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BUREAU
GRAVIMETRIQUE
INTERNATIONAL

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N° 72

Juin 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 text. 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 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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BULLETIN D'INFORMATION

Juin 1993

N° 72

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ANNOUNCEMENT

JOINT MEETING

of the
International Gravity Commission (IGC)
and the
International Geoid Commission (ICG)

September 12-16, 1994
Graz, Austria

The International Gravity Commission and the International Geoid Commission will organize a joint meeting to be held in Graz from Sept. 12-16, 1994.

Specific topics concerning gravity will be dealt with on Sept. 12, while those concerning the geoid will be discussed on Sept. 16. Topics of common interest will be dealt with during the mid part of the meeting.

Participation fee :	US \$ 125.-
Accompanying persons :	US \$ 60.-
Deadline for abstracts :	July 1, 1994

Local organization :

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PRELIMINARY PROGRAM

Sunday, Sep. 11 : 13:00 - 18:00 BGI Directing Board Meeting

Monday, Sep. 12 : 09:00 - 13:00 IGC Technical reports
15:00 - 18:00 Gravity instrumentation

Tuesday, Sep. 13 : 09:00 - 13:00 Intercomparison campaign
15:00 - 18:00 Standards, networks, data bases,
software

Wednesday, Sep. 14 : 09:00 - 13:00 Space & airborne gravity and gradiometry
15:00 - 18:00 Geophysical inversion of gravity and geoid

Thursday, Sep. 15 : 09:00 - 13:00 Sightseeing
15:00 - 18:00 Altimetry

Friday, Sep. 16 : 09:00 - 13:00 International projects and advanced
techniques, including the Geoid in Europe
15:00 - 18:00 ICG Technical session

Saturday Sep. 17 : 09:00 - 13:00 Subcommission for the Geoid in Europe
Technical Session
15:00 - 18:00 Poster Presentation

<p>PART I</p> <p>INTERNAL MATTERS</p>

GENERAL INFORMATION

- 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.

<p style="text-align: center;">EOL LAND DATA FORMAT RECORD DESCRIPTION 126 characters</p>
--

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 = $R \leq 5$ Meters	
		2 = $5 < R \leq 20$ M (approximately 0'01)	
		3 = $20 < R \leq 100$ M	
		4 = $100 < R \leq 200$ M (approximately 0'1)	
		5 = $200 < R \leq 500$ M	
		6 = $500 < R \leq 1000$ M	
		7 = $1000 < R \leq 2000$ M (approximately 1')	
		8 = $2000 < R \leq 5000$ M	
		9 = $5000 \text{ M} < R$	
		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 = $E \leq 0.02$ M	
		2 = $.02 < E \leq 0.1$ M	
		3 = $.1 < E \leq 1$	
		4 = $1 < E \leq 2$	
		5 = $2 < E \leq 5$	
		6 = $5 < E \leq 10$	
		7 = $10 < E \leq 20$	
		8 = $20 < E \leq 50$	
		9 = $50 < E \leq 100$	
		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.)
	<i>computed according to the next mentioned radius & density</i>	
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 = $E \leq 0.01$ mgal	
	2 = $.01 < E \leq 0.05$ mgal	
	3 = $.05 < E \leq 0.1$ mgal	
	4 = $0.1 < E \leq 0.5$ mgal	
	5 = $0.5 < E \leq 1.$ mgal	
	6 = $1. < E \leq 3.$ mgal	
	7 = $3. < E \leq 5.$ mgal	
	8 = $5. < E \leq 10$ mgal	
	9 = $10. < E \leq 15.$ mgal	
	10 = $15. < E \leq 20.$ mgal	
	11 = $20. < E$ mgal	
94-99	Correction of observed gravity (unit : microgal)	(6 char.)
100-105	Reference station	(6 char.)
	<i>This station is the base station (BGI number) to which the concerned station is referred</i>	

106-108	Apparatus used for the measurement of G	(3 char.)
	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	
109-111	Country code (BGI)	(3 char.)
112	Confidentiality	(1 char.)
	0 = without restriction	
1 = with authorization	
	2 = classified	
113	Validity	(1 char.)
	0 = no validation	
	1 = good	
	2 = doubtful	
	3 = lapsed	
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	
	9-16	Latitude (unit : 0.00001 degree)	(8 char.)
	17-25	Longitude (unit : 0.00001 degree)	(8 char.)
	26-27	Accuracy of position	(9 char.)
		The site of the gravity measurements is defined in a circle of radius R	(2 char.)
		0 = no information	
		1 = $R \leq 5$ Meters	
		2 = $5 < R \leq 20$ M (approximately 0'01)	
		3 = $20 < R \leq 100$ M	
		4 = $100 < R \leq 200$ M (approximately 0'1)	
		5 = $200 < R \leq 500$ M	
		6 = $500 < R \leq 1000$ M	
		7 = $1000 < R \leq 2000$ M (approximately 1')	
		8 = $2000 < R \leq 5000$ M	
		9 = $5000 \text{ M} < R$	
		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 = $E \leq 0.02$ Meter	
		2 = $.02 < E \leq 0.1$ M	
		3 = $.1 < E \leq 1$	
		4 = $1 < E \leq 2$	
		5 = $2 < E \leq 5$	
		6 = $5 < E \leq 10$	
		7 = $10 < E \leq 20$	
		8 = $20 < E \leq 50$	
		9 = $50 < E \leq 100$	
		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) <i>computed according to the next mentioned radius & density</i>	(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 <i>when the depth is not corrected depth, this information is necessary. For example : zone 50 for the Eastern Mediterranean Sea</i>	(2 char.)
94-95	Accuracy of gravity 0 = no information 1 = $E \leq 0.01$ mgal 2 = $.01 < E \leq 0.05$ mgal 3 = $.05 < E \leq 0.1$ mgal 4 = $0.1 < E \leq 0.5$ mgal 5 = $0.5 < E \leq 1.$ mgal 6 = $1. < E \leq 3.$ mgal 7 = $3. < E \leq 5.$ mgal 8 = $5. < E \leq 10.$ mgal 9 = $10. < E \leq 15.$ mgal 10 = $15 < E \leq 20.$ mgal 11 = $20. < E$ mgal	(2 char.)
96-101	Correction of observed gravity (unit : microgal)	(6 char.)
102-110	Date of observation <i>in Julian day - 2 400 000 (unit : 1/10 000 of day)</i>	(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 :

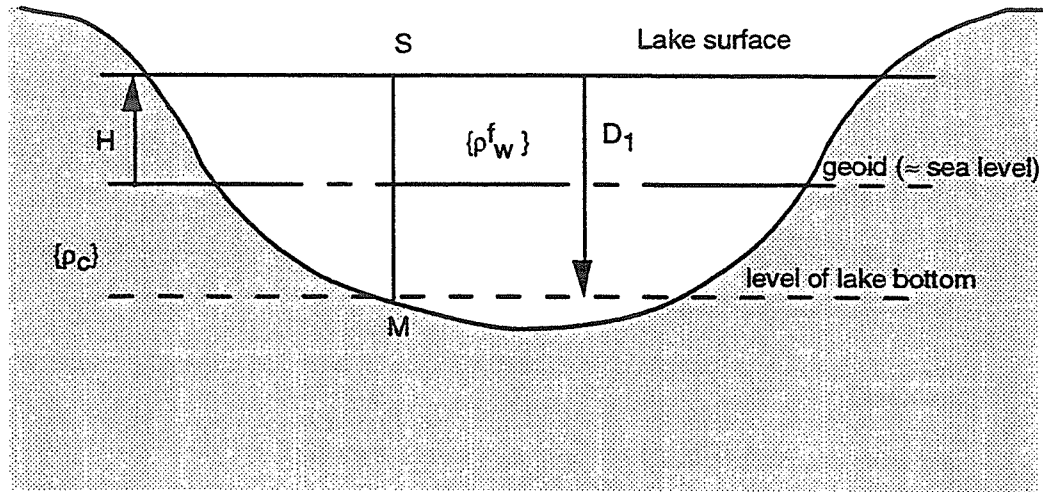
g	: observed value of gravity
γ	: theoretical value of gravity (on the ellipsoid)
Γ	: vertical gradient of gravity (approximated by 0.3086 mgal/meter)
H	: elevation of the physical surface of the land, lake or glacier ($H = 0$ at sea surface), positive upward
D_1	: depth of water, or ice, positive downward
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 ($667.2 \cdot 10^{-13} \text{ m}^3 \text{ kg}^{-1} \text{ s}^{-2}$) $\Rightarrow k = 2 \pi G$
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).

