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N° 88

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INFORMATIONS for CONTRIBUTORS

Contributors should follow as closely as possible the rules below :

Manuscripts should be typed (single spaced), 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).

NOTA : *The publisher welcomes the manuscripts which have been prepared using WORD 6 for Macintosh and also accepts ASCII files on diskettes 3"5.*

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.

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. 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 O and zero, the letter l and the number one, kappa and k, mu and the letter u, nu and v, eta and n, also subscripts and superscripts should be clearly noted and easily distinguished. Unusual symbols should be avoided.

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 have 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.

Table. 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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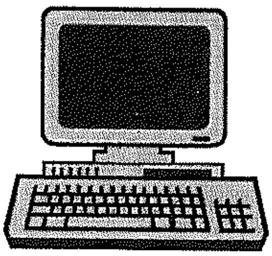

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Bulletin d'information n° 88

PART I

INTERNAL MATTERS

GENERAL INFORMATION

1. HOW TO OBTAIN THE BULLETIN
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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 information 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, an issue contains the National Reports as presented at the International Gravity Commission meeting. 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 (88 have been issued as of June 30, 2001 but numbers 2,16, 18,19 are out of print).

- or subscribe for regularly receiving the two bulletins per year (the special issues are obtained at additional cost).

Requests should be sent to:

Mrs. Nicole LESTIEU
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18, Avenue Edouard Belin
31401 TOULOUSE CEDEX 4 - 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 75 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

2.5.1. CD-Roms

The non confidential data, which have been validated by various procedures are available on two CD-ROMs.

The price of these is :

- *800 (Eight hundred) French francs for individual scientists, universities and research laboratories or groups working in geodesy or geophysics.*
- *3000 (Three thousand) French francs for all other users.*

Most essential quantities are given, in a compressed format. The package includes a user's guide and software to retrieve data according to the area, the source code, the country.

2.5.2. Data stored in the general data base

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 2.3 km to 167 km	
	13 = tc computed from 5.2 km to 167 km	
	14 =tc (unknown radius)	
	15 = tc computed to zone M (58.8 km)	
	16 = tc computed to zone G (3.5 km)	
	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	
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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 2.3 km to 167 km	
	13 = tc computed from 5.2 km to 167 km	
	14 =tc (unknown radius)	
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	16 = tc computed to zone G (3.5 km)	
	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	Mathew's zone	(2 char.)
	when the depth is not corrected depth, this information is necessary. For example : zone 50 for the Eastern Mediterranean Sea	
94-95	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	
96-101	Correction of observed gravity (unit : microgal)	(6 char.)
102-110	Date of observation	(9 char.)
	in Julian day - 2 400 000 (unit : 1/10 000 of day)	
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**	(1 char.)
	0 = without restriction	
	1 = with authorization	
	2 = classified	
123	**Validity**	(1 char.)
	0 = no validation	
	1 = good	
	2 = doubtful	
	3 = lapsed	
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_o), 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:

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

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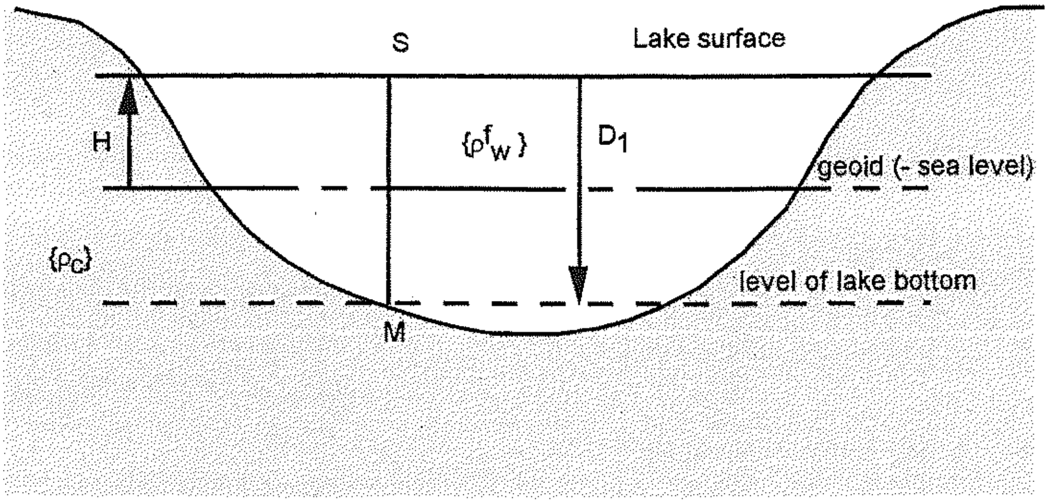
* cf. "On the definition and numerical computation of free air gravity anomalies", by H.G. Wenzel. Bulletin d'Information, BGI, n° 64, pp. 23-40, June 1989.

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 :

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

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

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
EOL land data format		
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	Lake surface above sea level with bottom above sea level	$FA = g + \Gamma H - \gamma_0$
		$BO = FA - k\,\rho_w^f D_1 - k\,\rho_c (H - D_1)$
4	Lake bottom, above sea level	$FA = g + 2\,k\,\rho_w^f D_1 + \Gamma(H - D_1) - \gamma_0$
		$BO = FA - k\,\rho_w^f D_1 - k\,\rho_c (H - D_1)$
5	Lake bottom, below sea level	$FA = g + 2\,k\,\rho_w^f D_1 + \Gamma(H - D_1) - \gamma_0$
		$BO = FA - k\,\rho_w^f H + k\,(\rho_c - \rho_w^f)(D_1 - H)$
6	Lake surface above sea level with bottom below sea level	$FA = g + \Gamma H - \gamma_0$
		$BO = FA - k\,\rho_w^f H + k\,(\rho_c - \rho_w^f)(D_1 - H)$
7	Lake surface, below sea level (here $H <$ o)	$FA = g + \Gamma H - \gamma_0$
		$BO = FA - k\,\rho_c H + k\,(\rho_c - \rho_w^f) D_1$
8	Lake bottom, with surface below sea level ($H <$o)	$FA = g + (2\,k\,\rho_w^f - \Gamma) D_1 + \Gamma H - \gamma_0$
		$BO = FA - k\,\rho_c H + k\,(\rho_c - \rho_w^f) D_1$
9	Ice cap surface, with bottom below sea level	$FA = g + \Gamma H - \gamma_0$
		$BO = FA - k\,\rho_i H + k\,(\rho_c - \rho_i)(D_1 - H)$
10	Ice cap surface, with bottom above sea level	$FA = g + \Gamma H - \gamma_0$
		$BO = FA - k\,\rho_i D_1 - k\,\rho_c (H - D_1)$
EOS Sea Data Format		
1	Ocean Surface	$FA = g - \gamma_0$
		$BO = FA + k\,(\rho_c - \rho_w^s) D_1$
2	Ocean submerged	$FA = g + (2\,k\,\rho_w^s - \Gamma) D_2 - \gamma_0$
		$BO = FA + k\,(\rho_c - \rho_w^s) D_1$
3	Ocean bottom	$FA = g + (2\,k\,\rho_w^s - \Gamma) D_1 - \gamma_0$
		$BO = FA + k\,(\rho_c - \rho_w^s) D_1$

