat: Sur la partie droite de l'entrée du pont de Oued-Mzi qui se trouve à la sortie de la ville et sur la route d'Alger.

53-Ghardaïa-1: Intersection des routes N1 et celle menant à Hassi-R'mel, sur le terre plein central et devant les panneaux indicateurs des "sens interdit et obligatoire".

54-Messaâd: Sur la partie droite de l'entrée du pont de Oued Messaâd qui se trouve à la sortie du village et sur la route de Bousaâda.

55-Berriane: Mosquée du village, sur la première marche d'escalier, tout à fait à droite et contre le mur.

56-Guerrara: Contre le pilier droit de l'entrée au monument du village.

57-Ghardaïa-2-: En venant de Ouargla, à l'intersection des routes N1 et N49 qui se trouve à environ 24 kms de Ghardaïa, sur la dalle en ciment consolidant le panneau indicateur de direction de cette dernière et d'Alger.

58-El-Alia: Siège de l'APC (Mairie), sur la partie droite de la première marche d'escalier.

59-Ouargla: En allant vers Touggourt, intersection des routes N49 et N56 qui se trouve à 14 kms de Ouargla, contre le panneau indicateur de direction de la N49.

60-Hassi-Messaõud-1: Intersection des routes N3 et N36 qui se trouve à 20 kms de cette ville, au milieu du terre plein central et devant le panneau "STOP".

60R-Hassi-Messaoud-2 (station de remplacement): Institut Algérien du Pétrole, devant le premier lampadaire de droite de l'allée menant à l'entrée de celui-ci et contre la bordure du trottoir.

61-Touggourt-1: En allant de Touggourt vers Ouargla, à l'intersection des routes N3 et W33, devant le panneau indicateur de direction.

62-Touggourt-2: Agence touristique qui se trouve sur la place de la liberté, devant la porte d'entrée.

63-Biskra-2: En allant de Biskra vers El-Oued et Touggourt, à l'intersection des routes N3 et N48, devant le panneau indicateur de direction.

64-El-Oued: Siège de l'APC (Mairie), contre le pilier droit du portail d'entrée et sur le trottoir.

65-Khangat-Sidi-Nadji: Agence postale, à droite de l'entrée principale et sous la boite aux lettres.

66-Négrine: Poste de la police des frontières, en face de la station d'essence, préau de droite (côté garage) et à gauche du pilier droit (contre le mur).

67-Khenchela-1: Monument ayant la forme d'une pyramide, devant le pilier droit du portillon d'entrée et sur le trottoir.

67R-Khenchela-2 (station de remplacement): Monument qui se trouve en face du siège de l'APC (Mairie), devant le pilier droit de l'entrée.

68-Tébessa: Cimetière des martyrs qui se trouve à la sortie de la ville, en allant vers Souk-Ahras, devant le pilier droit du portail d'entrée.

69-Aïn-Beida: Devant l'entrée principale du souk-el-fellah (grande surface), sur l'extrêmité droite de la première marche d'escalier.

70-El-Aouinet: Monument qui se trouve à 1000 mètres du village et sur la route de Tébessa, au milieu de la dernière marche d'escalier.

71-Guelma: En allant vers Annaba, sur le côté droit de l'entrée du pont de Oued-Seybouse.

72-Souk-Ahras: A la coupole qui se trouve dans le jardin du centre ville, au milieu de la première marche d'escalier et en face de la statue du lion.

73-Annaba: En allant vers Skikda, à 500 mètres de l'intersection des routes N44 et N21, sous l'autopont, à droite et contre le milieu du mur.

74-El-Kalaâ: Monument qui se trouve devant le port de pêche et en face de l'ancienne église, au milieu de la marche supérieure.

On the Reference Gravity Networks of Romania

Lucian Besutiu, Vlad Rosca*, Nicolae Gulie***

Introduction

The earliest known gravity observations were carried out on the Romanian territory by the turn of the century. Pendulum measurements were reported for 13 stations in northern Transylvania, by the Military Geographic Institute of Vienna in 1892, for 10 stations in central Transylvania in 1903 - 1913 by the Hungarian Geodetic Institute and for Bucharest and Galati by Boras, in 1900 (Tanni, 1942).

The first gravity reference network of Romania was established between 1941-1948 (Socolescu, 1950) as a 50 pendulum stations configuration uniformly spaced over the territory. This net allowed the drawing of the first national gravity map at the scale 1:1.500.000, in 1957, by I. Vencov and R. Botezatu.

In 1956 was started the construction of a first order gravimetric network, with a central point configuration, by using a Norgaard gravimeter. The whole description of the operation and the definite values of the 15 stations of the network are published in a comprehensive report (Botezatu, 1961). The accuracy of this network was well within the specification of the instrument, the greatest observed triangle closure error was 0,19 mgals.

The evolution of the instruments on one hand and the destruction by various human activities of almost half the stations of the first order triangulation on the other hand, determined in 1976 the designing and thereafter the realisation of a new first order network together with a second order reference gravity net.

By designing the reference gravity networks, the following basic requirements have been taken into account :

a. the including of Botezatu's first order triangulation stations within the frame of the new network ;
b. an uniform geographical distribution of the network stations ;
c. sites and ties between the stations allowing for gravity differences less than 100 mgals i.e. within the dial range of the gravimeters.

Besides, the designing had to decide on some other problems as for instance :

1. the covering range corresponding to each network ;
2. the type of the net ;
3. the measuring technique, i.e. :
   - the minimal number of measurements on each tie required to assure the requested accuracy of the network
   - the type and number of utilised gravimeters
   - transportation and measuring programme.

The experience of the first gravimetric network of Romania, the theoretical works done by Sobakar (1962, 1970) and by the authors of the design, led to the establishing of the main features of the project which are pointed out in the following.

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I. A second order reference gravity network comprising 222 stations. This figure corresponds to a mean coverage of 1 st/1065 sqkm, fulfilling the requirements of further high resolution mapping developments.

II. A first order control gravity network of 19 stations assures the accuracy of the second order reference network and also permits an uniform transmission of an absolute gravity value throughout the reference nets.

III. Both networks are triangle networks.

IV. At least 6 independent measurements have been carried out on each side of these triangles, in order to tend to a + 0.02 mgals accuracy for gravity value assigned to the side. Simultaneous measurements with three gravimeters have been performed at least twice, in different days, on each tie.

V. Helicopter transportation meeting the best the accuracy and metrological safety requirements of the networks setting up, has been used in as much as possible.

VI. To avoid the fate of Botezatu's network, airport has been sited far from buildings and runways. Besides, each 1st order station situated on an airport, has been doubled by a 2nd order station in the nearest locality.

The construction of the networks

The configuration and the sites. According to the designing principles already mentioned, a 1st order and a 2nd order triangulation have been set as it is shown in the plate.

The 1st order network comprises 19 stations linked by 42 sides building up 24 triangles. On 9 sides gravity differences are greater than 100 mgals.

The 2nd order network is represented by 222 stations, linked by 608 sides into 387 triangles.

Gravity differences on 2 sides are between 90 and 100 mgals and greater than 100 mgals on 9 sides.

Most of the 1st order stations are situated on airports and the pillars are represented by granite blocks with the dimensions 80/80/30 cm. The 2nd order triangulation stations are situated in churches, schools, other public buildings where special bronze stakes have been planted. For each site a location sheet has been completed as illustrated in fig. 1.

The instruments. Measurements on both networks have been carried out with 3 gravimeters simultaneously : Worden-Master 1003, Scintrex no. 240, Scintrex no. 356 (geodetic). On the 2nd order network on several sides the meter Scintrex 356 has been replaced by the Scintrex 340 gravimeter.

Checking and calibration of the gravimeters have been performed every year on a vertical calibration line (350 m altitude difference and 13 km highway distance of approx. 78 mgals, located near Brasov). The calibration gravity interval for the line was determined as an average of the values obtained with 3 different gravimeters calibrated by tilting in 1972 in Czechoslovakia and 1978 in Moscow in the calibrating laboratory of the Earth Physics Institute of the Sciences Academy of the Soviet Union. The adopted gravity difference turned out to be in a very good agreement with a La Coste - Romberg gravimeter occasional measurement.

Dial constants resulting from calibrating on the line during the networks measurements period, are plotted on the graphics shown in fig. 2. This plot shows a decrease tendency of this parameter with time of approx. 2×10^{-5} mgals/div/year for the gravimeters Worden 1003, Scintrex 356, Scintrex 340 and constancy for Scintrex 240 (with a stochastic fluctuation for this latter one).

As an evidence for the calibration agreement between the gravimeters used for the networks measurements, the plots of fig. 3-5 have been prepared, showing the relationship of measured gravity differences deviations versus the gravity differences themselves. Since the deviations are randomly distributed for the whole group of instruments and for the instruments compared two by two, a good calibration agreement has been inferred for the Worden 1003 and Scintrex 240 meters at least. Fig. 5 seems to indicate a slight disagreement between the Worden 1003 and Scintrex 356 gravimeters. As it will be shown, in the following steps taken into the construction of the networks, provisions for possible calibration disagreements have been made in analysing the triangles misclosures too.

As far as the problem of the validity of the used dial constants is concerned, the lack of absolute gravity measurements in Romania leaves open the problem of the reference networks gravity scale.

The measurements technique and the external influences. All the measurements were carried out as independent links, according to the scheme A-B-A. With each gravimeter at least two independent links, in different days, on every side, have been performed. High scattering of measured values determined additional measuring.

On the 1st order network helicopter transportation has been used exclusively, allowing short link durations. A graphic of these durations (fig. 6) indicates that 60 % of the links were performed within 3 hours.

On the 2nd order network, on 448 sides helicopter transportation has been used and on 292 sides the links have been made by car. A duration lay-out is shown in fig. 7.

A concern about the influence of the external factors on the measurements executed, existed too during the construction of the networks. Unfortunately conditions for practical inference of such influences have been very modest.

The literature on the subject comprises studies on temperature effect (Simon, 1979, Altman, 1970), on air pressure effect (Kiviniemi, 1964, Kubackova et al., 1979) on magnetic field variation effects (Divis, Tobyas, 1979).

Following the results of these studies, several observations have been made during the measuring operations.

The 1003 Worden gravimeter provided with a thermostat, has been the only temperature controlled instrument. Graphics showing gravity values deviations and corresponding r.m.s. are reproduced in fig. 8.

The optimal working temperature indicated by the manufacturer was 80°F. As it might be seen from the graphics, climatic conditions were such that temperatures inside the instrument went down to 76° F without a significant difference in the deviations.

Although the reference gravity network stations are generally situated at comparable altitudes (ranging between 1 m and 875 m) and air pressure differences on the measuring points might be considered as negligible, the problem of pressure hysteresis effects due to the crossing flights over the Carpathian Mountains has been examined. Divis et al. (1971), Csapo (1979) reported 0.25 mgals/1000 m pressure hysteresis effects for the Scintrex gravimeters. In order to have a qualitative information about such a pressure effect on the networks measurements, triangle closures plots against flight altitudes have been prepared (fig. 9).

The regression straight lines drawn for each gravimeter show a dependence of triangles closures on the flight altitudes reached by measuring the triangle links. For the gravimeters Worden 1003 and Sharpe 356 a decreasing tendency of the triangle closures is observed for higher flight altitudes. The regression line for gravimeter Scintrex 240 shows an opposite tendency. As a general remark one might point out the fact that misclosures are around the value of 0.10 mgals which corresponds to already quoted published data.

In order to obtain an information about the effect of a magnetic field upon the used gravimeters, azimuthal checking in a horizontal 10^{-4} At/m field has been carried out. An extreme value of 0.08 mgals for the Scintrex 240 has been observed. Since the geomagnetic field horizontal component within the Romanian territory does not exceed 0.25×10^{-4} At/m, an eventual care for a constant instrument orientation and avoidance of massive steel constructions has been inferred.