* 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 :

$$\begin{aligned} \delta g_s &= g_s - k \rho_w^f D_1 + k \rho_c (D_1 - H) \\ &= g_s - k \rho_w^f [H + (D_1 - H)] + k \rho_c (D_1 - H) \\ &= g_s - k \rho_w^f H + k (\rho_c - \rho_w^f)(D_1 - H) \\ \Rightarrow BO &= \delta g_s + \Gamma H - \gamma_0 \end{aligned}$$

The table below covers most frequent cases. It is an update of the list of formulas published before, where four typing errors have been corrected.

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 with bottom above sea level	$FA = g + \Gamma H - \gamma_0$ $BO = FA - k \rho_w^f D_1 - k \rho_c (H - D_1)$
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 with bottom below sea level	$FA = g + \Gamma H - \gamma_0$ $BO = FA - k \rho_w^f H + k (\rho_c - \rho_w^f) (D_1 - H)$
A	Lake surface, below sea level (here $H < 0$)	$FA = g + \Gamma H - \gamma_0$ $BO = FA - k \rho_c H + k (\rho_c - \rho_w^f) D_1$
B	Lake bottom, with surface below sea level ($H < 0$)	$FA = g + (2 k \rho_w^f - \Gamma) D_1 + \Gamma H - \gamma_0$ $BO = FA - k \rho_c H + k (\rho_c - \rho_w^f) D_1$
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.

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 $20^{\circ} \times 20^{\circ}$), 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 x Δ' area : 10F/ $\Delta\Delta'$ 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 the polygon.

3.2.3. Data Screening

. 1 F per screened point

. 250 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

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

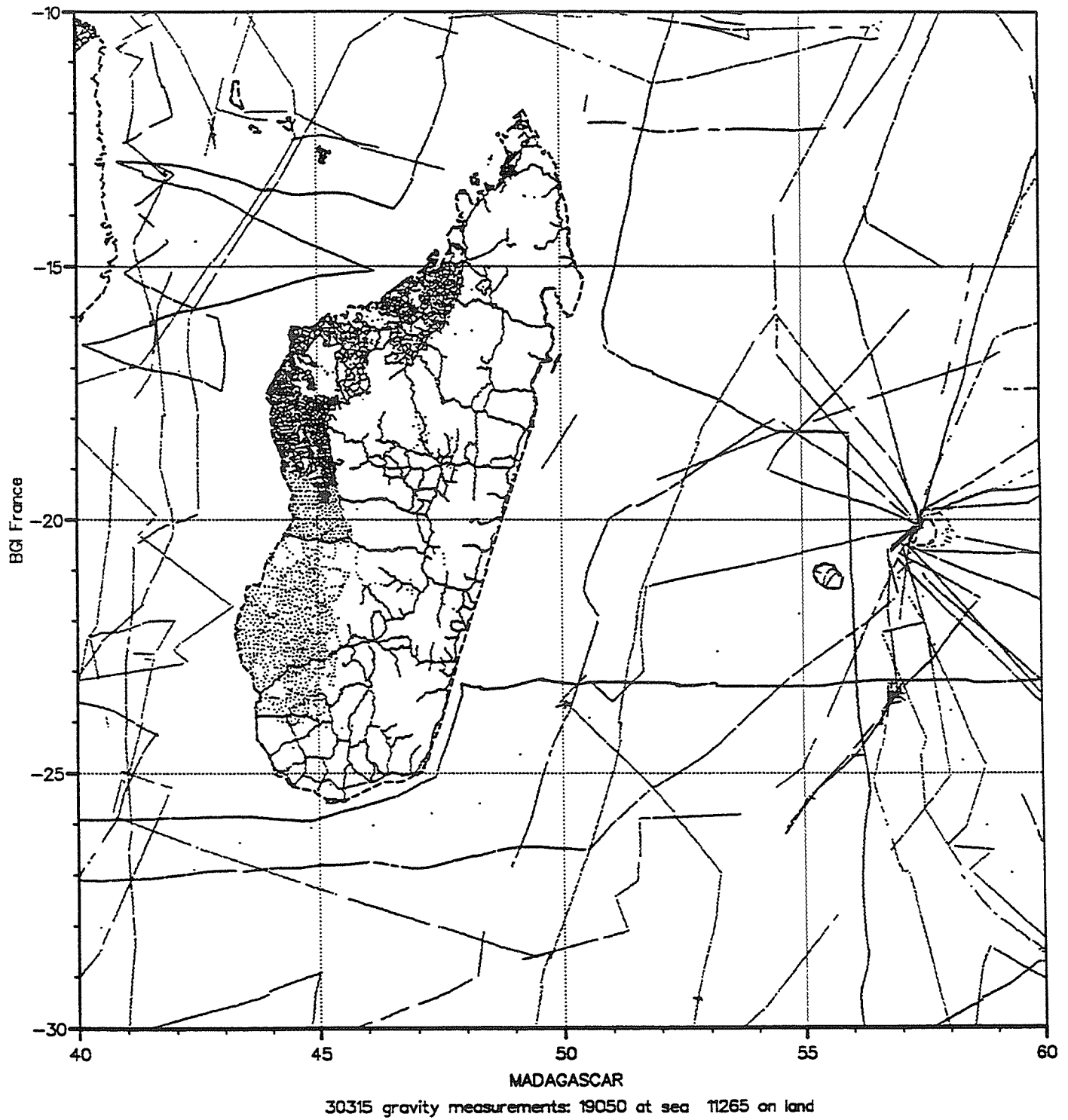
(Vol. 1 and 2)	1979	150 FF
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. Black and white copy of maps : 150 F per copy

. Colour copy : price according to specifications of request.

Mailing charges will be added for air-mail parcels when "Air-Mail" is requested)
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Map 1. Example of data coverage plot



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

BGI GRAVITY DATA: MEAN FREE AIR ANOMALY

1ST FIELD: POINTS NUMBER

2ND FIELD: MEAN VALUE (MGAL)

3RD FIELD: R.M.S (MGAL**2)