All requests for data must be sent to :

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In case of a request made by telephone, it should be followed by a confirmation letter, or fax. 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 as tarfiles on DAT cartridge (4 mm). for large amounts of data, or on diskette in the case of small files. The exact physical format will be indicated in each case. Also a FTP anonymous service is available on our computer center.

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 CD-Roms : see 2.5.1.
. 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 DAT cartridge
(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 scale, 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).

. 5 F/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

. on CD-Roms : see 2.5.1.

. 1 F per measurement for non commercial use (guaranteed by signed agreement), 5 F per measurement in other cases (direct or indirect commercial use - e.g. in case of use for gridding and/or maps to be sold or distributed by the buyer in any project with commercial application). Minimum charge : 500 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 for non commercial use (guaranteed by signed agreement), 5 F per screened point in other cases (cf. 3.2.1.).

. 500 F minimum charge

3.2.4. Gridding

Same as 3.1.4.

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
DAT cartridge (4 mm) 100 F

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

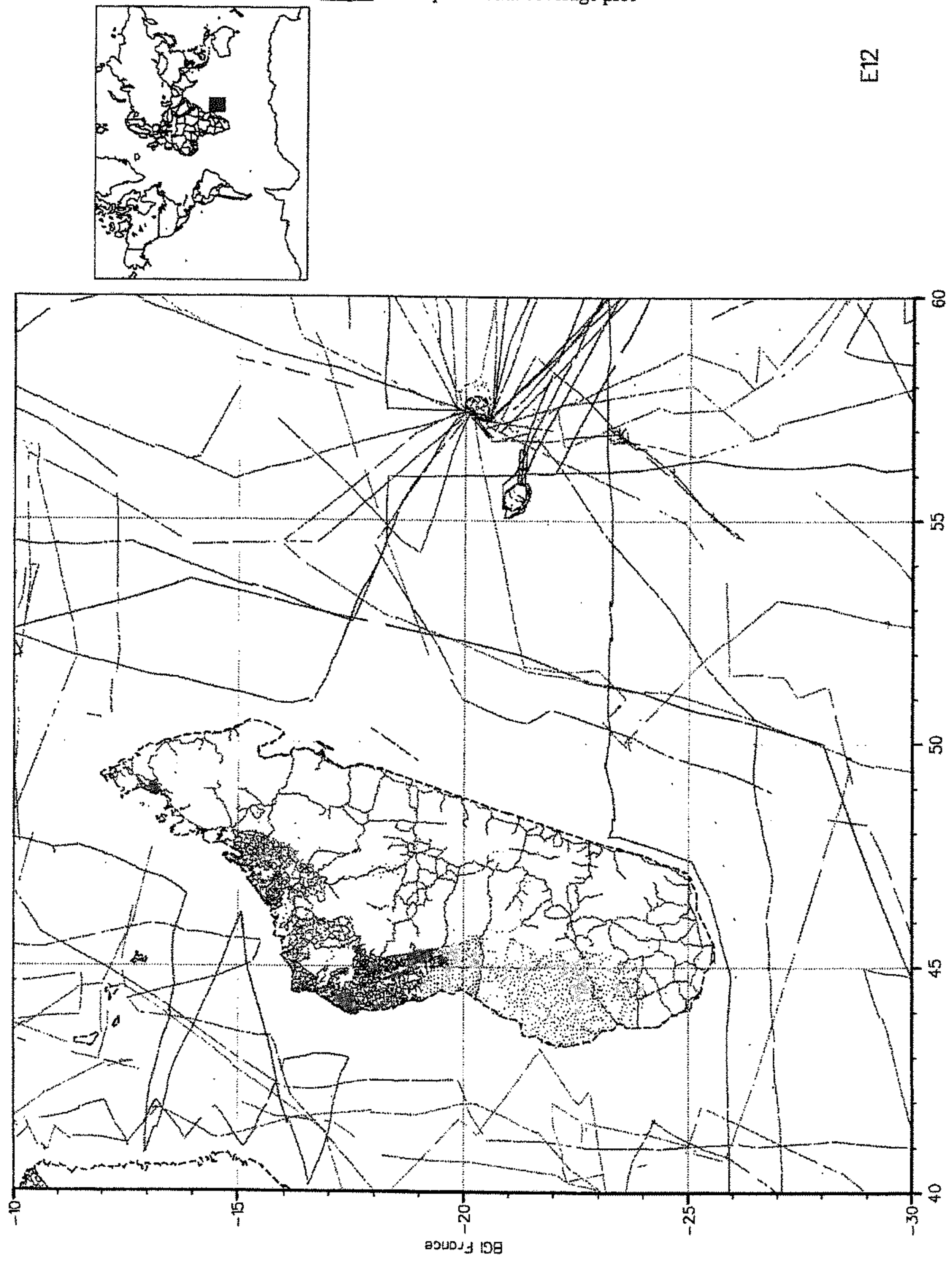
(Vol. 1 and 2)	*1979*	*150 FF*

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

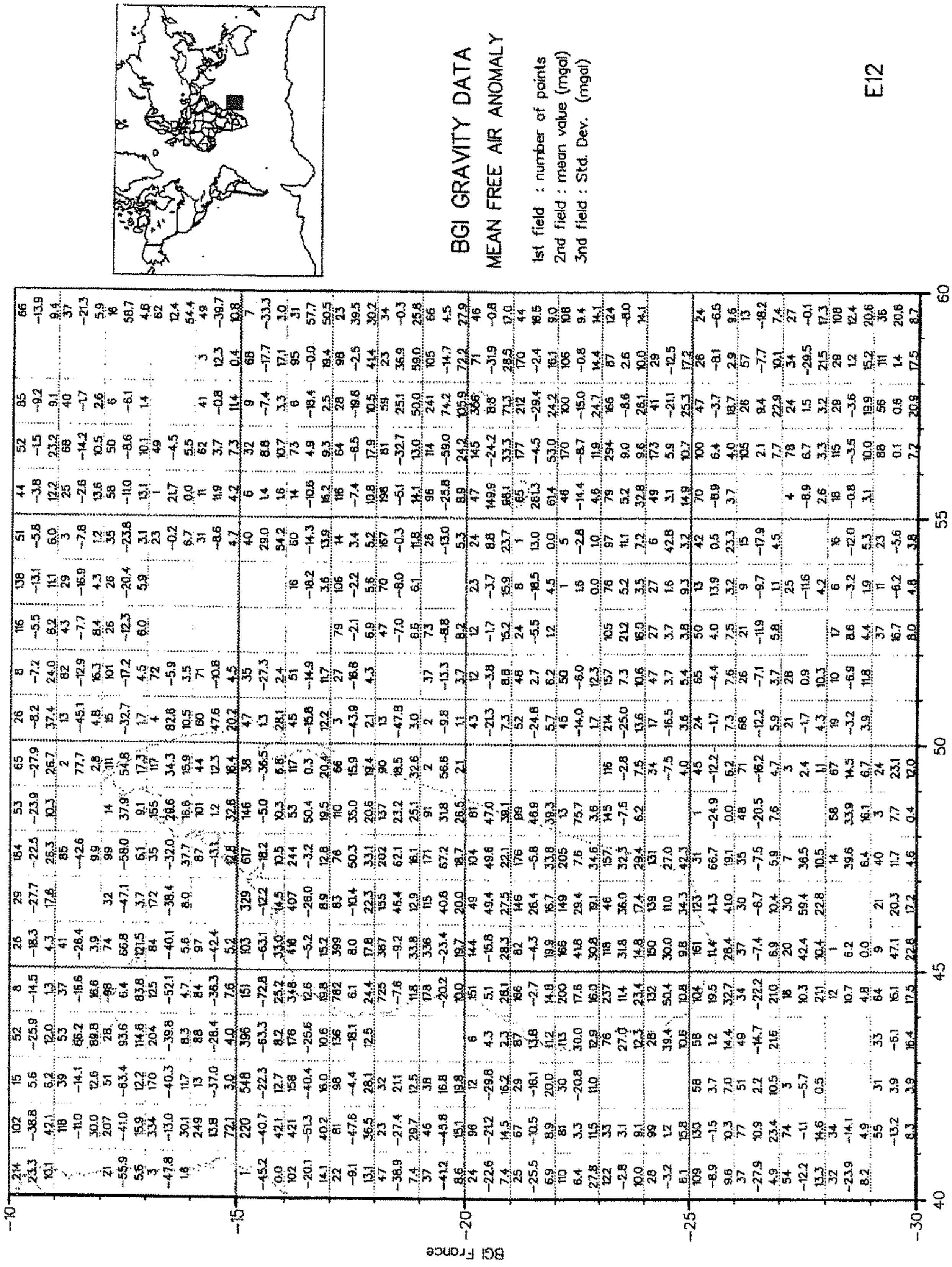
. Colour copy : price according to specifications of request.

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

Map 1. Example of data coverage plot



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



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.

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* 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

SOME CONSIDERATIONS ON THE GRAVITY SYSTEM OF ROMANIA

by

Lucian Besutiu[1], Adrian Nicolescu[1], Vlad Zorilescu[2]

ABSTRACT

As a former socialist country, Romania faces several problems in joining the European Union. One of them is the integration of the Romanian gravity standard into the gravity system of European Community. Within the last decade of the XX-th century, two absolute gravity campaigns on the Romanian territory provided the opportunity for this integration. A slight difference, of about two tenths of milligals, was revealed between gravity datum provided by USNIMA and UNIGRACE campaigns. Gravity ties between UNIGRACE absolute gravity sites and base stations of the Romanian gravity reference networks generally showed a good agreement between both Romania gravity datum or calibrating scale, and the gravity system of EC. Therefore, it is expected that the re-adjustment of the Romanian gravity reference networks constrained by the UNIGRACE data will provide small alterations only.