The accuracy of the measurements. The following indicators have been taken into consideration by estimating the accuracy of the measurements performed on both reference networks :

- the measurements amplitude (defined as the difference between extreme values obtained among a row of observations) ;
- the root mean square error of an individual measurement and of the average of the measurements performed on one side ;
- the triangle misclosures.

Given the measuring technique we described, the first two indicators should define the internal accuracy and the third one the external accuracy.

For the 1st order network, internal accuracy statistics is illustrated by fig. 10-12.

External accuracy is revealed by schemes 13-16 and the graphics of fig. 17, 18.

For the 2nd order network accuracy statistics are illustrated by fig. 19 - 21.

Networks adjustment

As a result of field measurements and preliminary data processing, the observed gravity intervals along the network ties are more or less close to their real values, the errors affecting them being mainly of random nature. Thus, the national gravity reference network (**ngrn**) behaves as a high entropy system that must be balanced.

The inherent presence of the errors is usually reflected within greater or smaller misclosures. The next step in the ngrn achievement is a misclosures adjustment. A short analysis of this procedure clearly shows that it is not able to eliminate the above mentioned errors. Still, an improvement of the measurements quality stands in the mastering of the errors level, meaning that, after the adjustment, there will be no errors greater than a determined/computable value.

As stated by Gibson (1941), any adjustment where
i. the misclosures along any loop is zero and
ii. the sum of corrections around any junction is zero is a least squares adjustment.

To use the least squares method, three conditions must be fulfilled :
(i) randomness of errors ;
(ii) small value errors only ;
(iii) the revealing of the errors within the functional model.

By examining some national gravity reference networks, the first remark regards the obvious changing in their authors' attitude, during the time, face to the problem of the network adjustment. Generally, the more accurate the gravimeter used, the less complicated was the functional-stochastic model for the misclosures adjustment (Woolard, 1958 ; Afshar, Zomorrodian, 1970).

Still, special care was paid to the instrumental drift (Kiviniemi, 1964), scale factor (Trager, 1975), or weighting coefficients. Intricate stochastic functional models were recommended for the adjustment of a common gravity control network of the East European countries by the Geodetical Service of East Germany.

Within the former I-st order gravity network of Romania, two functional-stochastic models were used for the adjustment (Botezatu, 1961 ; Botezatu, Panoiu, 1976). The main difference between them standed in the weighting systems (equal adjustability on all ties and various adjustabilities, related to the standard deviation of the results on each tie), but in the second case, some supplementary ties within the network design were also taken into consideration.

Unlike other ngrn, performed by measuring with a single gravimeter, the number of the instruments used, as well as the repeated determinations along each network tie, allowed an easier statistical processing for the Romanian ngrn. Under these circumstances, the arithmetic means of all the observed values on each tie, gathered with all the gravimeters, represent the most appropriate values for a least squares treatment.

A comprehensive study concerned with the adjustment of the I-st order gravity network led the authors from the Military Topographic Department to the following functional stochastic model :

- simple arithmetic means of the measured gravity intervals on each tie as values to be adjusted : values that did not correspond to a normal scattering, as stated by statistical criteria, were not considered ;

- scale factors as deduced from the measurements on the national calibration line Brasov-Poiana Brasov for the dial constant : for the geodetic dial, values provided by manufacturer were taken into consideration ;

- independent measurements on all the ties (diagonal covariance matrix) ;

- the adopted weight on each tie was inverse to the average of time intervals of the measuring cycles.

Two other functional stochastic models were performed at the Institute of Geology and Geophysics.

Variant (a) had the following characteristic features :

- simple weighted arithmetic means of the observed gravity intervals on each tie, as values to be adjusted (Worden measurements were considered twice more reliable than Scintrex gravity meter results) ;
- scale factors were those one established by tilting calibration ;
- tidal corrections were separately applied ;
- diagonal covariance matrix ;
- equal adjustability on all ties.

The second variant (b) consisted of a different stochastic model. To set ties adjustabilities, gravity intervals measured within I-st and II-nd order **ngrn** were compared. The difference between the results obtained on both ways grouped into 5 statistical classes, determining various confidence levels of measurements.

According to the concordance of the results, the adjustability on each tie belonged to one of the above mentioned 5 categories, as revealed within the following table.

Table 1

Difference range (mgals)	Standard deviation (mgals)	Weighting coefficient (a) (mgals)
0.00--0.03	+ 0.02	+ 5 k
0.04--0.07	+ 0.05	+ 2 k
0.12--0.11	+ 0.10	+ k
0.12--0.15	+ 0.15	+ 2/3 k
0.22--0.29	+ 0.25	+ 2/5 k

k = factor deduced under the condition $\sum p = 1$.

Therefore, each tie was weighted according to the formula :

$$p_i = \frac{\sigma_i * a}{\sigma_o}$$

where σ_i = standard deviation for a specified difference range ;
σ_o = global standard deviation for the whole network ;
a = weighting coefficient.

The results quality for various adjustment models are shown in the table 2.

Adjustment model	Corrections range (mgals)	Standard deviation of the weighting unit (mgals)
DTM	-0.12--0.14	+ 0.07
IGG-a	-0.22--0.24	+ 0.13
IGG-b	-0.22--0.22	+ 0.02

The adjustment of the II-nd order gravity network followed a similar procedure.

The functional stochastic model created by the team of the Military Topographic Department (MTD), started from the classical working equation of the gravimeter :

$$\Delta g = \Delta n * k + \Delta N * K$$

where k and K are dial constants as provided by measurements made on the national calibration line Brasov, n and N are small and geodetic dial readings.

The II-nd order ngrn was adjusted as a free network, without any constraint, as resulted within the frame of the I-st order ngrn. Simple arithmetic means of the results on each tie were the values to be adjusted. Diagonal covariance matrix was used. The weights on ties were inverse to the length of the measuring time interval.

The accuracy of the adjusted gravity values range between ±0.035 and ± 0.061 mgals.

Acknowledgements

The gravity reference networks of Romania have been realised by a large team comprising specialists and assistants from IGG and MTD. Marius Visarion (IGG) and Vasile Dragomir, (MTD) have initiated the project and concluded the agreement by which the contribution of each institution has been established. Mircea Mihailescu (MTD) contributed the designing study. Nicolas Puiu (MTD) planted the marks and topographically documented all the network stations. Most of the gravity measurements have been carried out by Constantin Placinta and Gheorghe Grigore (IGG). Gravity measurements have been made also by Adrian Nicolescu who contributed statistical plots too. Felicia Alexandru (MTD) and Ruxandra Stefanescu (IGG) contributed the adjustment computations.

Dorel Zugravescu (Institute of Geodynamics) kindly offered Earth tidal data.

The pilots Miron Rinditean and Sziklody Gabor have flown most of the helicopter ties.

The authors wish to point out the merits of all these co-workers for the realisation of the reference gravity networks of Romania and express them by this means too, their whole gratitude.

Thanks are extended also to Prof. Yuri Boulanger and to Roald Rukavishnikov, from the Institute of Earth Physics from Moskow, without whose help the gravimeters tilting calibration would not have been possible.

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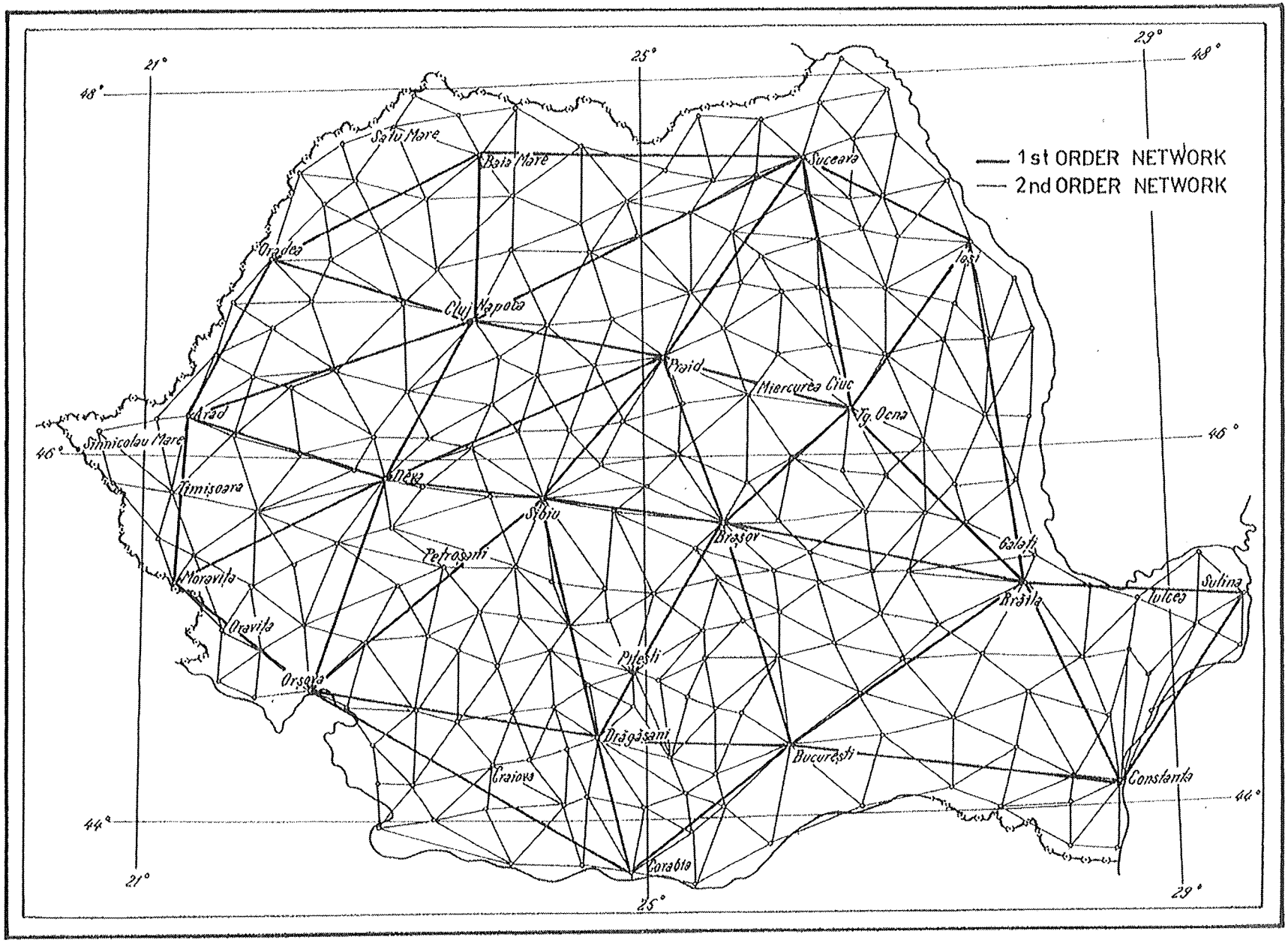
LIST OF ILLUSTRATIONS


1st ORDER NETWORK
2nd ORDER NETWORK
Satu Mare
Baia Mare
Suceava
Oradea
Iași
Cluj Napoca
Praid
Miercurea Ciuc
Tg. Ocna
Arad
Sînnicolau Mare
Timișoara
Deva
Sibiu
Brașov
Galați
Petroșani
Moravița
Orșova
Pitești
Brăila
Tulcea
Sulina
Târgșani
București
Craiova
Constanța
Corabia
48°
46°
44°
21°
25°
29°

REPUBLICA SOCIALISTĂ ROMÂNIA

REȚEAUA GRAVIMETRICĂ DE ORDINUL II

STAȚIA GRAVIMETRICĂ DRAGOMIRESTI Nr. 192 JUDEȚUL VASLUI

TRAPEZUL GAUSS: L-35-55-B-a

Coordonate geografice: $\varphi =$ $\lambda =$

Coordonate Gauss: $X =$ $Y =$

Altitudinea (sistemul de cote M. Baltică): 226,758 m.