-10	213 23.4 10.1	105 -40.2 42.3	15 5.6 6.2	75 -25.6 13.0	16 -12.8 2.1	26 -18.3 4.3	29 -27.7 17.6	184 -22.5 25.3	53 -23.9 10.3	65 -27.9 26.7	26 -8.2 37.4	8 -7.2 24.0	116 -5.5 8.2	138 -13.1 11.1	52 -5.9 5.9	44 -3.8 12.2	54 -1.8 22.8	84 -9.2 9.2	66 -13.9 9.4
		151 -20.4 32.5	41 -15.2 13.2	48 96.1 132.0	64 -18.3 13.8	41 -26.4 3.9		85 -42.6 9.9		2 77.7 2.8	13 -45.1 4.8	82 -12.9 16.3	43 -7.7 8.4	29 -16.9 4.3	2 -8.1 1.3	25 -2.6 13.6	67 -14.4 10.5	40 -1.7 2.6	37 -21.3 5.9
	21 -55.9 5.6	257 -42.7 17.2	51 -63.4 12.2	27 129.1 219.8	121 21.1 165.0	72 85.1 158.0	32 -47.1 3.7	100 -57.9 6.1	15 37.2 9.1	111 54.8 17.3	15 -32.7 1.7	101 -17.2 4.5	26 -12.3 6.0	26 -20.4 5.9	35 -23.8 3.1	58 -11.0 13.1	50 -8.6 10.1	6 -6.1 1.4	16 58.7 4.8
	3 -47.8 1.6	375 -13.6 29.9	170 -40.3 11.7	223 -39.3 8.4	134 -52.4 4.7	85 -40.1 5.7	171 -38.5 8.0	34 -31.5 8.1	154 29.6 16.7	117 34.3 15.9	4 82.6 10.5	72 -5.9 3.5			23 -2 6.7	1 21.7 0.0	49 -4.5 5.5		63 11.3 54.6
		284 3.6 77.8	24 -35.7 3.3	108 -27.8 4.3	84 -36.3 1.6	57 -42.4 5.2		87 -13.1 12.8	101 12.3 32.6	44 47.6 16.4	71 -10.8 20.2				31 -8.6 4.7	11 11.9 4.2	62 3.7 7.3	41 -8 11.4	3 12.3 4
	1 -45.2 0.0	247 -45.1 42.5	575 -22.2 13.1	396 -63.3 25.2	151 -72.8 32.4	103 -63.6 14.3	322 -12.4 9.7	612 -18.5 10.3	145 -4.9 6.8	38 -36.5 28.1	47 1.3 2.4	35 -27.3 2.4			42 28.9 53.0	6 1.4 1.6	32 8.8 10.7	9 -7.4 3.3	68 -17.7 17.1
	102 -20.1 14.1	480 -47.1 41.9	159 -40.4 15.9	175 -25.5 10.5	346 12.6 19.8	414 -5.1 15.2	407 -26.0 8.9	240 50.4 19.5	53 3.3 20.4	117 -15.8 12.2	45 -14.9 11.7	51 -16.9 11.7		30 -15.8 3.8	84 -14.0 14.9	28 -9.5 16.2	73 4.9 9.3	6 -18.4 2.5	95 -7.0 19.4
	44 -7.9 13.0	105 -42.2 35.5	98 -4.4 28.1	136 -18.1 12.5	774 6.0 24.4	384 8.1 17.6	83 -10.4 22.3	76 50.3 33.1	110 35.0 20.6	66 15.9 19.4	3 -43.9 2.1	27 -15.8 4.3	79 -2.1 6.9	133 -2.2 5.9	14 3.4 5.2	146 -10.3 11.5	68 -8.6 19.3	28 -19.8 10.5	98 -2.5 41.4
	67 -40.4 6.8	46 -26.6 29.7	32 21.1 12.5		720 -7.5 11.7	380 -9.3 34.2	154 46.3 12.9	202 62.1 16.1	137 23.2 25.1	90 18.5 32.6	13 -47.8 3.0	37 -13.3 8.9	100 -5.7 6.1	74 -8.1 11.8	71 -3 14.1	167 -5.1 14.2	198 -34.1 50.0	114 25.1 59.0	59 36.9 59.0
	47 -42.2 7.9	92 -44.9 15.2	38 16.8 19.8		176 -20.1 10.0	330 -23.5 19.8	115 40.8 20.0	171 67.2 18.7	91 31.8 26.5	2 56.5 2.1	2 -9.8 1.1	37 -13.3 8.9	100 -5.7 6.1	74 -8.1 11.8	71 -3 14.1	167 -5.1 14.2	198 -34.1 50.0	114 25.1 59.0	59 36.9 59.0
-20	24 -22.6 7.4	152 -23.3 14.5	17 -33.2 15.0	6 4.3 2.3	151 -15.2 28.1	142 49.4 27.6	49 49.6 22.1	104 47.0 39.1	81 47.0 39.1		43 -21.3 7.3	24 -2.9 8.8	24 -8 15.1	23 -3.7 15.9	24 8.8 23.7	47 149.9 98.1	153 -24.5 32.5	368 8.6 30.6	96 -33.1 28.0
	26 -24.4 8.6	105 -11.3 9.0	58 -15.3 19.9	97 12.4 12.2	166 -2.7 14.8	81 -4.2 20.1	146 26.4 16.7	76 46.9 39.3	99 46.9 39.3		52 -24.8 5.7	77 5.1 5.9	24 -5.5 1.2	8 -18.5 4.5	1 13.0 0.0	65 281.3 61.4	202 -6.8 50.2	210 -29.2 24.2	170 -2.4 16.1
	184 7.6 29.5	147 3.4 11.4	60 -20.0 11.0	113 30.0 12.9	200 17.6 16.0	165 41.9 30.9	150 29.2 19.1	203 7.3 34.4	13 75.7 3.6		47 -14.0 1.7	73 -5.2 11.8		1 1.6 0.0	5 -2.8 1.0	51 -14.3 4.4	186 -9.7 11.9	100 -15.0 24.7	106 -8 14.4
	155 -3.1 10.5	59 5.2 7.9		76 27.0 12.3	236 11.5 23.4	118 31.8 14.8	46 36.0 17.4	157 32.3 29.4	145 -7.5 6.2	116 -2.8 7.5	214 -25.0 23.6	185 7.5 10.3	105 21.2 16.0	76 5.2 3.5	97 11.1 7.2	104 6.4 30.2	295 9.1 9.6	185 -8.7 26.1	87 2.6 10.0
	33 -3.4 5.9	126 6.2 17.3		28 39.4 10.6	132 50.4 10.8	151 30.1 9.7	138 10.8 34.4	131 27.0 42.3		34 -7.5 4.0	17 -16.5 3.6	76 4.3 5.6	27 3.7 3.8	27 1.6 9.3	12 43.2 3.2	61 7.9 16.7	173 5.9 10.7	41 -21.1 25.3	29 -12.5 17.2
	134 -7.5 9.6	167 -5 10.0	58 3.7 7.0	12 1.2 14.4	19.5 11.4 32.7	11.4 41.7 28.4	122 41.7 41.0	31 66.7 19.1	1 -24.9 0.0	45 -12.2 6.2	48 -1.2 7.3	76 -3.1 8.1	70 6.4 7.9	26 14.3 3.2	53 8.5 26.3	70 -8.9 4.0	100 6.4 4.0	47 -3.7 18.7	26 -8.1 2.9
	37 -27.9 4.9	126 16.8 22.3	69 4.8 10.3	71 -8.9 22.0	37 -22.3 20.2	37 -7.4 6.9	30 -6.7 10.4	35 -7.5 5.9	48 -20.5 7.6	71 -16.2 4.7	93 -10.1 6.3	52 -5.6 3.7	21 -11.9 5.8	9 -9.7 1.1	15 -17.9 4.5		105 2.1 7.7	27 9.8 22.6	56 -8.2 9.4
	75 -9.5 14.8	81 2.7 18.8	3 -5.7 .5		35 11.6 20.6	40 42.6 10.4	60 38.5 22.8	14 36.7 10.5		6 2.5 1.1	42 -1.4 4.2	55 1.1 10.2		25 -11.6 4.2		4 -8.9 2.6	78 6.7 3.3	24 1.5 3.2	34 -28.5 21.5
	63 -24.0 7.8	34 -14.1 4.9			12 10.7 4.8	1 6.2 0.0		28 39.8 6.4	79 38.0 15.9	134 14.6 6.7	38 -3.0 3.9	20 -6.6 11.8	17 8.6 4.4	16 -3.2 1.9	18 -8 3.1	115 -3.5 10.0	29 -3.6 19.9	29 1.2 15.2	108 12.4 20.6
-30		55 -13.2 8.3	31 3.9 3.9	33 -5.1 16.4	64 16.1 17.5	9 47.1 22.8	21 20.3 17.2	40 11.7 4.6	3 7.7 .4	48 23.0 22.0			37 16.7 8.0	11 -6.2 4.8	23 -5.6 3.8		88 1.1 7.2	57 5.6 20.7	111 1.4 17.5