Key words: gravity, reference network, Romanian, European Community

INTRODUCTION

Romania is a middle size (approx. 237,500 sq. km) Central European country that formerly belonged to the socialist countries community. As it is generally known, this community had more or less different metrological standards as compared to the West European countries. This is why, in the attempt of joining European Community, Romania has also to integrate its gravity standard into the gravity system of Europe. The paper deals with history and achievements within the domain.

THE FIRST GRAVITY CONTROL NETWORK OF ROMANIA

Gravity determinations have a long and fruitful history in Romania. Between 1890-1916, sparse pendulum stations were performed by foreign researchers, especially on the Transylvania territory (Borrass, 1911; Oltay, 1930; Tanni, 1942). The first absolute gravity value at the Military Astronomical Observatory in Bucharest was settled by Prof. Borrass on 1900. Within the second phase (1940-1948), 50 stations almost regularly spaced on the Romanian territory were measured by using an Askania pendulum (Socolescu, 1950). Based on repeated pendulum measurements (made on 1941 and 1947), an absolute gravity value was assigned at the Surlari Geomagnetic Observatory pillar (980 542.90 mgals) according to the Potsdam gravity system (Socolescu & Bisir, 1956).

All the above-mentioned determinations were characterized by modest accuracy and were not appropriate for a modern gravity system.

The first Romanian gravity control network achieved by using relative gravity meters was accomplished by Botezatu (1961). As it can be seen in the Fig. 1, it had been designed as a triangle based network with central-station and consisted of 15 base stations linked by 28 gravity ties.

The base stations were located at the airports only and transport along the gravity ties was performed by plane.

The Nörgaard T.N.K.-1380 gravity meter was used to do the gravity determinations. Measurements were corrected by drift and tidal effects. Tidal corrections were applied, by mistake, after the removal of drift effect, fact that affected the results accuracy. The network was adjusted by taking into account equal weighting for all the ties (Botezatu, 1961).