Stația a fost legată de reperul de nivelment tip B DT M. 26799 Biserica DRAGOMIRESTI-VASLUI, având cota 225,984 m., din linia de nivelment de ord. III VASLUI-BACĂU

Gravitatea observată:

Gravitatea normală (Stockholm 1930):

Reducerea Faye:

Reducerea Bouguer: $\rho = 2.20\ g/cm^3$ $\rho = 2.67\ g/cm^3$

Reducerea de relief: $\rho = 2.20\ g/cm^3$ $\rho = 2.67\ g/cm^3$

Schema legăturilor stației cu stațiile învecinate din rețea

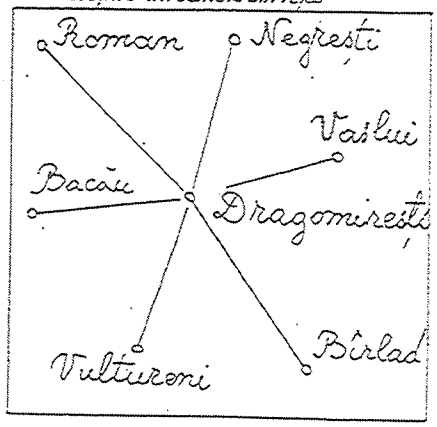
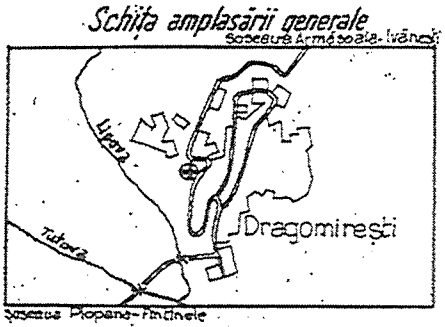
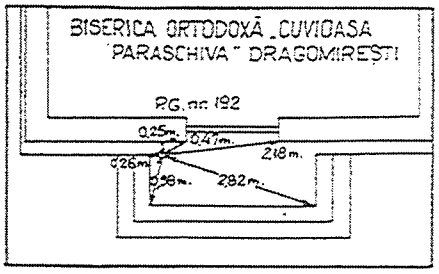


Fig. 1a

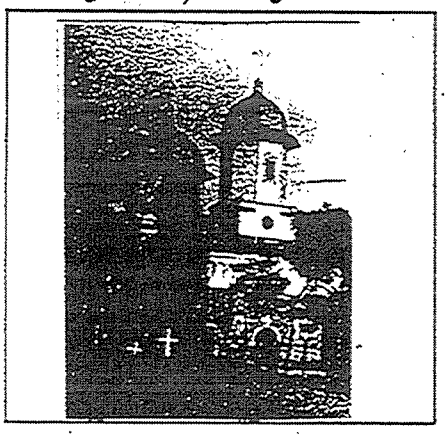
Schița amplasării generale



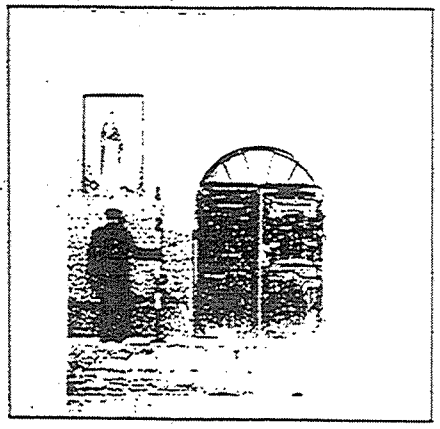
Schița amplasării detaliate



Fotografia amplasării generale



Fotografia amplasării detaliate



Accesul: Punctul gravimetric este amplasat în biserica ortodoxă „Cuvioasa Paraschiva" din comuna DRAGOMIREȘTI. El se găsește pe treapta de sus de la intrare în stânga ușii.

Stația este marcată cu un reper din fontă, de tip A (pe suprafețe orizontale) cu inscripția P. Gr. II seria 192 și are în apropiere o plăcuță cu inscripția: Punct gravimetric ord. II

I.G.G.
str. Caransebeș 1 sector 8

D.T.M.
B-dul 1 Mai 124 sector 1

BUCUREȘTI

Fig. 1b

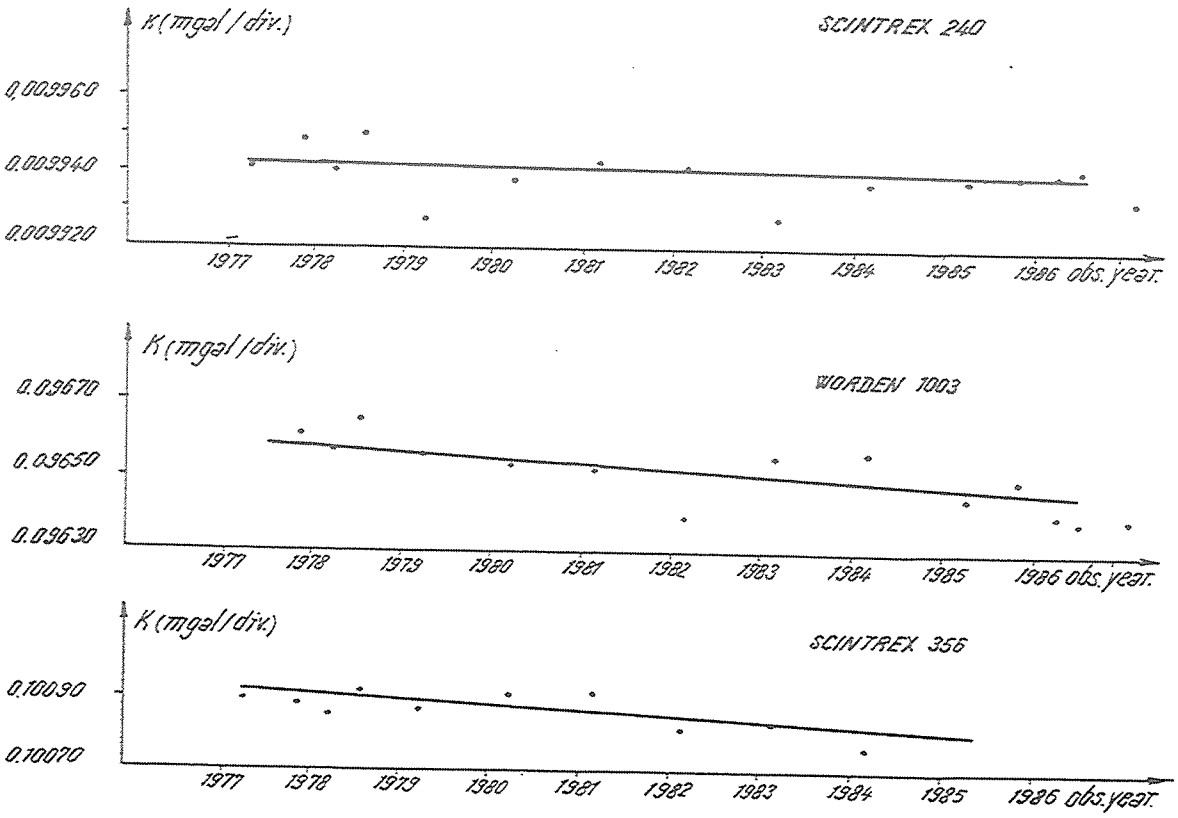

K(mgal/div.)
SCINTREX 240
0.003960
0.003940
0.003920
1977
1978
1979
1980
1981
1982
1983
1984
1985
1986 obs. year.
K(mgal/div.)
WORDEN 1003
0.09670
0.09650
0.09630
1977
1978
1979
1980
1981
1982
1983
1984
1985
1986 obs. year.
K(mgal/div.)
SCINTREX 356
0.10090
0.10070
1977
1978
1979
1980
1981
1982
1983
1984
1985
1986 obs. year.

Fig. 2

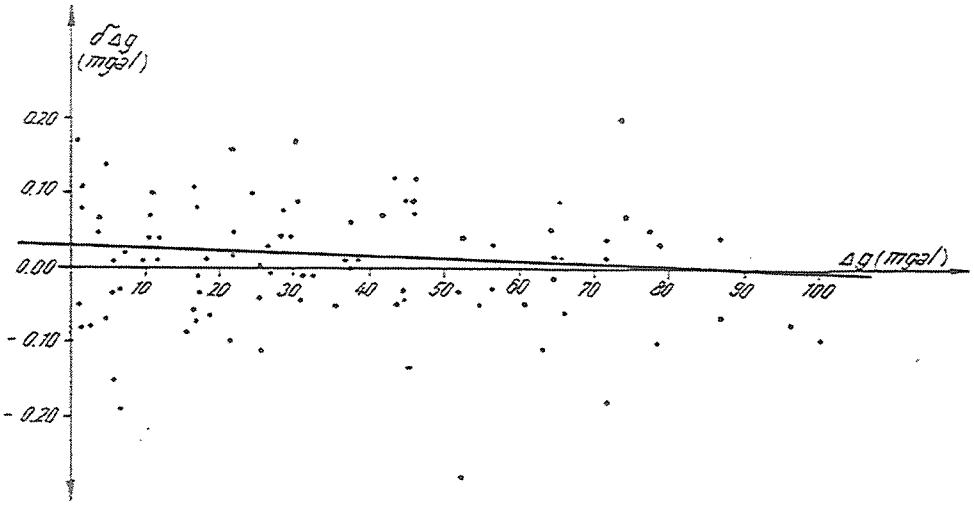

δΔg
(mgal)
0.20
0.10
0.00
- 0.10
- 0.20
10
20
30
40
50
60
70
80
90
100
Δg(mgal)

Fig. 3

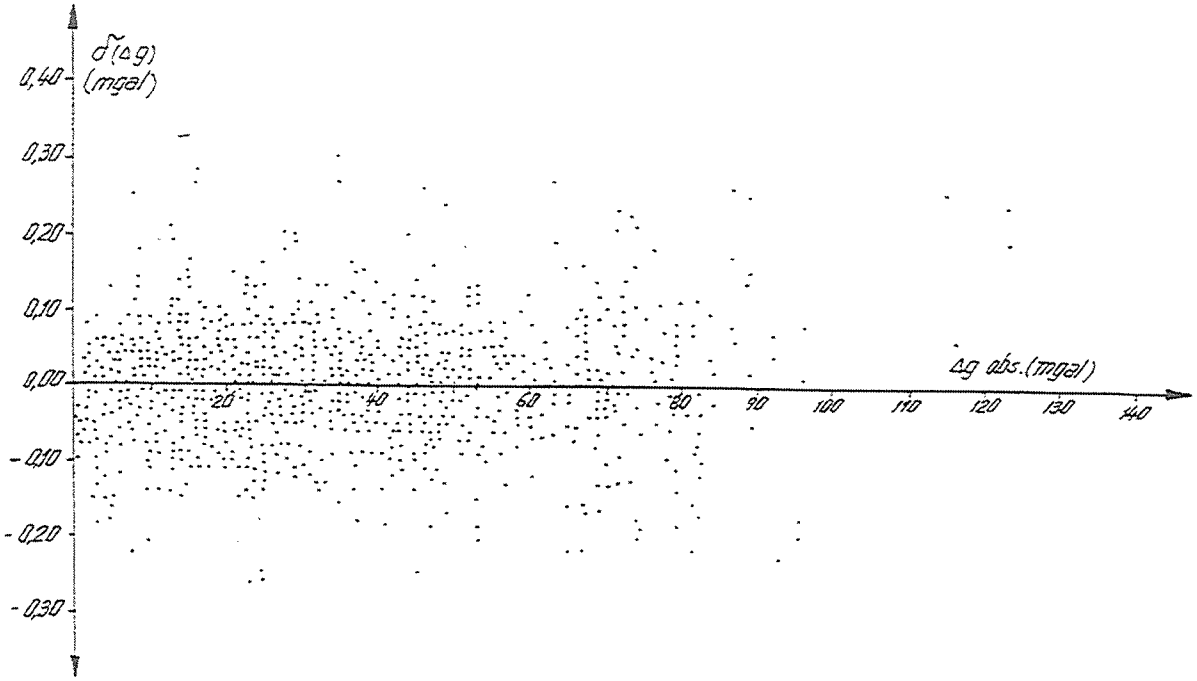

δ(Δg)
(mgal)
0,40
0,30
0,20
0,10
0,00
-0,10
-0,20
-0,30
Δg obs.(mgal)
20
40
60
80
90
100
110
120
130
140