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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, 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 magnetic 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

THE BUREAU GRAVIMETRIQUE INTERNATIONAL

A TEN YEAR STATUS REPORT

G. Balmino
Director of B.G.I.
Secretary General of I.U.G.G.

1. INTRODUCTION

In geodesy, gravity values play a great part in the modelling of the Earth gravity field, which is of permanent use for the computation of precise satellite orbits. It is also an essential information for the determination of the geoid, and for the definition of the ocean mean surface used for the study of the global circulation (Balmino et al., 1986). In geophysics, the interpretation of the gravity field anomalies allows to study density variations in the lithosphere or the mantle, with applications in oil and mineral prospecting (Balmino, 1986a).

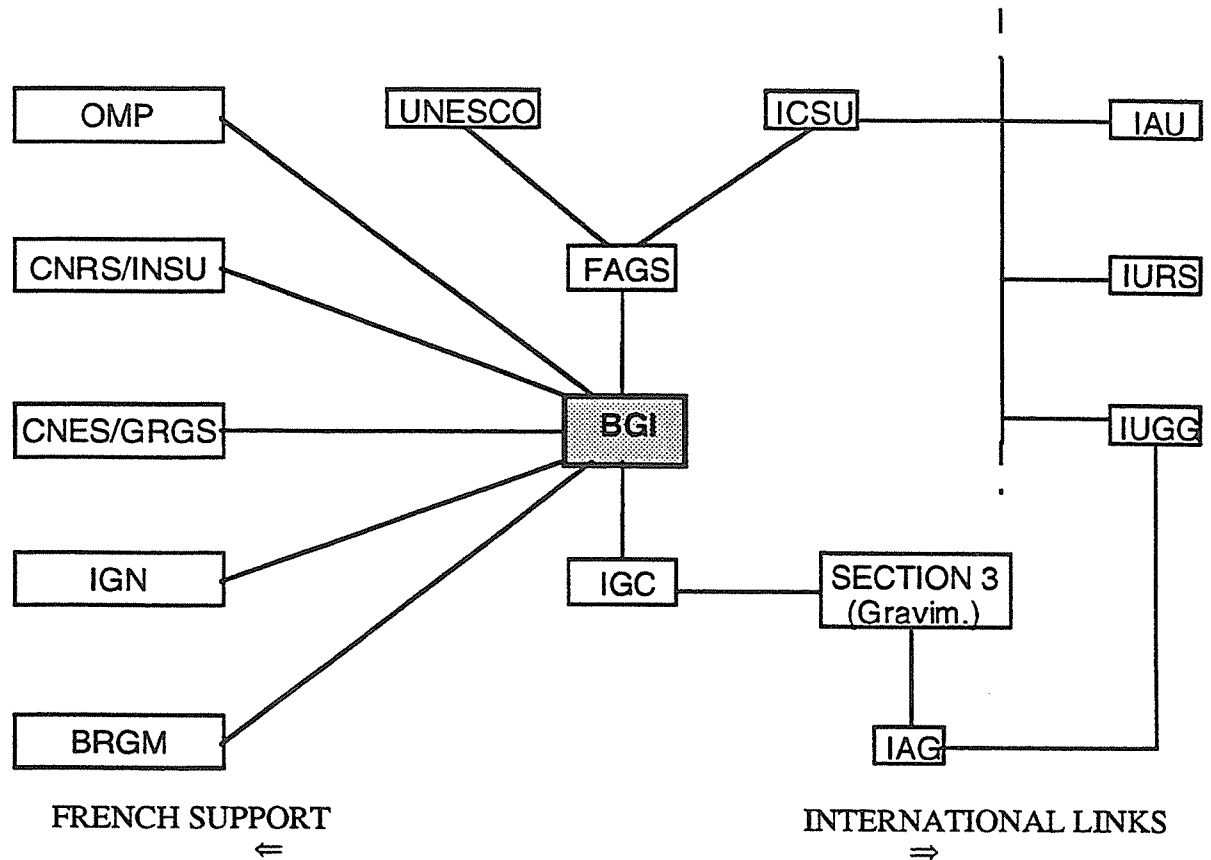
The Bureau Gravimétrique International (BGI) is one of the offices of the Federation of Astronomical and Geophysical Services (FAGS) which operates under the auspices and in part thanks to the financial support of the International Council of Scientific Unions (ICSU) and the United Nations Educational Scientific and Cultural Organisation (UNESCO). Primarily interested in the activities of these services are the International Astronomical Union (IAU), the International Union of Radio-Sciences (IURS), and of course the International Union of Geodesy and Geophysics (IUGG). - see fig. 1 and Melchior (1989). It may also be considered as an executive arm of the International Gravity Commission (IGC) within the International Association of Geodesy (IAG), one of the seven associations of which IUGG is composed.

The idea of a service for gravity data and related matters originated during the 1951 IUGG General Assembly in Brussels and BGI was created in 1953. Its offices have been located in France since the beginning, when pioneer works were being done by the first directors : Reverend Father Lejay from the Society of Jesus, Academician Tardy, and then Professor Levallois.

The central office is in Toulouse (France) since 1980, in the premises of the Observatoire Midi-Pyrénées (OMP) of which it is one of the services. The other french supporting organisations are : the Centre National d'Etudes Spatiales (CNES), the Institut Géographique National (IGN), the Centre National de la Recherche Scientifique (CNRS) - via the Institut National des Sciences de l'Univers (INSU), and the Bureau de Recherches Géologiques et Minières (BRGM). There exists a covenant between these agencies to guarantee their support to BGI.

BGI has a Directing Board composed of ten voting members (comprising the IGC president, vice-president, secretary, the section III chairman, the BGI director, plus elected members), and non voting members : the chairmen of the IGC-BGI working groups ; the secretary of the Board ; two ex-officio members (the Geoid Commission president and a FAGS representative). The Directing Board meets once every year.

Fig. 1. Links of BGI with international and national (french) bodies



List of Acronyms :

BGI	Bureau Gravimétrique International
BRGM	Bureau de Recherches Géologiques et Minières
CNES/GRGS	Centre National d'Etudes Spatiales/Groupe de Recherches en Géodésie Spatiale
CNRS/INSU	Centre National de la Recherche Scientifique/Institut National des Sciences de l'Univers
FAGS	Federation of Astronomical and Geophysical Services
IAG	International Association of Geodesy
IAU	International Astronomical Union
ICSU	International Council of Scientific Unions
IGC	International Gravimetric Commission
IGN	Institut Géographique National
IUGG	International Union of Geodesy and Geophysics
IURS	International Union of Radio Science
OMP	Observatoire Midi-Pyrénées
UNESCO	United Nations Educational, Scientific and Cultural Organisations

2. OBJECTIVES AND TERMS OF REFERENCE

The main task of BGI is to collect, on a world-wide basis, all gravity measurements and pertinent information about the gravity field of the Earth, to compile them and store them in a computerized data base in order to redistribute them on request to a large variety of users for scientific purposes. The data consist of : gravimeter observations (mainly location - three co-ordinates, gravity value, corrections, anomalies ...), mean free-air gravity values, gravity maps, reference station descriptions, publications dealing with the Earth's gravity. BGI also has access through one of his

host agencies to satellite altimetry derived geoid heights (presently from Geos 3, Seasat, Geosat, ERS1, Topex/Poseidon) ; spherical harmonic coefficients of current global geopotential models ; mean topographic heights. These data are sometimes used internally for data validation and geophysical analysis.