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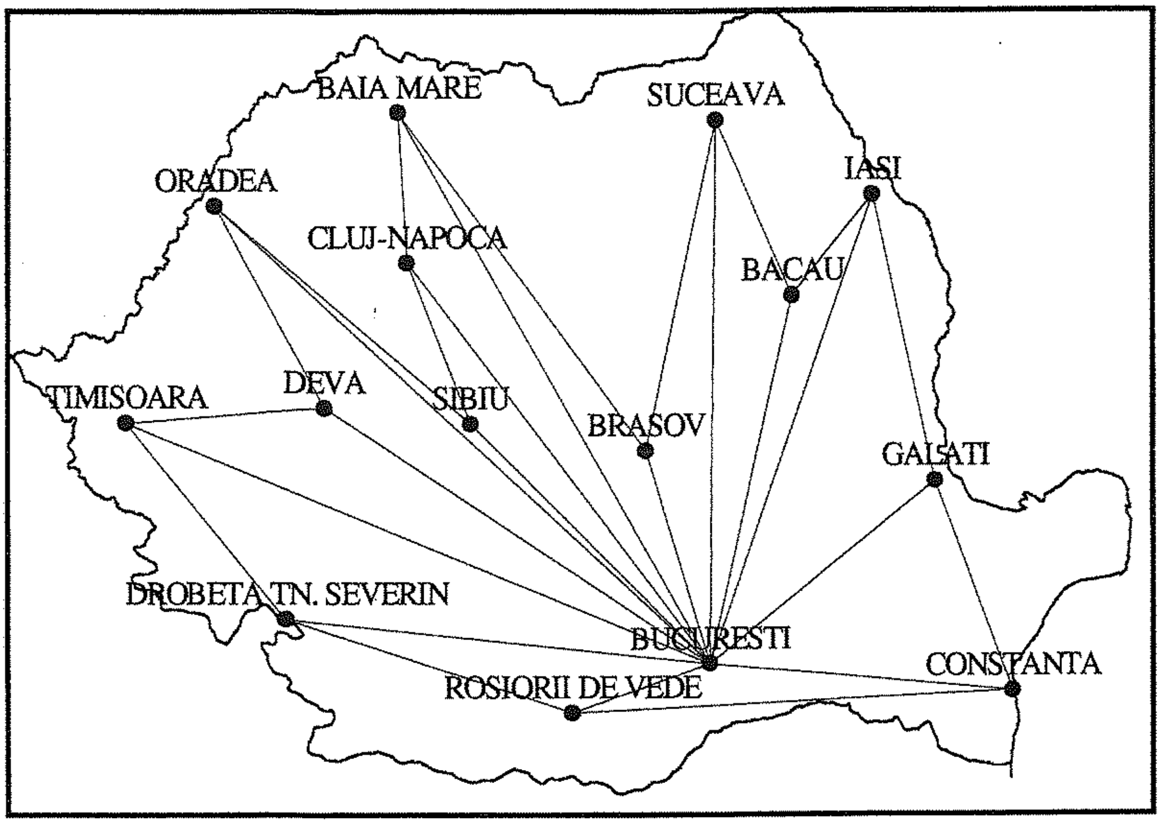

Fig. 1 The first Romanian gravity nework design (according to Botezatu, 1961)

Several years later, eight new base stations and 18 gravity ties were added to the former national gravity control network. Various adjustability along the ties, related to the standard deviation of gravity determinations, were used (Botezatu and Panoiu, 1976).

In both cases, absolute gravity has been transferred to the base stations of the network by linking the central station of the gravity control network to the pendulum absolute gravity station Surlari.

MODERN GRAVITY REFERENCE NETWORKS OF ROMANIA

Taking into account the impressive technological achievements in the construction of the relative gravity meters, several years after the completion of the first gravity control network, the National Committee for the Gravity Map of Romania (NCGMR) decided to up-date the national gravity system. Accordingly, a new I-st order and a II-nd order gravity reference networks were designed (Besutiu et al, 1976-unpublished report). Several variants of the project were handled over to the NCGMR, among which one was especially designed with all the gravity ties within the small dial range of the Scintrex CG 2 gravity meter only to ensure measurements maximum accuracy. Unfortunately, it was rejected due to the missing base stations in the close neighbourhood of the eastern state border. Finally, the NCGMR decided, between accuracy and homogeneity, for a compromise variant of the I-st order network (Fig. 2). The achievement of a II-nd order gravity reference work, consisting of 222 base stations, was also recommended. The triangle system was preserved but central station design was abandoned due to its higher costs. Transport along the gravity ties was by helicopter.

Two Scintrex CG 2 and a Worden gravity meters owned by the Geological Institute of Romania were used for gravity determinations. Field measurements lasted for about ten years (1976-1987). A thorough analysis of the measuring and processing approaches and the gathered results was presented in