Fig. 4

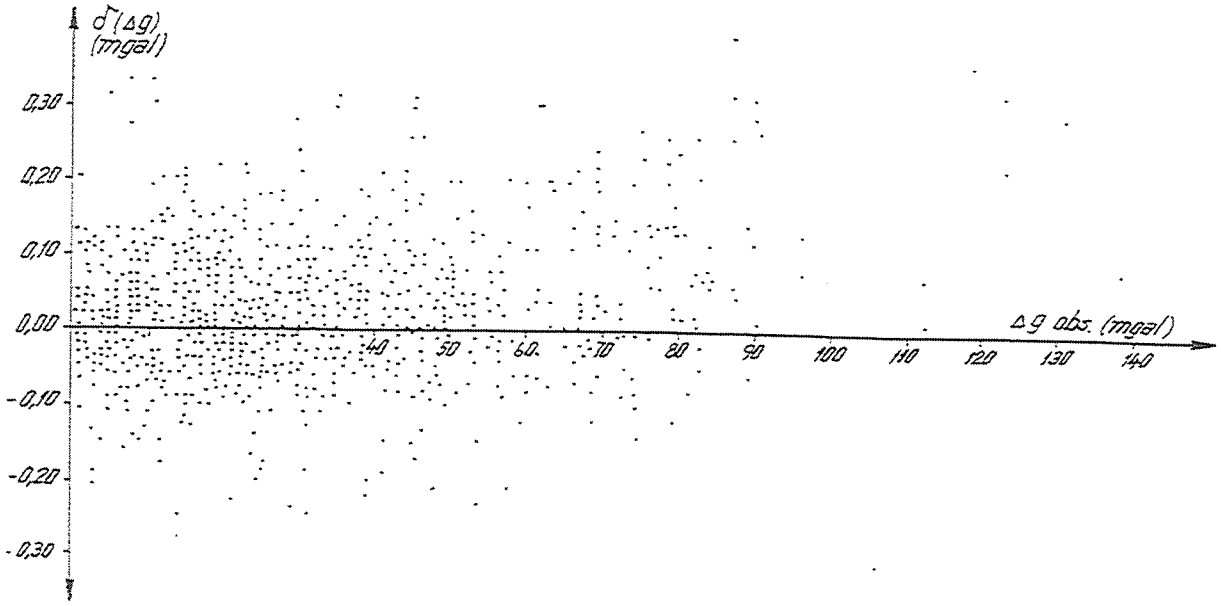

δ(Δg)
(mgal)
0,30
0,20
0,10
0,00
-0,10
-0,20
-0,30
Δg obs. (mgal)
40
50
60
70
80
90
100
110
120
130
140

Fig. 5

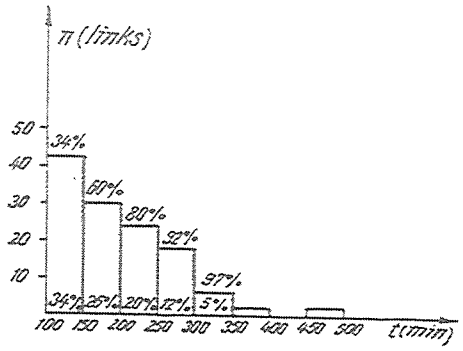

n (links)
50
40
30
20
10
34%
60%
80%
92%
97%
34%
26%
20%
12%
5%
100 150 200 250 300 350 400 450 500
t(min)

Fig.6

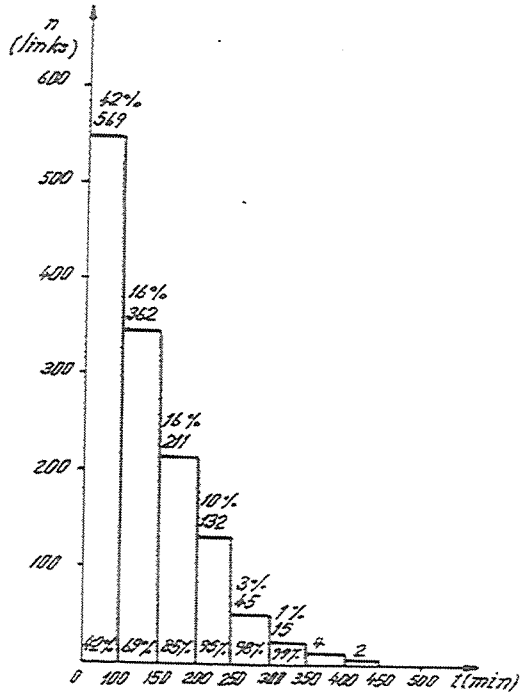

n (links)
600
500
400
300
200
100
42%
569
16%
362
16%
211
10%
132
3%
45
1%
15
4
2
42%
68%
85%
95%
98%
99%
0 100 150 200 250 300 350 400 450 500
t(min)

Fig. 7

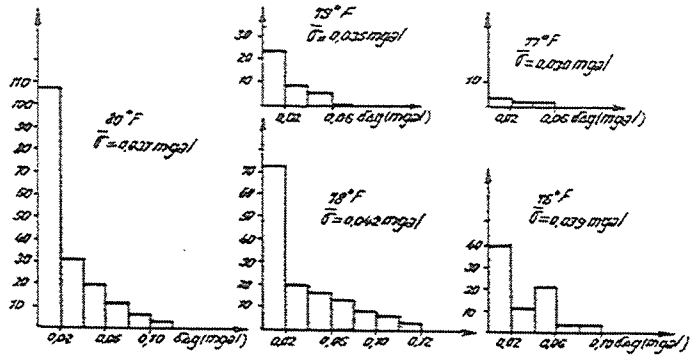

80°F
σ=0,037 mgal
75°F
σ=0,035 mgal
77°F
σ=0,030 mgal
78°F
σ=0,042 mgal
76°F
σ=0,039 mgal
dag (mgal)