The data collection activities are especially conducted in the framework of large regional projects, in order to densify the world data coverage, and BGI has put emphasis on the validation of received measurements, so as to improve the quality of the delivered information.

Four working groups are presently helping BGI in different tasks :

- WG1 : Data Processing. Our Canadian colleagues, who have chaired this group from the beginning, have provided invaluable help to the Bureau.
- WG2 : World Gravity Standards. This group is now in charge, and probably for a long time, of the deployment of the International Absolute Gravity Base Station Network (IAGBN)
- WG5 : Monitoring of Non Tidal Gravity Variations. Newly established, this group has a large variety of problems to deal with, due to the growing use of superconducting gravimeters.
- WG6 : Intercomparison of Absolute Gravimeters. For a long time under the responsibility of Prof. Boulanger, the activity is now controlled by this group which continues to organise comparisons of instruments about every four years at the Bureau International des Poids et mesures (B.I.P.M.) in Sèvres, near Paris ; the next campaign is to take place in November-December of this year.

Other working groups (WG3, WG4) terminated their mandates and were naturally dismantled.

3. SERVICE ACTIVITIES

3.1. Providing Data to BGI

All kinds of gravity data can be sent to BGI, with or without restrictions of redistribution to be specified by the contributors, sometimes in the form of a protocol of usage.

Essential quantities and information for gravity data submission are :

a) 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

b) Measured (observed) gravity, corrected to eliminate the periodic gravitational effects of the Sun and the Moon, and the instrumental drift.

c) 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 : IGSN71.

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. Additional information are optional, but welcome.

3.2. Getting Data and Services from BGI

The most frequent service BGI can provide is data retrieval over a limited area. Data are sent on tapes or diskettes or printouts. Data coverage plots may also be provided, usually over $20^\circ \times 20^\circ$ areas. Cases of massive data retrieval requests may be considered ; they are studied and may be processed in a specific way.

Other services include :

- data screening,
- provision of gravity base station information (on micro-fiches, sometimes rushed by fax),
- data evaluation and gridding,
- computation of mean values (simple means ; computation by collocation available in the course of 1993),
- contouring,
- supply of maps, or information on existing maps (catalogue available in printed form and on tape).

The cost of the services have been established in view of the categories of users-mostly contributors of measurements and scientists, and also considering the large amount of support of our host organisations. The charging policy is explained in detail in the Bulletin d'Information. Some of the services may be provided free of charge upon request, to data contributors, individuals working in universities, such as students, and generally to any person who can contribute to our activities on a data or documentation exchange basis.

3.3. The Publications

BGI issues a Bulletin d'Information twice a year (generally in June and December). It is sent to over 300 subscribers. 71 issues have been published so far. The Bulletin contains :

- . general information in the field, news about the Bureau itself, recent additions to our holdings,
- . contributing papers in gravimetry,
- . communications at meetings dealing with gravimetry (e.g. IGC meeting).

Every four years, an issue (which may be an additional one) contains the National Reports of Activities in Gravimetry (e.g. n°70).

Besides, the full catalogue of the holdings is issued every two years. It usually comes in two volumes : one contains the coverage plots of the measured gravity points in the form of maps covering $20^\circ \times 20^\circ$ areas (fig. 2), the other is a set of tables of statistics per square degree (number of points, mean free-air value and its r.m.s.) corresponding to each map of the first volume (fig. 3).

BGI has also prepared and published a brochure publicising its role and activities (distributed mainly at the Vancouver and Vienne IUGG General Assemblies, also on other occasions), and realised (with IGN Space Company) a Spot image map with contours of Bouguer gravity anomalies.

Technical Reports are also produced, on an irregular basis, on problems, software and various applications dealt with at the Bureau.

Fig. 2. Example of data coverage plot

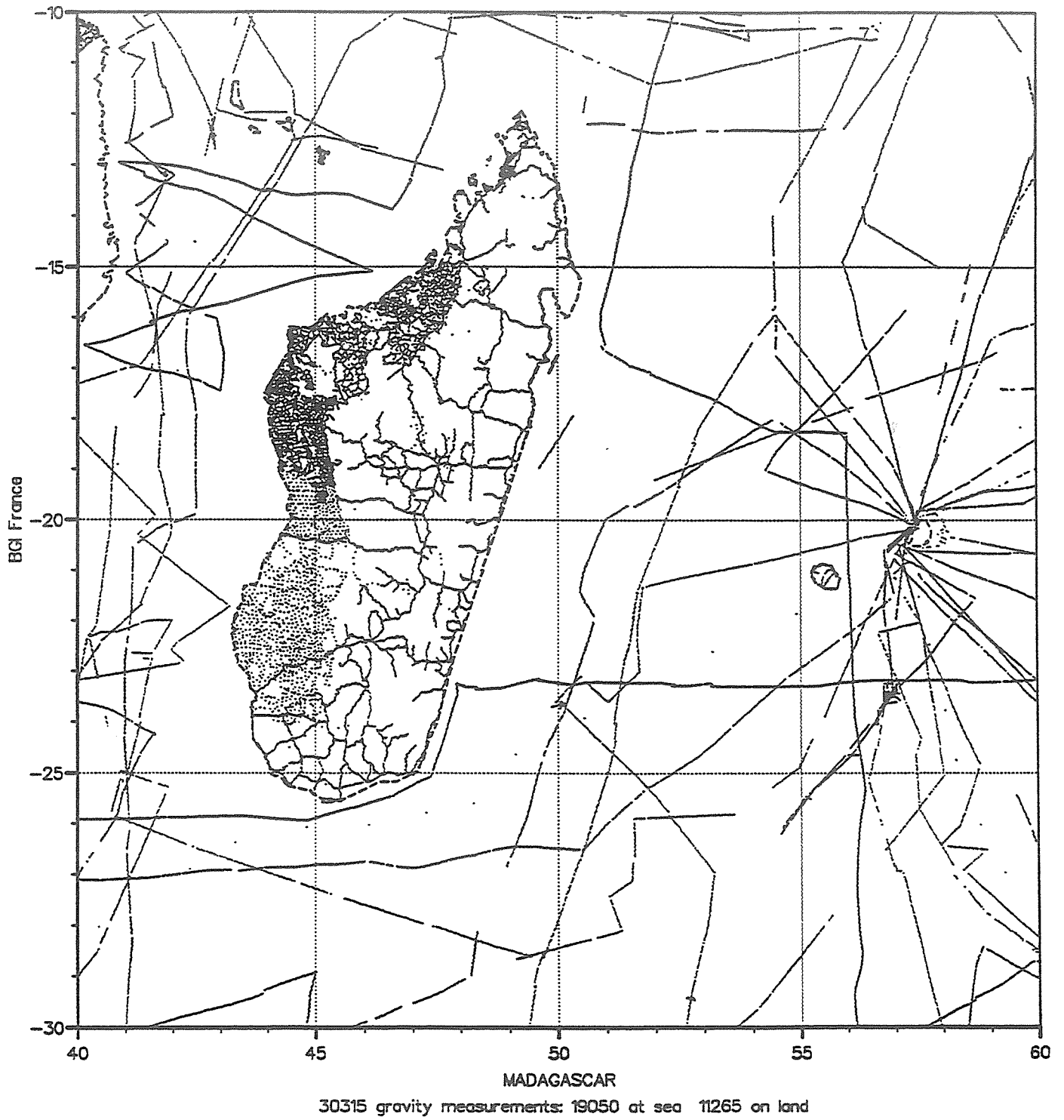


Fig. 3. Example of detailed index (Data coverage corresponding to Map 1)