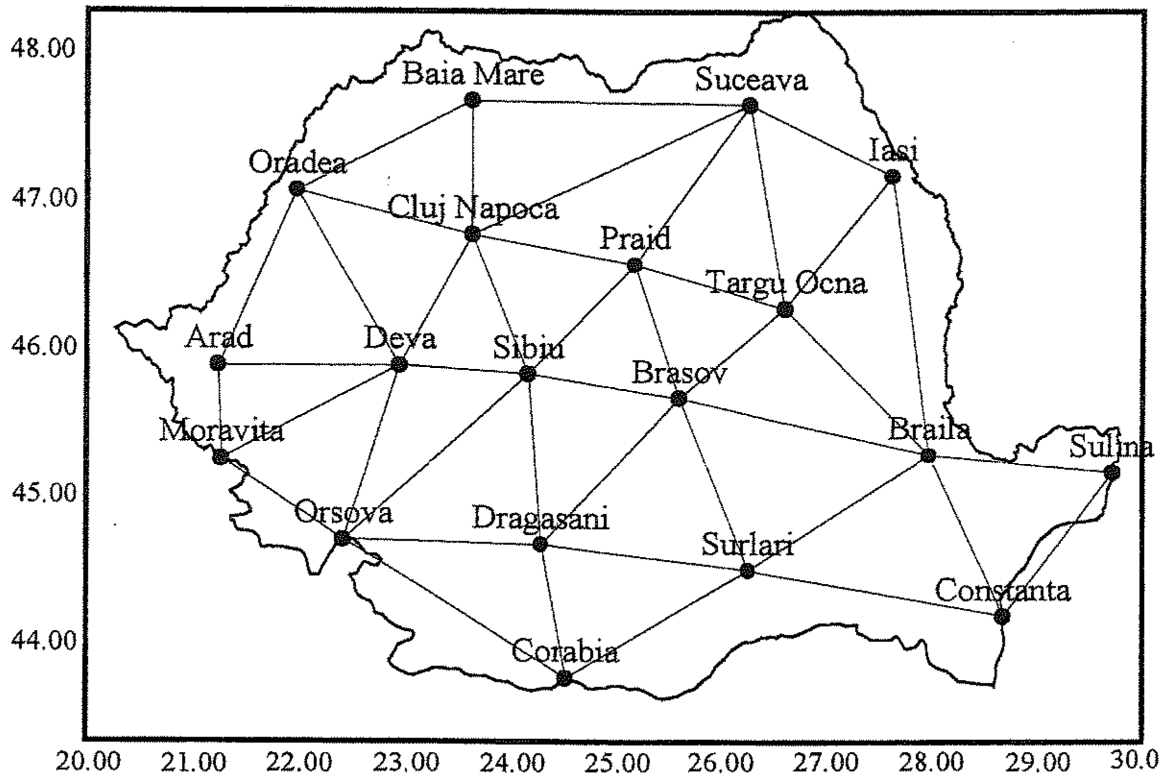

Fig. 2 The I-st order gravity reference network of Romania

previous papers (Besutiu et al, 1994). Scale factors of the meters were subject to some stochastic models used in the network adjustment. However, the best results were obtained when scale factor of each meter was fitted to 78.00 mgals for the calibration line. The figure represents an average of the determinations made on the national calibration line, by all the gravity meters owned by the Geological Institute of Romania, within the main time span of the measuring campaign. Absolute gravity was transferred to the network base stations from the same absolute station Surlari.

The latest variant of a I-st order gravity reference network for the Romanian territory was started recently by the Army Topographical Service (Rotaru and Cioancă, 1996). The project (Fig. 3) consists of much fewer gravity ties between the base stations and the triangle system was abandoned. Field observations were made by two LaCoste & Romberg model G gravity meters, owned by the U.S. Defence Mapping Agency, visiting twice every base station of the network, but gravity intervals were not measured as independent ties.

NATIONAL CALIBRATION LINE

The first attempt to construct a Romanian national gravity calibration line was represented by the calibration line Sinaia-Comarnic, settled in 1955 (Botezatu, 1961). The seven Nörgaard T.N.K. relative gravity meters owned by the Geological Committee of Romania were used on purpose. The mean value thus determined was 26.06 ± 0.03 mgals.

Several years later, with the technological improvements of the meters, another calibration line was settled that is still in use. It is approximately central Romania located, in Brasov area. A gravity interval of about 78 mgals is obtained between Brasov and Poiana Brasov, for an altitude range of about 350 meters.

During the years, various values have been assigned to the gravity range along this calibration line, according to the instruments used. As a rule, when a new lot of gravity meters reached the country

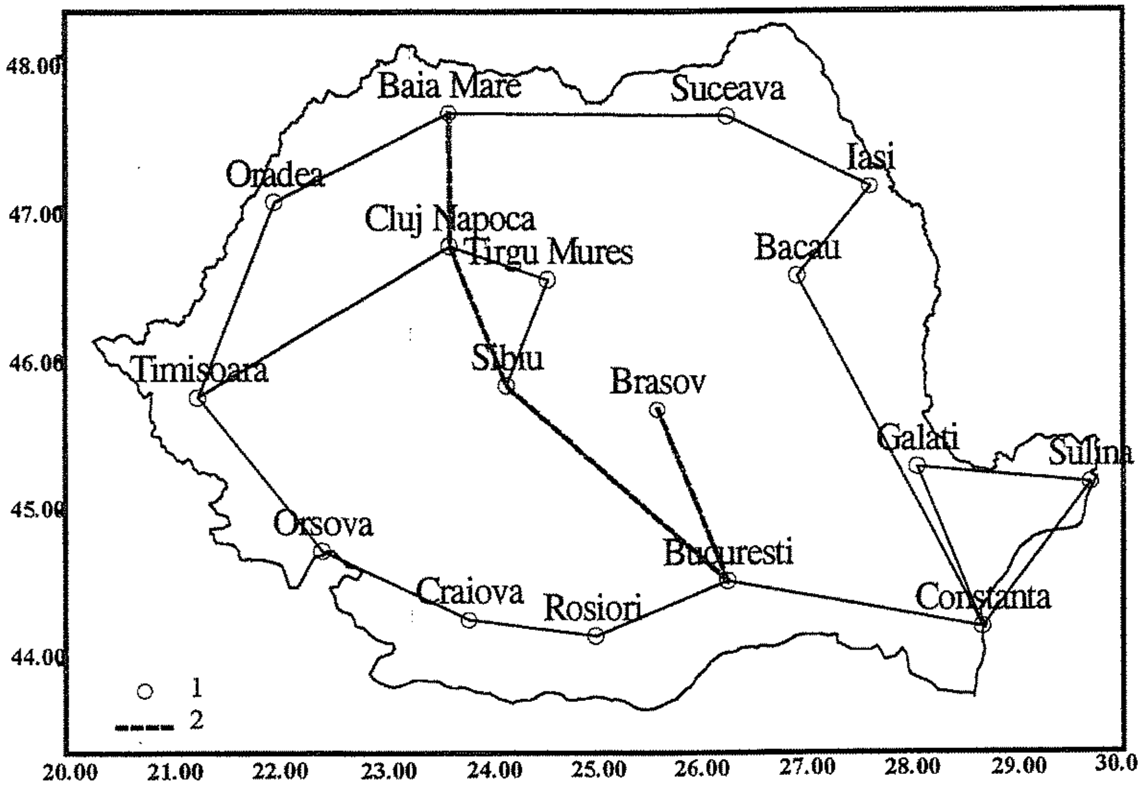

Fig. 3 The design of the Army Topographical Service I-st order gravity network

1, base stations; 2, calibration line

they were taken to measure on the calibration line. The average obtained by using the factory scale factor of each meter was considered as the calibrating standard. Every year, all relative gravity meters were performing several measurements on this calibration line and their scale factors were altered according to its value. Small deviations between figures provided by meters of «Prospectiuni» SA Company and meters owned by the Geological Institute of Romania were evidenced only (see Table 1).