Fig.8

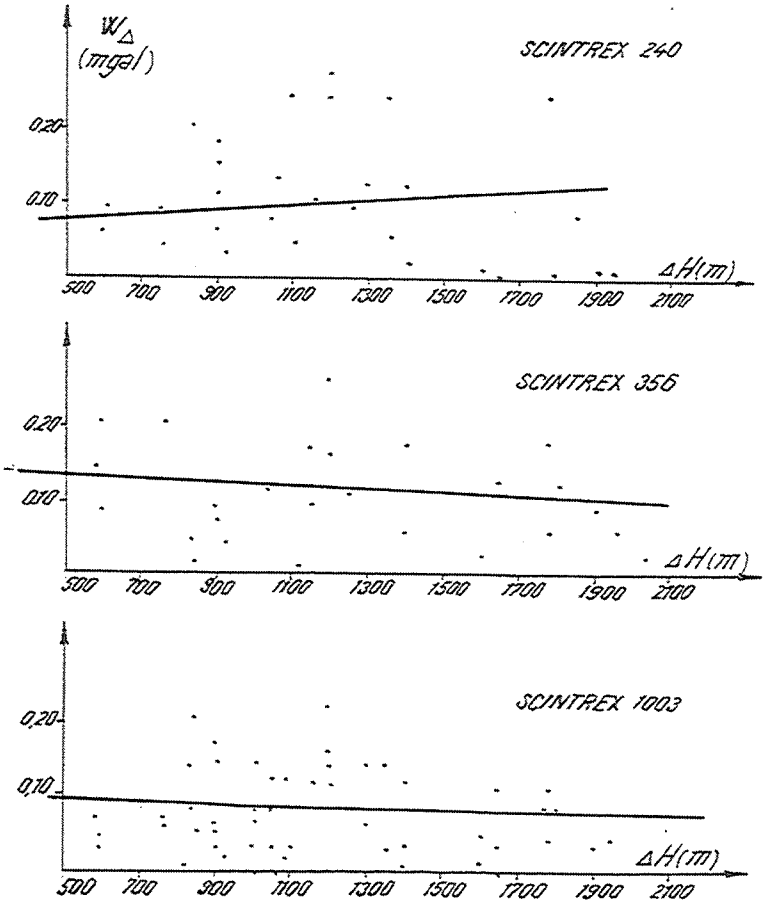

W/Δ
(mgal)
SCINTREX 240
SCINTREX 356
SCINTREX 1003
ΔH(m)
0,20
0,10
500
700
900
1100
1300
1500
1700
1900
2100

Fig.9

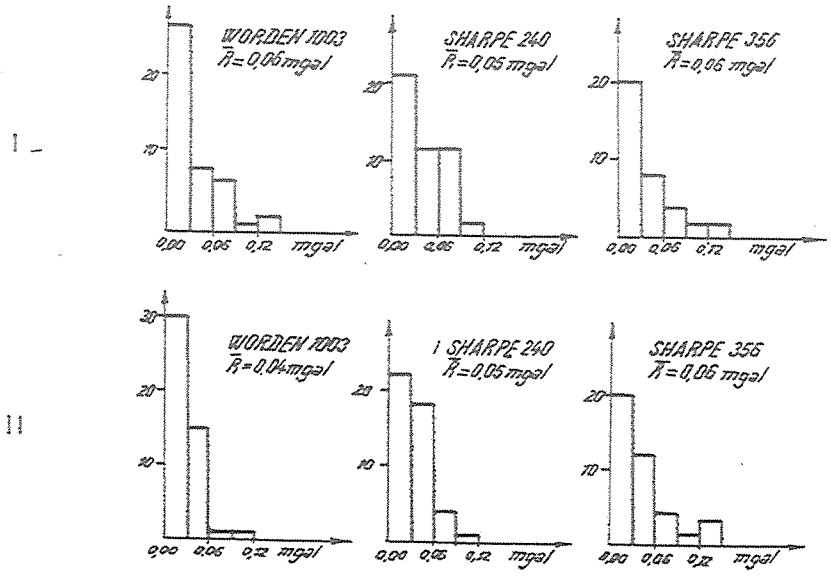


Fig. 10

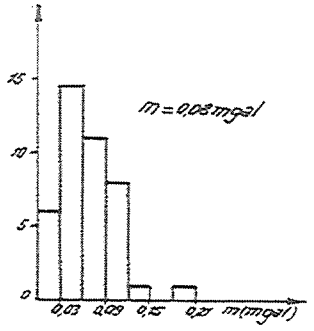


Fig.11

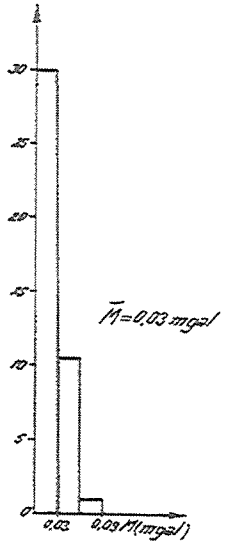


Fig.12

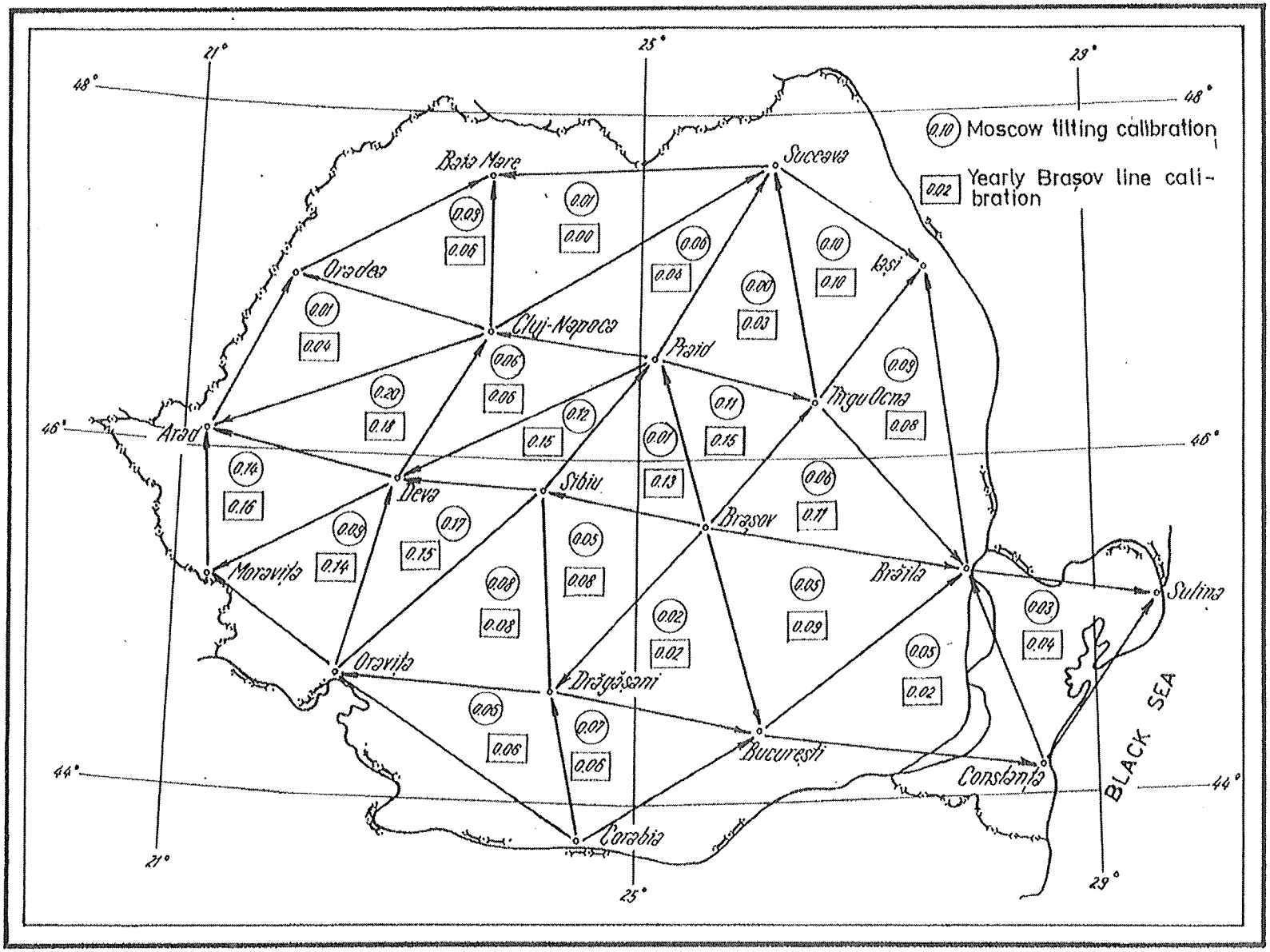

(0.10) Moscow tilting calibration
[0.02] Yearly Brașov line calibration
Baia Mare
Suceava
Oradea
Iași
Cluj-Napoca
Praid
Târgu Ocna
Arad
Deva
Sibiu
Brașov
Brăila
Sulina
Moravița
Oravița
Drăgășani
București
Constanța
Corabia
BLACK SEA
48°
46°
44°
21°
25°
29°

Fig. 13

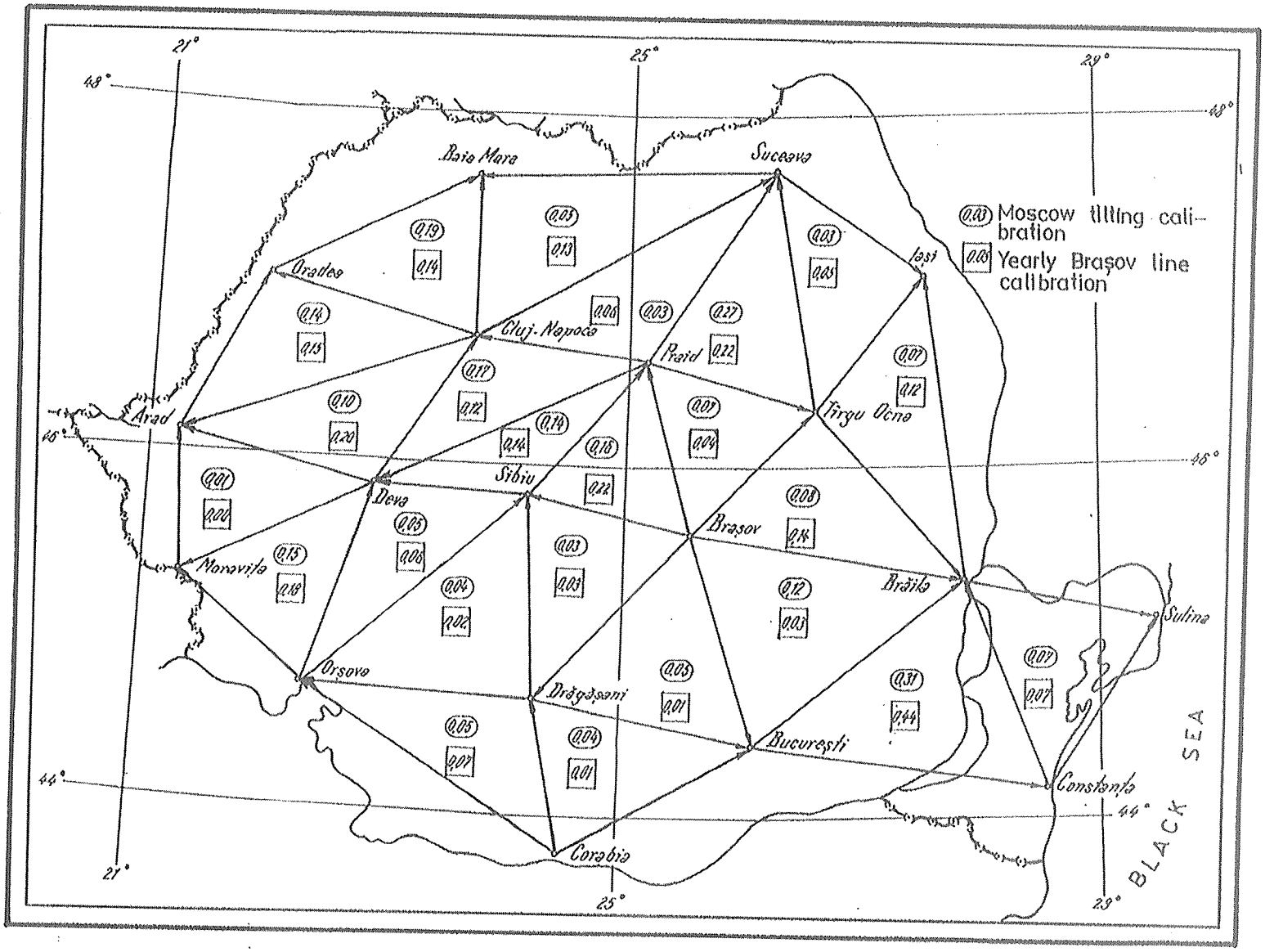

Baia Mare
Suceava
Oradea
Cluj-Napoca
Praid
Iași
Arad
Târgu Ocna
Deva
Sibiu
Brașov
Moravița
Brăila
Sulina
Orșova
Drăgășani
București
Constanța
Corabia
BLACK SEA
Moscow tilting calibration
Yearly Brașov line calibration

Fig. 14

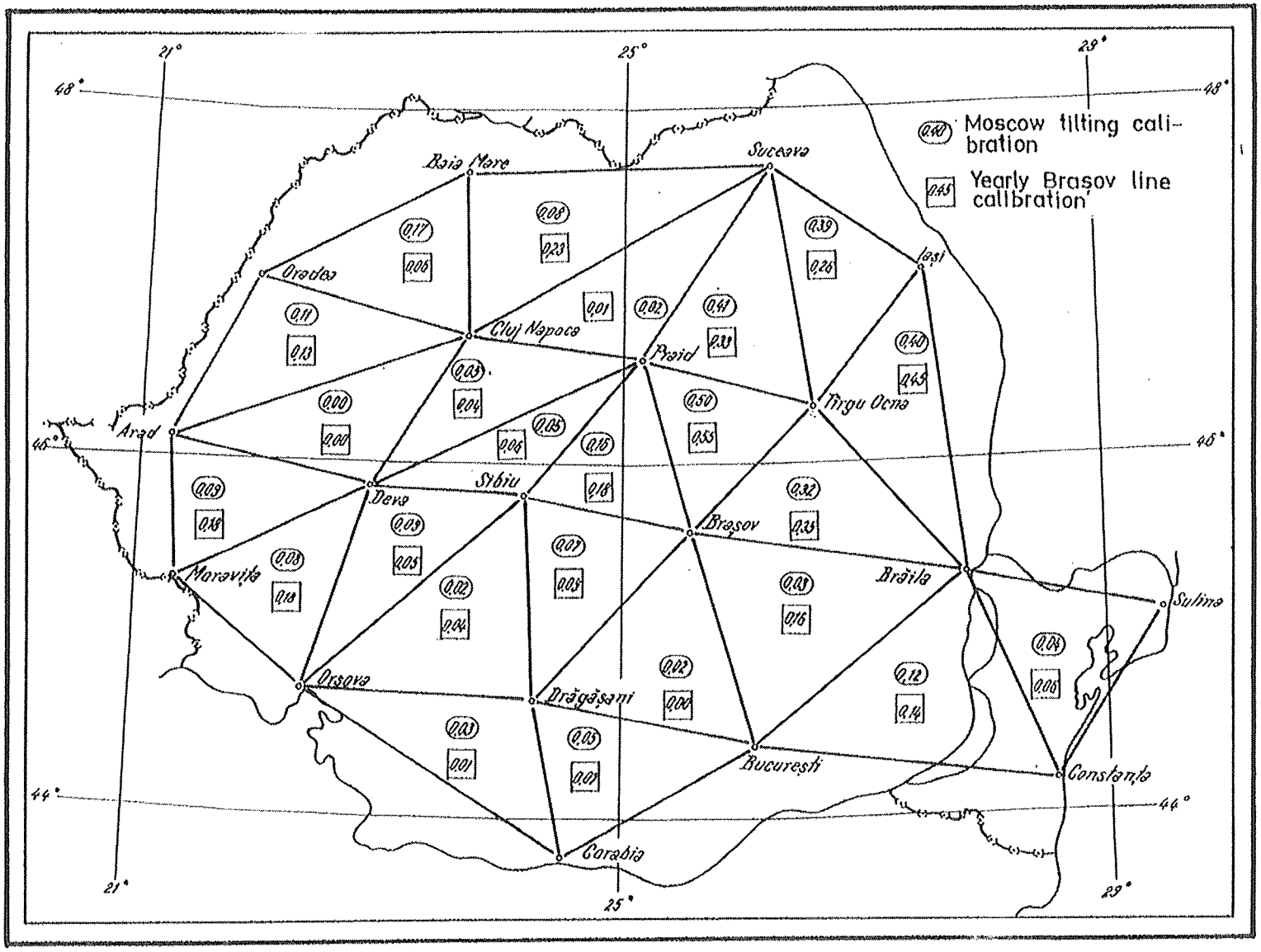

Moscow tilting calibration
Yearly Brașov line calibration
Baia Mare
Suceava
Oradea
Iași
Cluj Napoca
Praid
Târgu Ocna
Arad
Deva
Sibiu
Brașov
Moravița
Brăila
Sulina
Craiova
Drăgășani
București
Constanța
Corabia
48°
46°
44°
21°
25°
29°