BGI GRAVITY DATA: MEAN FREE AIR ANOMALY
 1ST FIELD: POINTS NUMBER
 2ND FIELD: MEAN VALUE (MGAL)
 3RD FIELD: R.M.S (MGAL**2)

-10	213 23.4 10.1	105 -40.2 42.3	15 5.6 6.2	75 -25.6 13.0	16 -12.8 2.1	26 -18.3 4.3	29 -21.7 17.6	184 -22.5 28.3	53 -23.9 10.3	65 -27.9 26.7	26 -8.2 31.4	8 -7.2 24.0	116 -5.5 8.2	138 -13.1 11.1	52 -5.8 5.9	44 -3.8 12.2	54 -1.8 22.8	84 -3.2 9.2	66 -13.9 9.4
		151 -20.4 32.5	41 -15.2 13.2	48 96.1 132.0	64 -18.3 13.8	41 -26.4 3.9		85 -42.6 9.9		2 77.7 2.8	13 -45.1 4.8	82 -12.9 16.3	43 -7.7 8.4	29 -16.9 4.3	2 -8.1 1.3	25 -2.6 13.6	67 -16.4 10.5	40 -1.7 2.6	37 -21.3 5.9
	21 -55.9 17.2	257 -42.7 12.2	51 -63.4 129.1	27 129.1 219.8	121 21.1 166.0	72 85.1 158.0	32 -47.1 3.7	100 -57.9 9.1	15 37.2 17.3	111 54.8 17.3	15 -32.7 1.7	101 -17.2 4.5	26 -12.3 6.0	26 -20.4 5.9	35 -23.8 3.1	58 -11.0 13.1	50 -8.6 10.1	6 -6.1 1.4	16 58.7 4.8
	3 -47.8 1.6	375 -13.6 29.9	170 -40.3 11.7	223 -39.3 8.4	134 -52.4 4.7	85 -40.1 5.7	171 -38.5 8.0	34 -31.5 38.1	154 29.6 15.7	117 34.3 15.9	4 82.6 10.5	72 -5.9 3.5			23 6.7	1 21.7 0.0	49 -4.5 5.5		63 11.3 54.6
		284 3.6 71.8	24 -35.7 3.3	108 -27.8 4.3	84 -36.3 7.6	97 -42.4 5.2		87 -13.1 12.8	101 1.2 32.6	44 12.3 16.4	60 47.6 20.2	71 -10.8 4.5			31 -8.6 4.7	11 11.9 4.2	62 3.7 7.3	41 -8 11.4	49 12.3 7.4
	1 -45.2 0.0	247 -45.1 42.5	575 -22.2 13.1	396 -63.3 8.2	151 -72.8 25.2	103 -63.6 14.3	322 -12.4 14.3	612 -18.5 9.7	145 -4.9 10.3	38 -36.5 6.8	47 1.3 28.1	35 -27.3 2.4			42 28.9 53.0	6 1.4 1.6	32 8.8 10.7	9 -1.4 3.3	68 -17.7 17.1
	102 -20.1 14.1	480 -47.1 41.9	159 -40.4 15.9	175 -25.5 10.5	346 12.6 19.8	414 -5.1 15.2	407 -26.0 15.2	240 -3.1 12.8	53 50.4 19.5	117 3.3 20.4	45 -15.8 12.2	51 -14.9 11.7		30 -16.8 3.8	84 -14.0 14.9	28 -9.5 16.2	73 4.9 9.3	6 -18.4 2.5	85 -0 19.4
	44 -7.9 13.0	105 -42.2 35.5	98 -4.4 28.1	136 -18.1 12.5	774 6.0 24.4	384 8.1 17.6	83 -10.4 22.3	76 50.3 33.1	110 35.0 20.6	65 15.9 19.4	3 -43.9 2.1	27 -16.8 4.3	79 -2.1 6.9	133 -2.2 5.9	14 3.4 5.2	145 -10.3 11.5	68 -8.6 19.3	28 -19.8 10.5	98 -2.5 41.4
	67 -40.4 6.8	46 -26.6 29.7	32 21.1 12.5		720 -7.5 11.7	380 -9.3 34.2	154 46.3 12.9	202 62.1 16.1	137 23.2 25.1	90 18.5 32.6	13 -47.8 3.0		74 -5.0 6.9	71 -8.1 6.1	167 -3 11.8	198 -5.1 14.1	114 -34.1 14.2	59 25.1 50.0	23 36.9 59.0
	47 -42.2 7.9	92 -44.9 15.2	38 16.8 19.8		176 -20.1 10.0	330 -23.5 19.8	115 40.8 20.0	171 67.2 18.7	91 31.8 26.5	2 56.5 2.1	2 -9.8 1.1	37 -13.3 3.7	100 -5.7 8.9		26 -13.0 5.3	97 -25.9 8.9	114 -59.6 24.4	262 69.9 102.5	105 -14.7 72.2
-20	24 -22.6 7.4	152 -23.3 14.5	17 -33.2 15.0	6 4.3 2.3	151 5.1 28.1	142 -15.2 27.6	49 49.4 27.5	104 49.6 49.1	81 47.0 37.0		43 -21.3 7.3	24 -2.9 8.8	24 -8 15.1	23 -3.7 15.9	24 8.8 23.7	47 149.9 98.1	153 -24.5 32.5	66 8.6 70.6	96 -33.1 28.0
	26 -24.4 8.6	105 -11.3 9.0	58 -15.3 19.9	97 12.4 12.2	166 -2.7 14.8	81 -4.2 20.1	146 26.4 16.7	176 -5.8 33.8	99 46.9 39.3		52 -24.8 5.7	77 5.1 5.9	24 -5.5 1.2	8 -18.5 4.5	1 13.0 0.0	65 281.3 61.4	202 -6.8 50.2	210 -29.2 24.2	170 -2.4 16.1
	184 7.6 29.5	147 3.4 11.4	60 -20.0 11.0	113 30.0 12.9	200 17.6 16.0	165 41.9 30.3	150 29.2 19.1	203 7.3 34.4	13 75.7 3.6		45 -14.0 1.7	73 -5.2 11.8		1 1.6 0.0	5 -2.8 1.0	51 -14.3 4.4	186 -9.7 17.9	100 -15.0 24.7	106 -8 14.4
	155 -3.1 10.5	59 5.2 7.9		76 27.0 12.3	236 11.5 23.4	118 31.8 14.8	46 36.0 17.4	157 32.3 29.4	145 -7.5 6.2	116 -2.8 7.5	214 7.5 13.6	185 7.5 10.3	105 21.2 16.0	76 5.2 3.5	97 11.1 7.2	104 6.4 30.2	295 9.1 9.6	165 -8.7 26.1	87 2.6 10.0
	33 -3.4 5.9	126 6.2 17.3		28 39.4 10.6	132 50.4 10.8	151 30.1 9.7	138 10.8 34.4	131 27.0 42.3		34 -7.5 4.0	17 -16.5 3.6	76 4.3 5.6	27 3.7 3.8	27 1.6 9.3	12 43.2 3.2	61 7.9 16.7	173 5.9 10.7	41 -21.1 25.3	29 -12.5 17.2
	134 -7.5 9.6	167 -5 10.0	58 3.7 7.0	58 1.2 14.4	104 19.5 32.7	161 11.4 28.4	122 41.7 41.0	31 66.7 19.1	1 -24.9 0.0	45 -12.2 6.2	48 -1.2 7.3	76 -3.1 8.1	70 6.4 7.9	26 14.3 3.2	53 8.5 26.3	70 -8.9 3.7	100 6.4 4.0	47 -3.7 18.7	26 -8.1 2.9
	37 -27.9 4.9	126 16.8 22.3	69 4.8 10.3	71 -8.9 22.0	37 -22.3 20.2	37 -7.4 6.9	30 -6.7 10.4	35 -7.5 5.9	48 -20.5 7.6	71 -16.2 4.7	93 -10.1 6.3	52 -6.6 3.7	21 -11.9 5.8	9 -9.7 1.1	15 -17.9 4.5		105 2.1 7.7	27 9.8 22.6	56 -8.2 9.4
	75 -9.5 14.8	81 2.7 18.8	3 -5.7 .5		35 11.6 20.6	40 42.6 10.4	60 59.5 22.8	14 36.7 28.8		6 2.5 1.1	42 -1.4 4.2	56 1.1 10.2		25 -11.6 4.2		4 -8.9 2.6	78 6.7 3.3	24 1.5 3.2	34 -28.5 21.5
	63 -24.0 7.8	34 -14.1 4.9			12 10.7 4.8	1 6.2 0.0		28 39.8 6.4	79 38.0 15.9	134 14.6 6.7	38 -3.0 3.9	20 -6.6 11.8	17 8.6 4.4	6 -3.2 1.9	16 -12.0 5.3	18 -8 3.1	115 -3.5 10.0	29 -3.6 19.9	29 1.2 15.2
-30		55 -13.2 8.3	31 3.9 3.9	33 -6.1 16.4	64 16.1 17.5	9 47.1 22.8	21 20.3 17.2	40 11.7 4.6	3 7.7 .4	48 23.0 12.0			37 16.7 8.0	11 -6.2 4.8	23 -5.6 3.8		88 .1 7.2	57 .6 20.7	111 1.4 17.5