Another approach of calibrating the relative gravity meters was on the tilting table. This way, different results were obtained when the scale factors of the meters owned by the Geological Institute of Romania were tested in Czech (Prague) and Russian (Moscow) laboratories. By comparing the tests to data provided by the calibration line, the Czech laboratories results proved to be closer.

Later on, with the acquisition of its own tilting table, several similar attempts were made within the Geological Institute of Romania gravity laboratory but the results were not too reliable.

Table no. 1 Various gravity intervals determined on the Brasov-Poiana Brasov calibration line

Year	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988
Gravity Range (mgals) *	78.13	78.13	78.12	78.03	77.99	78.01	77.99	78.02	78.00	78.06	77.97	77.98	78.03	78.06
	78.12	77.95	77.95	77.96	78.02	77.96	77.98	78.00	78.04	78.01	78.07	78.08	78.06	78.01

** mean values obtained by GIR meters only*

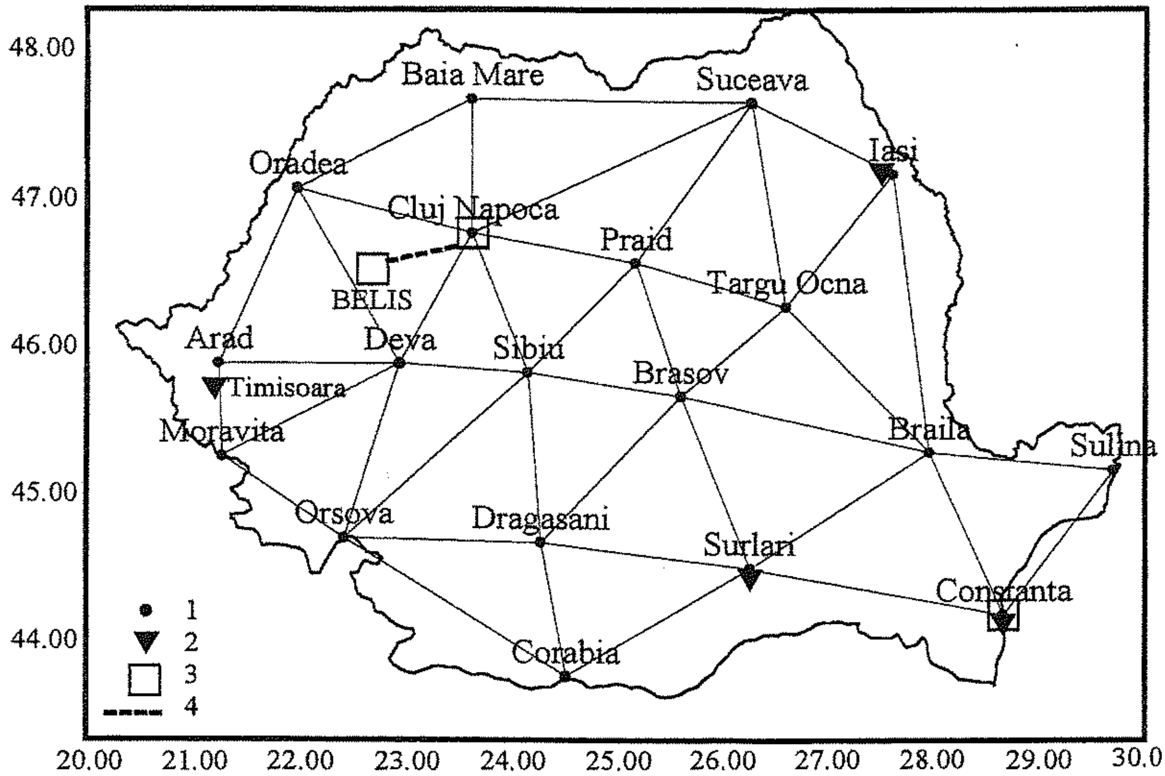

Fig. 4 The I-st order gravity reference network and absolute gravity sites on the Romanian territory

1) I-st order reference network base station; 2) USNIMA absolute gravity station; 3) UNIGRACE absolute gravity station; 4) UNIGRACE calibration line

ABSOLUTE GRAVITY CAMPAIGNS ON THE ROMANIAN TERRITORY

Within the last decade of the XX-th century, several gravity campaigns were made on the Romanian territory, by using absolute gravity meters.

The first absolute gravity determinations on the Romanian territory, by using a ballistic FG5-107 gravity meter, were performed on 1995 by an American team of the US National Imagery Mapping Agency - Geodesy and Geophysics Department (publications SMWD3-95-034 and GIMGD-97-035).

Starting in 1998 a EU project, UNIGRACE, has been aimed to integrate gravity systems of the former socialist countries from Central and Eastern Europe into the gravity system of European Community (Reinhart et al, 1998). Romania takes active part to the project as an associate partner. Two UNIGRACE absolute gravity stations (Cluj-Napoca and Constantza) are located on the Romanian territory (Rosca, 1999).

In order to achieve a modern calibration line, a third, auxiliary UNIGRACE station, was located within Belis area (about 70 kilometres away from Cluj-Napoca). Location of the absolute gravity stations on the Romanian territory is shown in Fig. 4. Absolute gravity determinations were performed at the above-mentioned sites by using an FG5-101 (Reinhart, 1999) and JILA-G5 ballistic gravity meters.

Relative gravity measurements were added by a team of the Geological Institute of Romania - Department Geophysics of Lithosphere at each absolute gravity station in order to evaluate the vertical gradient. Links between them and base stations of the Romanian gravity reference networks were also performed (Rosca and Besutiu, in press; Besutiu et al, in press).

GRAVITY SYSTEM EVALUATION

The whole evaluation of the Romanian gravity system was based on gravity determinations made with the LaCoste & Romberg D-214 meter, owned by the Geological Institute of Romania. Gravity ties between USNIMA and UNIGRACE absolute stations, or between UNIGRACE stations and base-stations of the national gravity reference networks were used on purpose.

Before and after the measuring campaign, the scale factor of the L&R D-214 meter was checked up on the above-mentioned UNIGRACE calibration line (Table no. 2).