Fig. 15

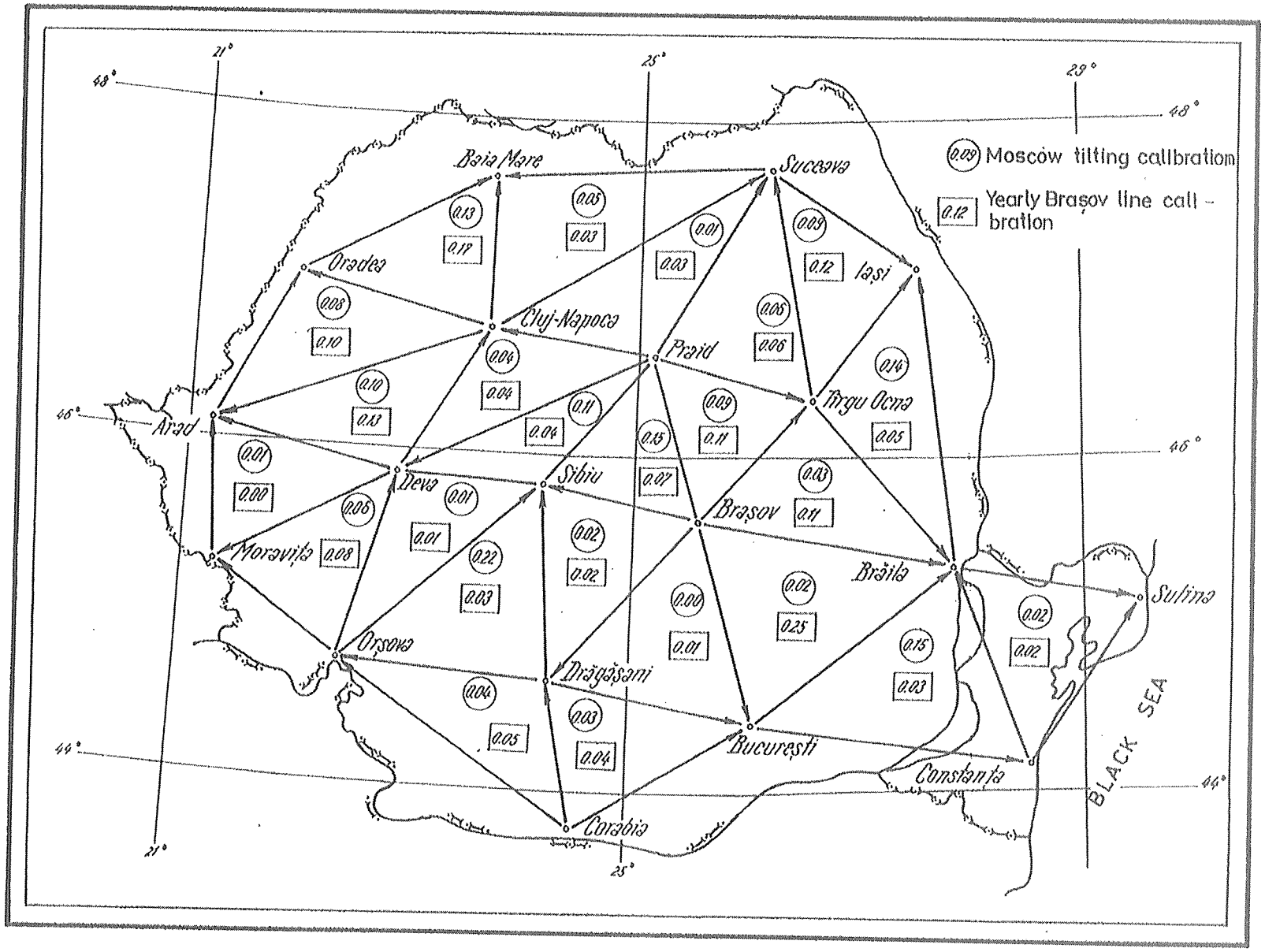

Baia Mare
Suceava
Oradea
Cluj-Napoca
Praid
Iași
Târgu Ocna
Arad
Deva
Sibiu
Brașov
Moravița
Orșova
Drăgășani
Brăila
Sulina
București
Constanța
Corabia
BLACK SEA
Mosców tilting callbration
Yearly Brașov line call - bration
48°
46°
44°
21°
25°
29°

Fig.16

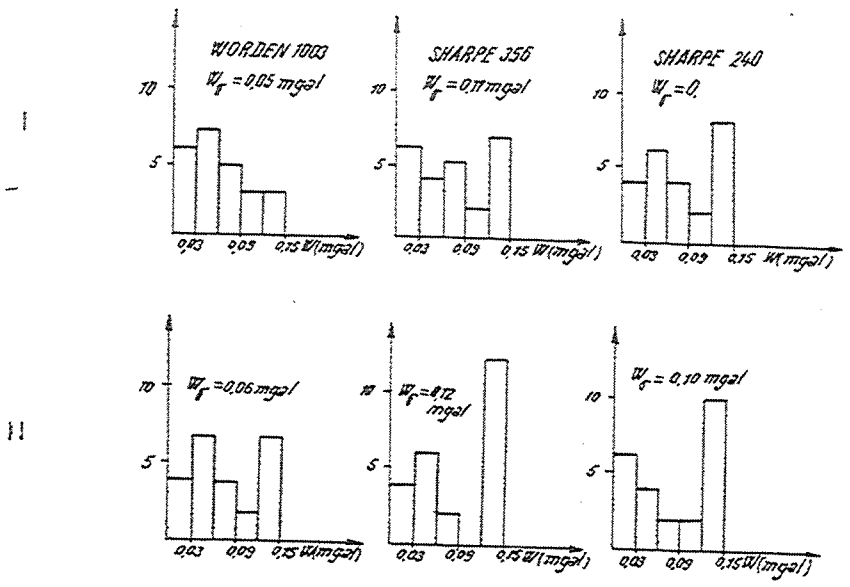

I
II
WORDEN 1003
W_f = 0,05 mgal
SHARPE 356
W_f = 0,11 mgal
SHARPE 240
W_f = 0,
W_f = 0,06 mgal
W_f = 0,12 mgal
W_f = 0,10 mgal
10
5
0,03
0,09
0,15 W(mgal)

Fig.17

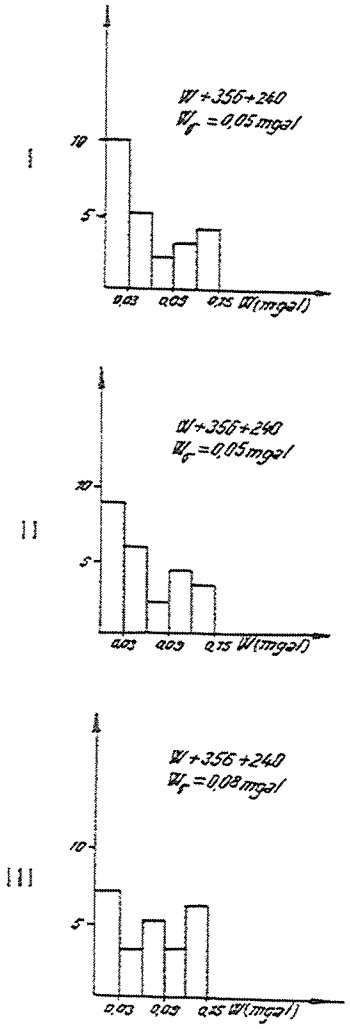

I
II
III
W+356+240
W_f = 0,05 mgal
W_f = 0,05 mgal
W_f = 0,08 mgal
10
5
0,03
0,09
0,15 W(mgal)

Fig.18

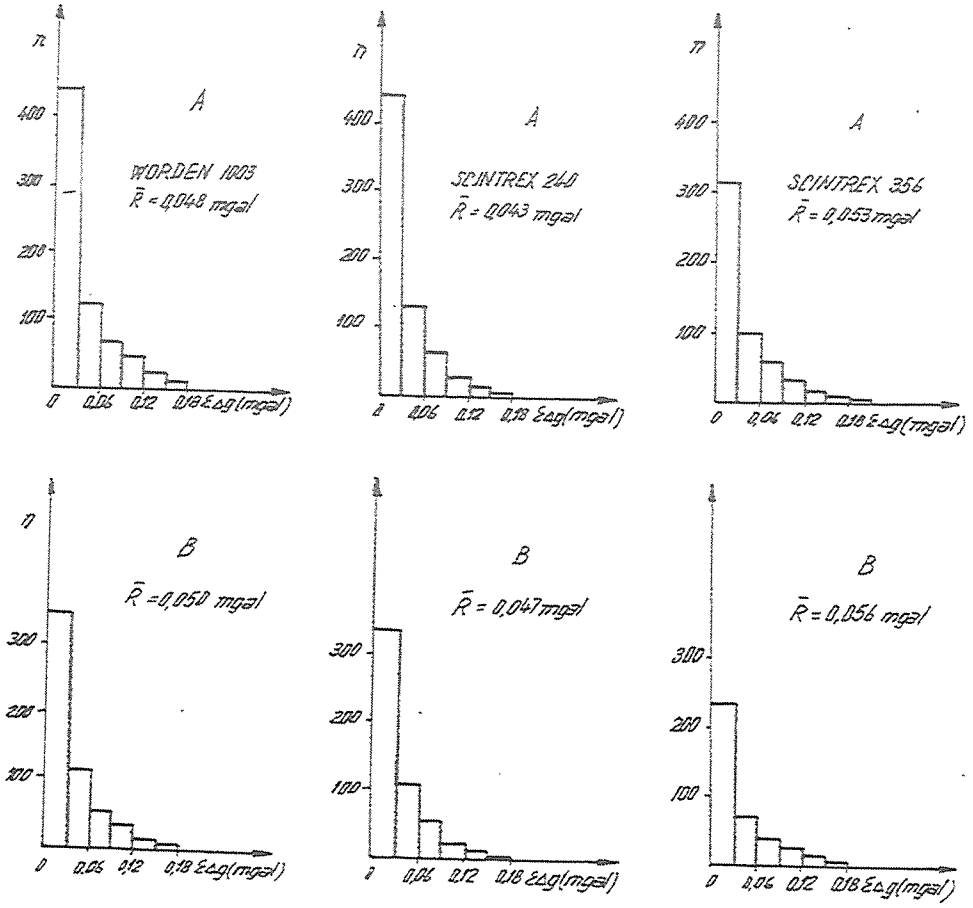


Fig. 19

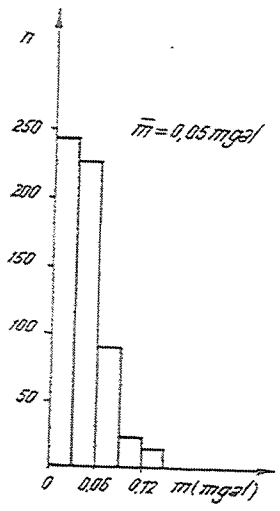


Fig. 20

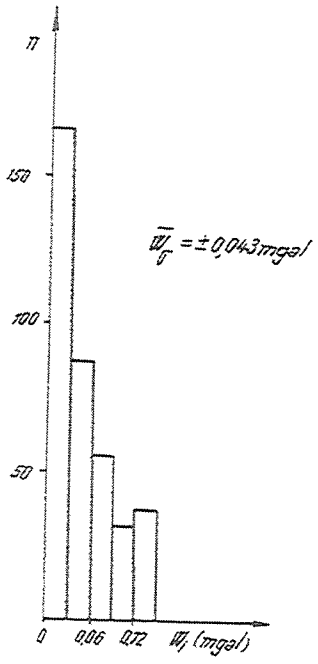


Fig. 21

IAG General Meeting
(9—13 August 1993, Beijing)