4.1. Data Base

The first computerised data base was established in 1976 with the help of BRGM, of IGN and of the Institut de Physique du Globe in Paris (where BGI was located at that time). A great deal of effort was put, between 1980 and 1982, at building up an entirely new data bank and management system on one of the CNES main frames (CDC Cybers). This resulted in a quite sophisticated system, entirely specific to gravity data, but very difficult to maintain. Along the years, after having suffered from computer changes and staff turn-over, also facing difficulties in upgrading the software (for instance to speed up the merging operations which had to be done more and more frequently with the increase of the data volume), B.G.I. decided to change its strategy in data base maintenance.

Instead of putting more efforts from BGI staff and following the availability of the ORACLE software on a main frame (IBM 4381) at CNES, it was decided in early 1991 and after extensive satisfactory testing to discontinue the usage of the old software (which was running on CDC Cybers) and to switch to ORACLE (level 6). A first version was operational in the fall of 1991. Attention was exerted to ensure no interruption in the services ; for this purpose, the two software with two different data bases have been run and used in parallel up to early 1992 until not a single failure appears with the new system. This is described by Toustou (1992a).

4.2. Data Collection

The data base content, as concerns actual measurements, is regularly increasing. It contains a little more than 4.5 million point values in about 3000 sources (to be for instance compared with 800 000 measurements in 1979). There still remain several sets of land data to be added. This has been a very slow process due to the characteristics of the old CDC software, until the new system was perfectly working. Large data sets of marine data were received from NGDC* in the context of the European Geoid Project and, recently, BGI acquired the totality of the NGDC data on CD-Rom. These will be processed and merged in the course of 1993.

New catalogues, available on request, will be produced in 1993,

- . General coverage of gravity data per 20 x 20 degrees area,
- . Index catalogue of data distribution : statistics per degree square.

In addition, new efforts were exerted in trying to get data from the ex-Eastern countries due to the important geopolitical changes. In most cases, gridded values of free-air gravity and topography were obtained such as in Poland (5' x 5'), Hungary (5' x 7.5'), Rumania (5' x 5').

As it was pointed out many times, and especially on the occasion of international meetings (e.g. Balmino, 1983), some countries still do not provide any gravity data to BGI. Whether this is due to military regulations or a policy which intends to protect some national economic interests, we feel that it does much harm to these countries which, in turn, cannot pretend receiving data from the bureau or from similar organisations, and with which scientists will be discouraged to cooperate in the long run.

4.3. Data Validation

A great deal of effort have been directed at validating data for several years. Firstly, several land data validation software were intercompared (on the occasion of a dedicated workshop in 1989) some of them developed by BGI - such as SYSTEVAL and DIVA/VERSET (Toustou et al., 1989),

* National Geophysical Data Center, Boulder, USA

Fig. 4. Bouguer anomaly map with six measurements predicted "doubtful"