Table no. 2 Gravity intervals determined by L&R D-214 meter on the UNIGRACE calibration line as compared to the absolute gravity determinations

Year	Gravity interval on the calibration line as provided by absolute measurements - mgals -	Gravity interval on the calibration line as provided by the L&R D-214 relative meter - mgals-	Deviation -mgals-
1999	172.125	172.108	0.017
2000	*172.128	172.098	0.030

** 2000 UNIGRACE campaign provisional value (Dr. Mäkinen, personal communication)*

The very small unfitting revealed, fully confirmed the accuracy of the scale factor of the meter as provided by the factory.

Gravity links between UNIGRACE stations and the Romanian gravity reference networks (rgrn) base stations revealed small discrepancies in gravity datum only (Table no. 3).

Table no. 3 Comparisons between absolute gravity provided by UNIGRACE stations and stations of the Romanian gravity reference networks

SITE	Year	UNIGRACE gravity (mgals)	Absolute gravity transferred from rgrn (mgals)	rgrn transfer station	Deviation (mgals)
Constantza	1998	*980570.047	980570.36	Constantza I-st order	-0.32
	2000	**980570.175	980570.36	Constantza I-st order	-0.19
	2000	**980570.175	980570.41	Constantza II-nd order	-0.23
Cluj-Napoca	1999	*980682.449	980682.84	Cluj-Napoca I-st order	-0.39
	2000	**980682.569	980682.87	Cluj-Napoca I-st order	-0.30
Belis	2000	**980510.441	980510.61	Huedin II-nd order	-0.17

** measured by FG5-101 absolute ballistic gravity meter*

*** measured by JILA-G5 absolute ballistic gravity meter (Dr. Mäkinen, personal communication)*

The Romanian gravity standard was also checked up by comparing a large gravity interval across the national territory (between Cluj-Napoca and Constantza), as provided by the I-st order Romanian gravity reference network and the UNIGRACE stations.

Table no. 4 summarises the results.

Table no. 4 Gravity interval between Constantza and Cluj-Napoca as provided by rgrn and UNIGRACE network

Gravity interval subject to analysis	Gravity meter	Δg according to rgrn (mgals)	Δg according to UNIGRACE* (mgals)	Deviation	
				Absolute (mgals)	Relative (%)
Cluj-Napoca – Constantza	L&R D-214	119.92	119.83	0.09	0.08

** 2000 UNIGRACE campaign provisional value (Dr. Mäkinen, personal communication)*

Absolute gravity provided for the Romanian territory by USNIMA and UNIGRACE campaigns were compared too. It is worth mentioning that a slight difference between the American and European standards was observed while measuring in Constantza area (Table no. 5).

Table no. 5 Comparison between gravity data provided by UNIGRACE and USNIMA stations in Constantza area

Specification	Absolute value		Evaluations	
Station Year	USNIMA 1995 (mgals)	UNIGRACE 2000 (mgals)	Gravity interval by L&R D-214 (mgals)	Deviation (mgals)
Gravity	*980569.929	**980570.177	0.262	0.014

** according to GIMGD-97-035*

*** 2000 UNIGRACE campaign provisional value (Dr. Mäkinen, personal communication)*

CONCLUSIONS

Following the analysis made on both national reference network datum and scale factor, it may be remarked that the gravity system of Romania is approaching well the European gravity standard. Several statements might conclude the brief analysis hereby made:

- gravity transferred from the first and second order rgrn to the UNIGRACE absolute gravity sites exhibited almost the same level;
- appropriate scale factor of the actual rgrn was evidenced;
- small differences between the absolute gravity provided by the American team and UNIGRACE teams (about two tenths of milligals) were revealed;
- it is expected that the re-adjustment of the rgrn, as constrained on the UNIGRACE project results, would provide minor alterations only.

The problem persisting in the integration of the Romanian gravity system into EU requirements is a matter of legislation, which still preserves a top-secret character to the catalogues with co-ordinates and absolute gravity of the rgrn base stations.

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THE EGYPTIAN NATIONAL GRAVITY STANDARDIZATION NETWORK

(ENGSN97)

By

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1. INTRODUCTION

An accurate gravity framework for Egypt has been established through the Egyptian National Gravity Standardization Network 1997 (ENGSN97). With a national homogeneous distribution and the utilization of precise instrumentation, the ENGSN97 serves as the accurate national gravity datum for Egypt. The project has been executed by the Survey Research Institute (SRI) starting in late of 1994 and finished in September 1998. The ENGSN97 consists of 5 absolute gravity stations and 145 relative gravity stations (Fig. 1)

2. FIELD MEASUREMENTS

According to the project's goals, the field observation campaigns include the collection of three types of measurements: relative gravity, GPS coordinates, and precise levels. This is, of course, beside the necessary absolute gravity measurements at some selected stations.

2.1 Absolute gravity measurements

Five absolute gravity stations have been established and observed to serve as an absolute gravity framework for the ENGSN97 network. The measurements, have been done by teamwork from the U.S. National Imagery and Mapping Agency (NIMA, formally DMA) in April 1997. The locations of these sites are Giza (30° 00' N, 31° 11' E), Helwan (29° 52' N, 31° 21' E), Marsa Matrouh (31° 21' N, 27° 14' E), Aswan (24° 05' N, 32° 54' E), and El-Kharga (25° 27' N, 30° 33' E). The measurements have been carried out using the FG5 absolute gravity meter, which has a higher level of robustness, reliability and an instrumental uncertainty estimate of $\pm$ 0.0011 mGal. In each observed site, 4800 drops have been collected in a 24-hour session. The processing of the collected data has been carried out in the DMA. High-precision geodetic coordinates of each site have been obtained using GPS sessions of at least 24 hours of satellites tracking. The orthometric heights of all sites have been obtained through precise levelling.

2.2 Relative gravity measurements

Four LaCoste and Romberge (LCR) gravimeters have been used mainly in measuring the relative gravity values of the ENGSN97:

* Two model G gravimeters (G938 and G940).
* Two model D gravimeters (D161 and D170).