THE FIRST RESULTS OF ABSOLUTE GRAVITY MEASUREMENT AT IAGBN STATIONS BEIJING AND NANNING

by

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Abstract

A general description of the locations and environmental conditions at two IAGBN stations in China, Beijing and Nanning, is given. Also presented are the first results of absolute gravity measurement at these stations and the instruments used. These results indicate that good agreement exists among the results obtained by different gravimeters at Beijing station. The gravity values at China Gravity Basic Net—85 (CGBN—85) stations obtained by transforming the observation values in 1990 at IAGBN station in the same city have been compared with the results determined by Italian gravimeter IMGC in 1981 and the adjusted values of CGBN—85 respectively.

1. Introduction

At the workshop of IAG SSG 3.87 held in July 2—4, 1985 at Paris, Beijin and Nanning had been recommended as candidated stations of IAGBN(A), and Nanning was finally accepted (Boedecker et al., 1986). In August 5, 1989 at the Special Meeting of IGC at Edinburgh, Beijing was also accepted as an IAGBN(A) station (Boedecker, 1989). Then the sites of these stations were carefully selected and observation rooms equipped with necessary facilities were set up. Up to the end of 1990, the absolute gravity measurements at Beijing IAGBN(A) station (abbreviated to "Beijing station" thereafter) had been accomplished using four sets of gravimeter, i.e. JILA G—5, JILA G—3, NIM—II and NIM—3. But only one gravimeter, JILA G—5, had been used for the measurements at Nanning IAGBN(A) station (abbreviated to "Nanning station" thereafter).

2. Location and environment

Beijing station (see appendix 1) is located in the absolute gravity observation room, which is in a cave excavated in a hillside and about 20m away from the entrance. It is one of the facilities of the Beijiatan Seismological Observatory affiliated to the Institute of Geophysics, State Seismological Bureau of China. It lies about 15 km northwest of Beijing. Two concrete pillars for absolute gravity observation are erected in the room, their tops are carefully polished and leveled with the floor. A brass marker is set to each pillar. On the marker of the longer pillar the symbols IAGBN and 1204 (the identification number of IAGBN) are carved. Observation conditions are good: low air humidity, stable temperature and very low microseimic noise level.

Nanning station (see appendix 2) is located in the Liuli Branch, Gaofeng Forestry. It is in the north of Nanning, about 20 km away. This is a specially built Gravity Observatory. Two concrete observation pillars were constructed on bedrock in the observation room. A brass marker is set to each pillar. On the marker of the northern pillar the symbols IAGBN and 1103 are carved. The microseismic noise level is low (in the day) or very low (at the night). During observation period, air conditioner can be equipped easily.

3. Absolute gravity measurements

In May and June, 1990 the absolute gravity observations at Beijing station were accomplished using Finnish gravimeter JILA G—5 (Makinen et al. , 1993) and German gravimeter JILA G—3 (Torge et al. , 1990). Before the setting up of Beijing IAGBN station, absolute gravity observations were made using two Chinese gravimeters. In March 1986, observations were made at an excentre station 2. 2 m apart using NIM—II, and in 1990 it was transformed to Beijing IAGBN station by relative observation (Guo Youguang, 1991 a,b). In June and November 1988, gravimeter NIM—3 was used for observation at the site of Beijing IAGBN station (Gao Jinglong, 1993) . The absolute gravity observations at Nanning station were accomplished using gravimeter JILA G—5 (Makinen et al. , 1993). All of these results and some rela-

Table 1. The results of absolute gravity measurements at IAGBN stations in China.

station name	Number IAGBN	Instru—ment	Epoch	heff mm	Number of drops	vertical gradient $\mu ms^{-2}/m$	Result at heff μms^{-2}	Result at Omm μms^{-2}	Result at 800mm μms^{-2}	Source
Beijing	1204	JILAG—5	5/1990	841	3750	—2. 386	9801103. 735	9801105. 742	9801103. 833	(1)
Beijing	1204	JILAG—5	6/1990	840	2850	—2. 386	9801103. 773	9801105. 777	9801103. 869	(1)
							mean	9801105. 760	9801103. 851	
Beijing	1204	JILAG—3	5/1990	821	1564	—2. 241	9801103. 885	9801105. 72	9801103. 932	(2)
Beijing	1204	NIM—Ⅱ	3/1986			—2. 237		9801105. 64		(3)
Beijing	1204	NIM—3	6,11/1988	900	506	—2. 386*)	9801103. 73	9801105. 88	9801103. 97	(4)
Nanning	1103	JILAG—5	5/1990	840	3200	—3. 020	9787457. 340	9787459. 877	9787457. 461	(1)

Note: (1) Makinen et at. ,1993.
(2) Torge et al. , 1990.
(3) Guo Youguang, 1991b.
(4) Gao Jinglong, 1993.
*) The gradient used for gravimeter JILA G—5.

tive information are given in Table 1. The NIM type gravimetre's results listed in Table 1 haven't applied the correction for polar motion, which would not excess 0. 07 μms^{-2}, and correction for air pressure. It is indicated that good agreement was reached among the results obtained by different gravimeters at Beijing station.

4. The determination of gravity gradients and relative connection

During the Sino — Finnish absolute gravity campaign in 1990, two LaCoste and Romberg (LCR) gravimeters without feedback system, number G — 920 and G — 922, were used for relative observation . For the determination of vertical gradient the gravity differences between (nominally) the pillar level and three different levels above it, i.e. 0.4 m, 0.8 m and 1.1 m, were measured. Four sets of observation, which consists of one two — way measurement (A — B — A), with each gravimeter were made at each relative height. It can be seen in Table 2 that the vertical gravity gradient at Beijing station changes slightly with height. For determining the vertical gravity gradient used by JILA G—3 in Table 1, only the difference between ground level and 1.0m height above ground have been measured ten times with each of the three LCR gravimeters with feedback system (Torge et al. , 1990).

Table2. The vertical gravity gradients.

Name of station:	Beijing				Nanning			
Relative height above the pillar m	Gravity difference μms^{-2}			Vertical gradient $\mu ms^{-2}/m$	Gravity difference μms^{-2}			Vertical gradient $\mu ms^{-2}/m$
	G—920	G—922	mean		G—920	G—922	mean	
0.434	1.018±0.003	1.065±0.017	1.042	−2.400	1.255±0.006	1.275±0.005	1.265	−2.915
0.800	1.915±0.012	1.903±0.024	1.909	−2.386	2.398±0.010	2.435±0.005	2.416	−3.020
1.100	2.465±0.021	2.485±0.017	2.475	−2.250	3.193±0.021	3.310±0.006	3.252	−2.956

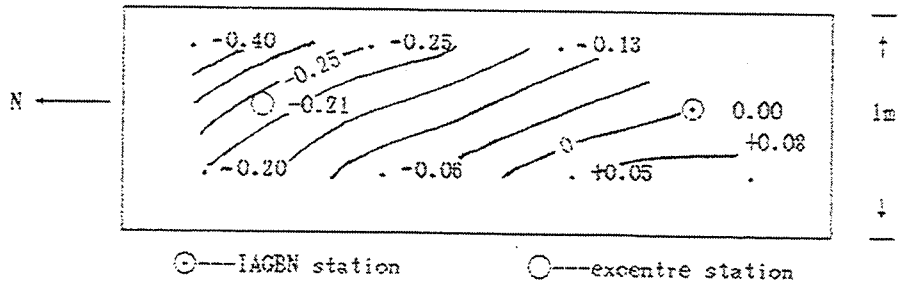

Fig. 1

In June 1989, a relative measurements were carried out at nine points, including the IAGBN station and excentre station, on two pillars at Beijing station. The results are shown in Fig. 1. It's of interest to note that horizontal gravity gradient in west—east direction is larger than that in north—south direction.

During the Sino—Finnish absolute gravity campaign, relative gravity measurements between the IAGBN station and CGBN—85 stations, i. e. Gravity Standard Station (GSS) and Gravity Basic Station (GBS), in the same city were made. The gravity differences between each two stations were determined using the aforemetioned two LCR gravimeters, each gravimeter gave two results. When the absolute measurements at the Beijing station were made using JILA G—3, relative connection was made only with Beijing GBS at Capital airport (Torge et al., 1990). The gravity values of CGBN—85 stations in 1990, which were obtained from the IAGBN stations using the results of relative measurements, are shown in Table 3.

Table 3. The gravity value of CGBN—85 stations in 1990.

IAGBN station (A)				Δg_{AB}	CGBN—85 station (B)		
Name	No.	Used absolute gravimeter	Observation gravity value μms^{-2}	μms^{-2}	Name	No.	Transformed gravity value μms^{-2}
Beijing	1204	JILA G—5	9801105.76	90.77	Beijing GSS	810	9801196.53
Beijing	1204	JILA G—5	9801105.76	211.29	Beijing GBS	800	9801317.05
Beijing	1204	JILA G—3	9801105.72	211.56	Beijing GBS	800	9801317.28
Nanning	1103	JILA G—5	9787459.88	42.80	Nanning GSS	2510	9787502.68
Nanning	1103	JILA G—5	9787459.88	−78.68	Nanning GBS	2500	9787381.20

5. Comparisons

The transformed gravity values of CGBN—85 stations were compared with the observation values using IMGC gravimeter in 1981 (Xu Shan et al., 1986) and the adjusted values of CGBN—85 (Jiang Zhi-heng et al., 1988) respectively (Table 4). The discrepancies between transformed absolute gravity values based on the results of gravimeter JILA G—5 in 1990 and those determined using gravimeter IMGC in 1981 at Beijing GSS and Nanning GSS are +0.07 and +0.25 μms^{-2} respectively. The polar motion reduction which hadn't been included in the results obtained using IMGC gravimeter wouldn't exceed 0.05 μms^{-2}. It seems that the gravity values of Beijing and Nanning have inconsiderably changed during 1981—90 and that the re-

sults obtained using gravimeters JILA G—5 and IMGC at these two stations are consistent to a large degree. The differences between the 1990 transformed result and adjusted value of CGBN—85 range from —0.15 to +0.08 μms^{-2}. Smaller differences imply that the results of CGBN—85 at Beijing and Nanning are reasonable.

Table 4. 1990 absolute gravity value as compared to IMGC and CGBN—85 results at CGBN—85 stations.