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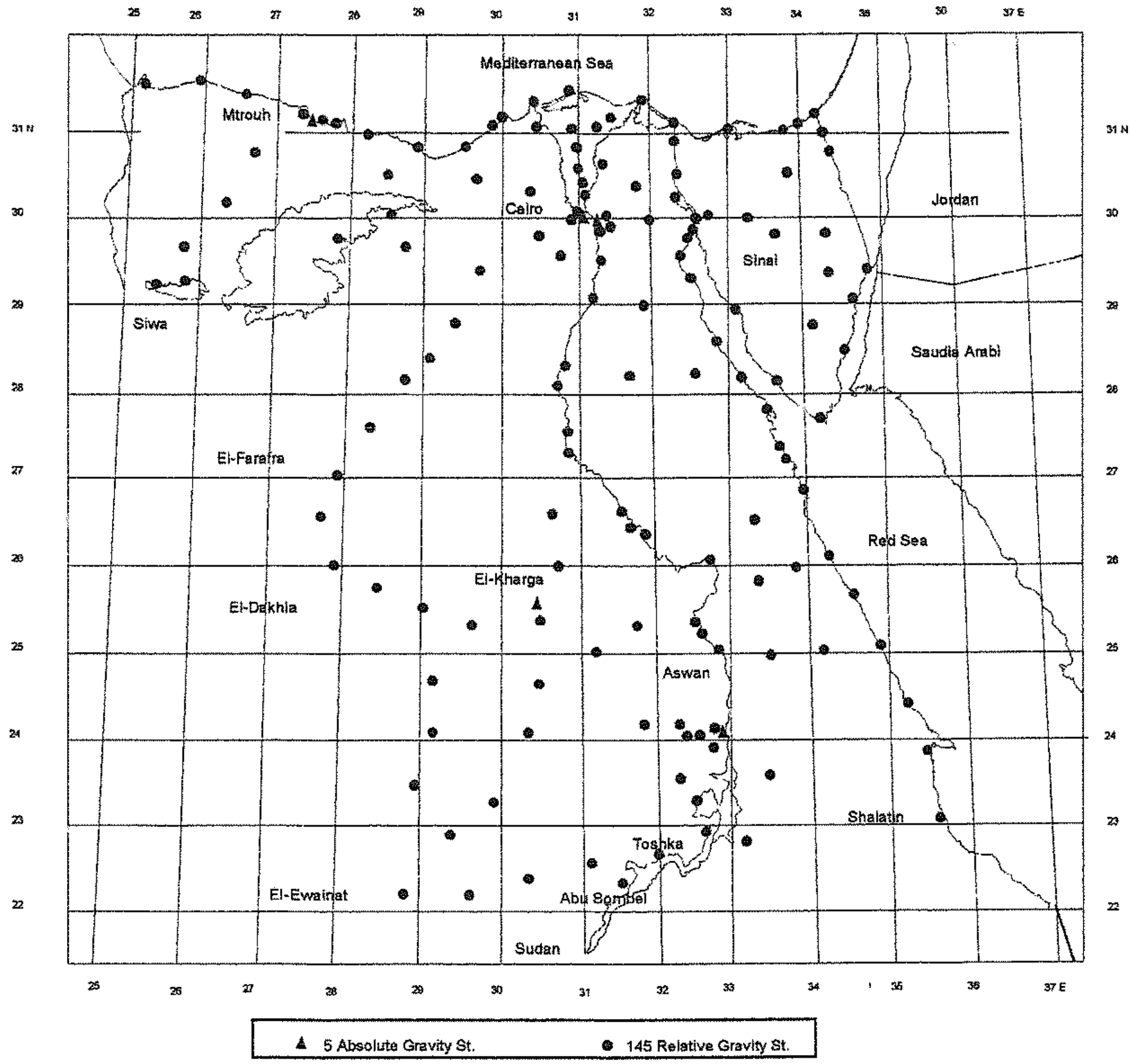

Fig. 1 : The Egyptian National Gravity Standardization Network (ENGSN97)

The connections of the relative gravity loops to the absolute gravity stations have been carried out using seven LCR relative gravity meters, three of them (G126, G131, and G269) belong to the U.S. DMA. All loops started from the nearest absolute gravity station.

2.3 GPS measurements

The satellite-based Global Positioning System (GPS) is the most recent and precise positioning technology used in a variety of civilian and military applications worldwide. A number of GPS receivers have been used to obtain accurate coordinates of the ENGSN97 stations. Since the station separations of the ENGSN97 network are in the average of 67 km, dual-frequency geodetic GPS receivers are used in each gravity loop. These types of receivers have a relative precision of 0.5 cm ± 1 part per million (ppm). During each gravity loop, three or four GPS receivers are utilized in a base line or a network mode to get relative base lines components. Usually, a station from the Egyptian zero-order GPS network is observed during each loop so that the ENGSN97 stations coordinates are referenced to the national datum. A program for GPS Network Adjustment, developed by the author, is frequently used in the adjustment of GPS networks [Dawod, 1991].

2.4 Precise levelling measurements

In each gravity loop in the ENGSN97 project, the orthometric height of each station is determined by the precise levelling technique. Wild N3 precise levels, with a precision of ± 0.1 mm, and Invar rods are used in levelling routes, each starts from a first-order bench mark.

3. FINAL RESULTS

Several gravity processing models have been developed in the form of observation equations, for a gravimeter reading, as a function of the involved unknown parameters, for each case of observation that can be encountered in practice, when establishing or densifying a first-order gravity network. Those developed processing models have been utilized and several efficient computer programs have been developed to process, adjust, and analyze gravity networks. The Gravity Network Processing and Adjustment (GNPA) software, developed by the author, is the main computational tool used in this project. It processes and adjusts a gravity network that consists of several field loops observed by several gravimeters, with or without time breaks in the observation scheme. The unknowns contain the gravity values of observed stations and two unknowns (orientation and drift) for each instrument. If a loop contains a break, its data set is further divided into two virtual data series and two unknowns have to be estimated to each data series.

Concerning the estimated gravity values at the network 150 stations, the obtained results indicate that the minimum adjusted gravity value was 978679.776 mGal while the maximum adjusted gravity value was 979504.981 mGal, with an average value of 979126.005 mGal. As an indication of the precision of the ENGSN97 network, the standard deviations of the adjusted gravity values range from ± 0.002 mGal to ± 0.048 mGal, with an average value of ± 0.021 mGal [Dawod, 1998].

The free-air and Bouguer gravity anomaly maps for Egypt have been updated based on utilizing all the available gravity data. The free-air gravity anomaly ranges from –122.42 mGal to 128.65 mGal with an average value of –3.21 mGal and RMS equals ± 28.55 mGal. The Bouguer gravity anomaly ranges from –130.97 mGal to 81.76 mGal with an average value of –21.77 mGal and RMS equals ± 28.38 mGal.

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