CGBN—85 station		1990 Absolute gravity value transformed to CGBN—85 station μms^{-2}	used absolute gravi—meter	1981 Absolute gravity value determined with IMGC μms^{-2}	Adjusted value of CGBN—85 μms^{-2}	$\Delta g1=$ (3)—(5) μms^{-2}	$\Delta g2=$ (3)—(6) μms^{-2}
name	number						
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Beijing GSS	810	9801196.53	JILAG—5	9801196.46	9801196.49	+0.07	+0.04
Beijing GBS	800	9801317.05	JILAG—5		9801317.20		—0.15
Beijing GBS	800	9801317.28	JILAG—3		9801317.20		+0.08
Nanning GSS	2510	9787502.68	JILAG—5	9787502.43	9787502.70	+0.25	—0.02
Nanning GBS	2500	9787381.20	JILAG—5		9787381.24		—0.04

6. Conclusion

The station site of IAGBN(A) stations in China, Beijing and Nanning, are excellent. The observation conditions are favorable. The first results of absolute gravity measurements at these stations manifest with high accuracy. These results provide a sound basis for future research on gravimetry and geodynamics.

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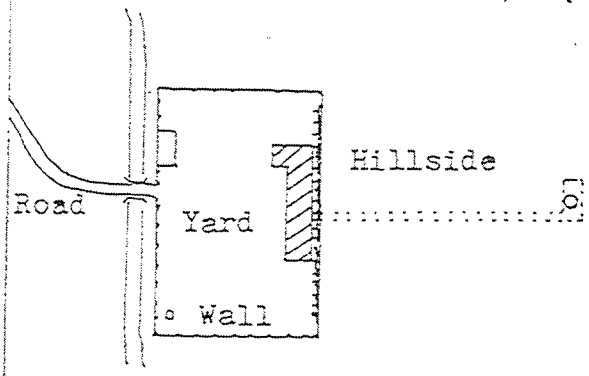
Appendix 1.

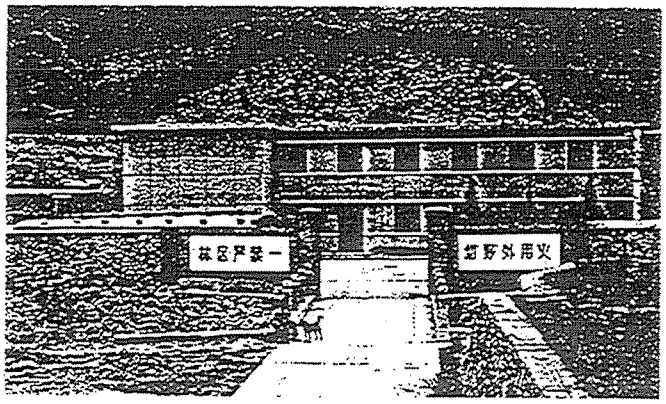
International Absolute Gravity Basestation Network (IAGBN)

Station Location: Beijing Country: People's Republic of China

φ= 40°01'.1 N λ= 116°10'.3 E H= 197.6m g= 9.801106 ms^{-2}

Overview / Access / Outside View / Topo Map

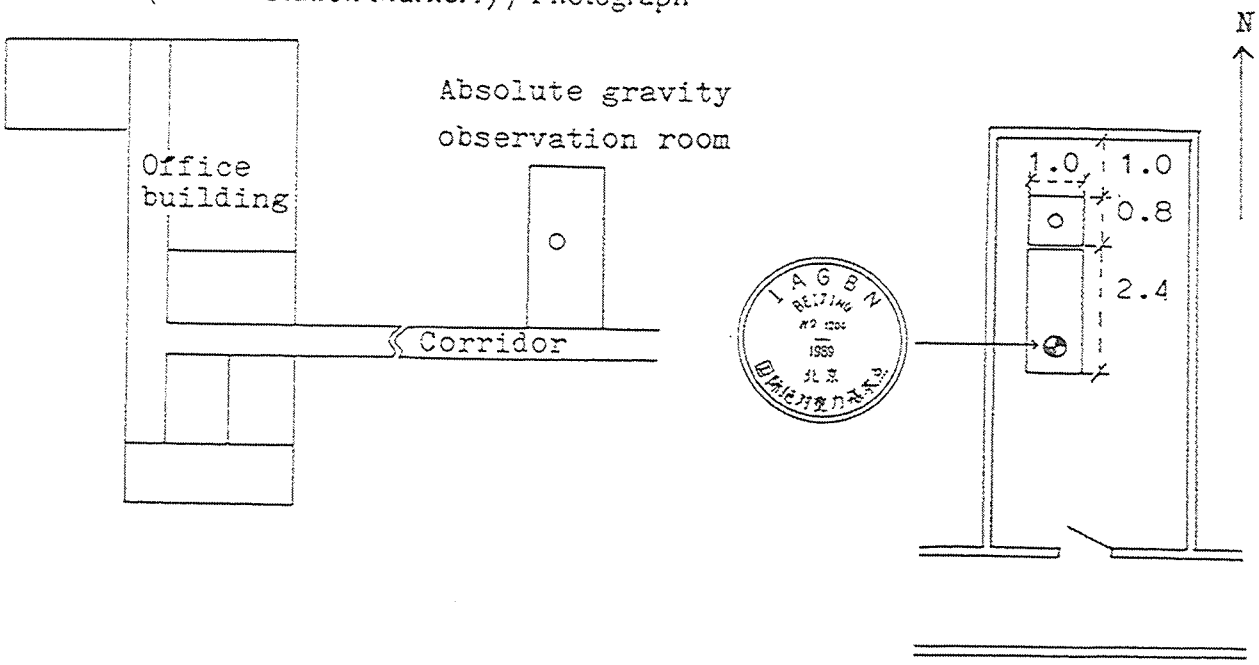




Remarks / Station Identity / Contact

The station is located in the absolute gravity room of the observation cave at the Beijiatan Seismographic Observatory of the Institute of Geophysics, State Seismological Bureau. It is about 15 km from Beijing. Two concrete piers were constructed on bedrock. The measurements were performed on the southern end of the longer pier. The station mark is a brass disk with 90-mm diameter.

Detailed Sketch (North? Station Marker?) / Photograph



Date / Author May 1991, Qiu Qixian

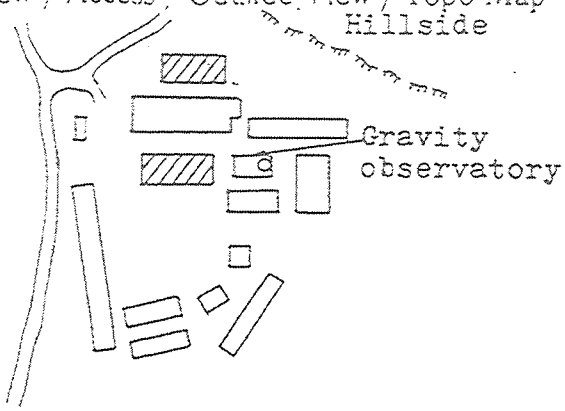
Appendix 2.

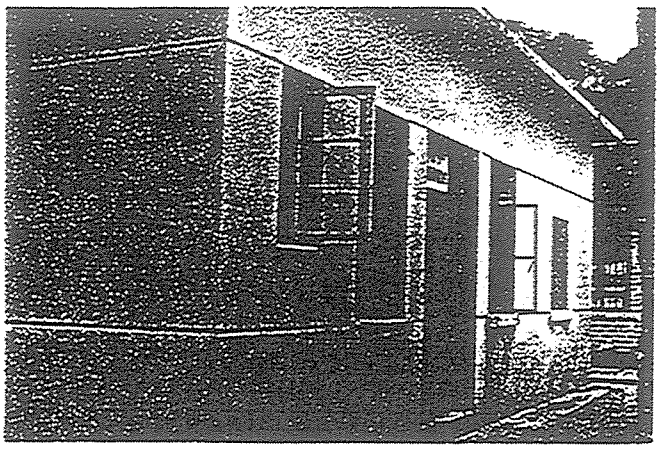
International Absolute Gravity Basestation Network (IAGBN)

Station Location: Nanning — Country: People's Republic of China

φ= 22°57'.8 N — λ= 108°19'.4 E — H= 188.1m — g= 9.787460 ms^{-2}

Overview / Access / Outside View / Topo Map

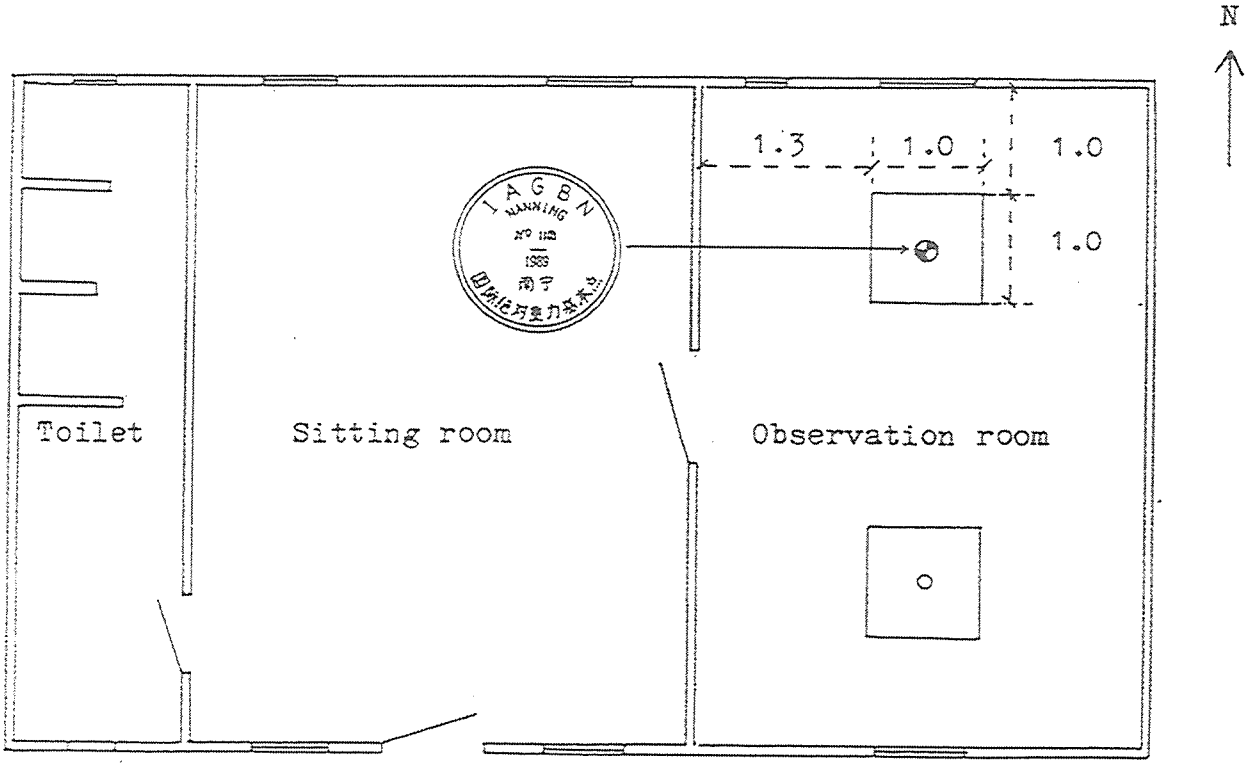




Remarks / Station Identity / Contact

The station is located in the Liuli Branch, Gaofeng Forestry, about 20 km from Nanning, in a specially built Gravity Observatory. Two concrete piers were constructed in the observation room, on bedrock. The measurements were performed on the northern pier. The station mark is a 90-mm brass disk in the center of the pier.

Detailed Sketch (North? Station Marker?) / Photograph



Date / Author May 1991, "Qiu Qixian"