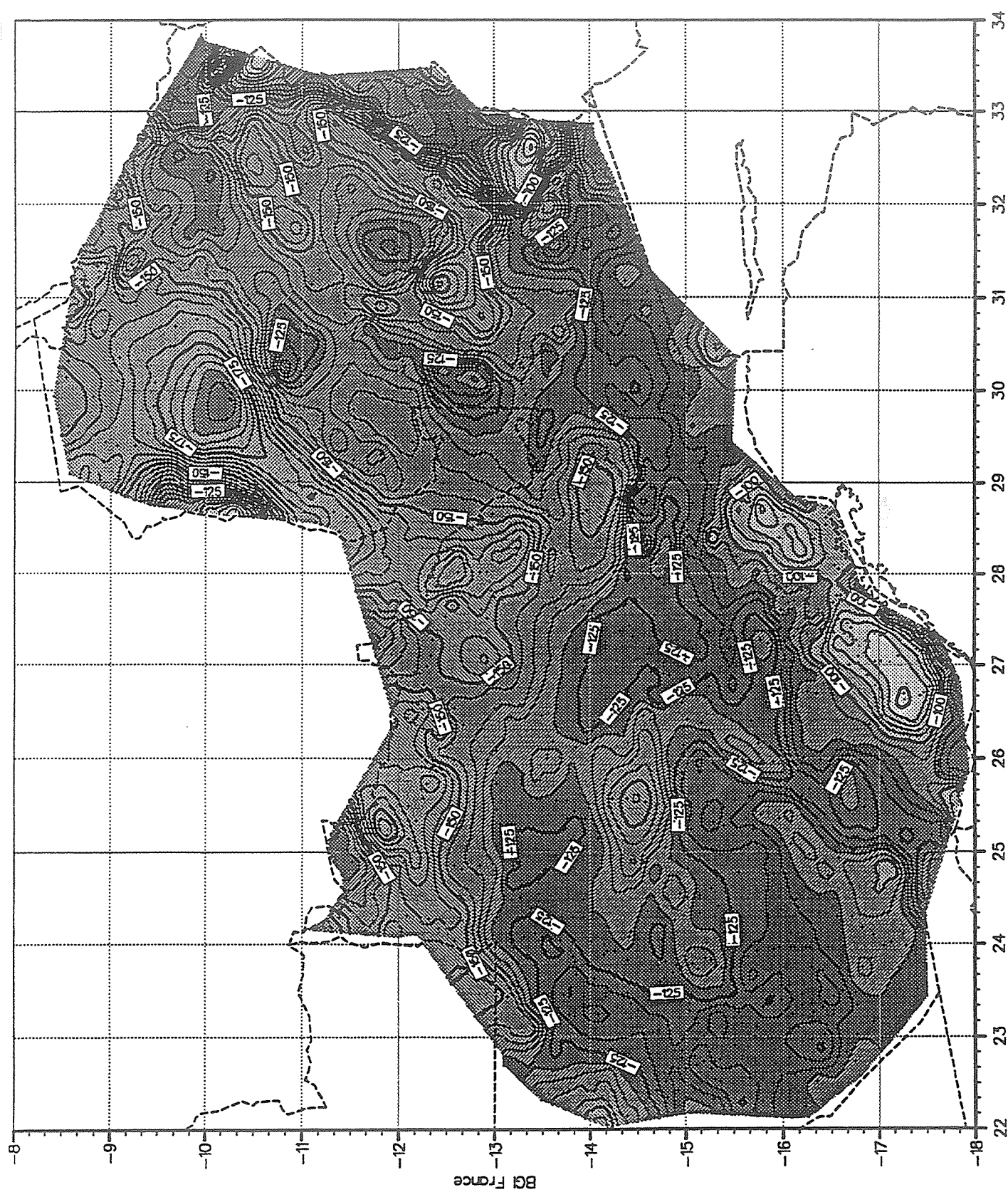


Fig. 5. Bouguer Anomalies - 1817 gravity measurements

others having been provided by working group members or associates. The in-house software was then used to validate all BGI land data on a one by one source basis (example on fig. 4) ; inter-source comparisons (adjustments using overlapping parts) still have to be done. Then was undertaken the conversion of DIVA/VERSET on a Sun-Sparc 2 workstation using the SUNPHIGS library, to allow future portability and (possibly) easier upgrading.

Plans are now made to install similar software for the validation of marine data especially to solve for cross-over minimisation parameters. A program (SEAGRA) for performing this task, was received from H.G. Wenzell. It was installed, upgraded ; in particular, the decomposition of each cruise into legs has been implemented in an automatic mode in late 1991. A complete tool in its first version is available and was presented at another workshop organised on these topics (Oct. 1992).

The final product of a validation session is the set of data with erroneous measurements being flagged, and maps of free-air and/or Bouguer anomalies (such as on fig. 5).

4.4. Requests

The Bureau has satisfied almost one thousand requests for data (of any type) in the last ten years, with sharp increases in 1986 and 1991 (fig. 6). This activity presently employs one person more than half-time.

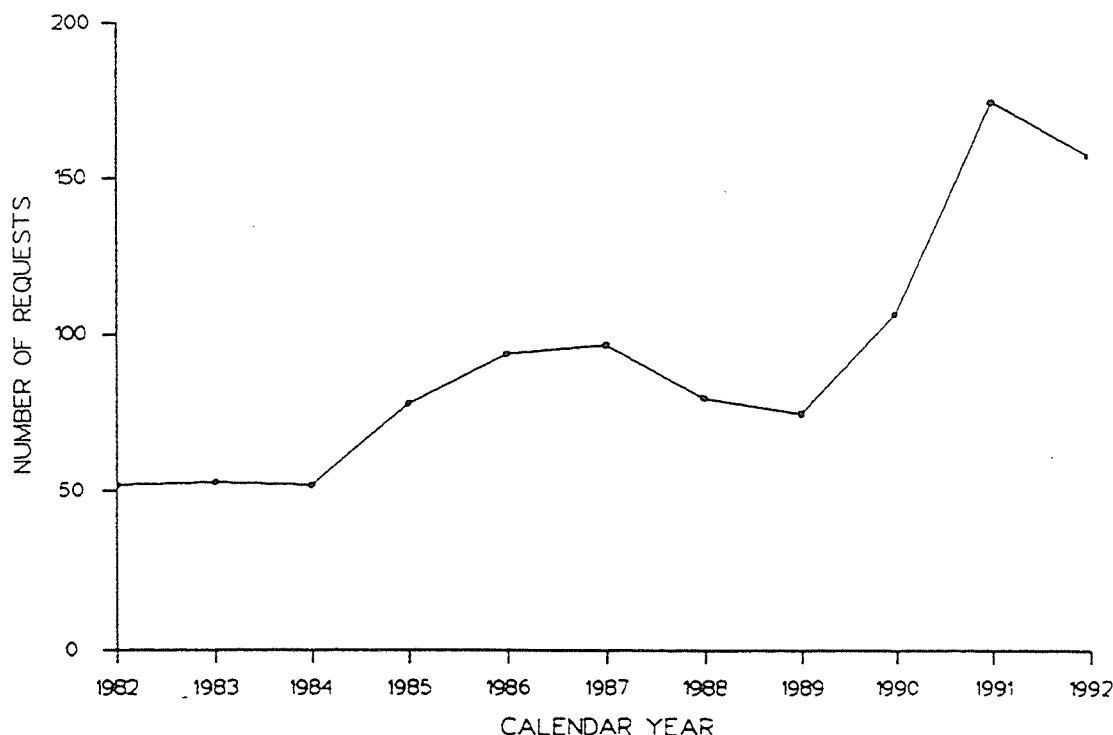


Fig. 6

4.5. Bibliography

Compiling bibliographical references of all publications received at the Bureau and dealing with gravimetry or closely related subjects has been an historical task. The digitisation of these references started with the current material in 1980 when the office was moved from Paris to Toulouse.

The digitization of the old bibliography (prior to 1980) was undertaken in 1990. This was a huge work which was performed by the BGI secretary, with an additional temporary help. It was completed in 1991. A file is available on floppy disk.

The corresponding data base is resident on hard disk on a P.C., also on the main frame IBM 4381 (where resides the gravity base), and is managed by means of the ORACLE software, too.

4.6. Miscellaneous

- training of students : data validation procedures, computational methods (determination of gravity, geoid, etc ... from spherical harmonic models ; numerical works with the integral equations of physical geodesy), graphics.

- compilation of absolute measurements : still difficult notwithstanding the help of Working Group 2 (agencies do not answer to our request for data and facts). This point was debated by the Directing Board in its last meeting (1992).

- status of IGSN 71* reference gravity stations : a situation was established in 1989, with the help of some sub-commissions of IGC. About 1200 stations (out of 1850) still exist, the others having been destroyed (generally when reconstructing buildings ...). The other reference stations (e.g. the ACIC* file) are updated from time to time. Their description sketches are on microfiches and numerical values (code number, site co-ordinates, g-value, microfiche number) are in a computer file (like for the IGSN71 network) ; there are about 8540 reference stations as of January 1993 (1220 in IGSN71*, 5200 in ACIC, 320 in WHOI*, 800 in LAGSN77*, 1000 in various national networks).

- BGI also archives gravity maps of various types and scales, from different origins. A map file and a catalogue (print-out and computer form) exist, which contain references of ~ 3000 maps. Software to extract information from the file exists. Nowadays, only a few new maps are added each year.

5. SPECIAL PROJECTS OR EVENTS

5.1. Contributions to Gravity Maps

- 10° x 10° maps displaying marine gravity data, cruises location and gravity values themselves were made at BGI for the following areas :

- . North Atlantic Ocean (in 1984).
- . Whole Pacific Ocean (in 1985).

This important work was done at the request of the Soviet Geophysical Committee to complete their Geological-Geophysical Atlas (finally published with the help of UNESCO in 1992). Subsequent interpretation work was performed in cooperation with Russian scientists (Kogan et al., 1985).

- Gravity Maps over the Mediterranean Area :

At the request of the UNESCO/IBCM project, BGI compiled a first series of 10 maps of Bouguer Gravity anomalies (scale 1:1 000 000) from existing measurements plus additional values which were gridded from maps, and a second series which is mostly based on the maps by Morelli.

A 3' x 5' grid was produced as an intermediate product.

- 5' x 5' Gravity Map of the World :

The Bureau and WG1 members (at the Geological Survey of Canada, GSC) prepared a 5' x 5' gravity map of the whole world. BGI produced the part of the basic grid over land areas (Bouguer anomalies) while GSC prepared the oceanic part (free air). It was published in 1991.

* IGSN : International Gravity Standardization Net 1971, ACIC : Aeronautical Chart and Information Center
WHOI : Woods Hole Oceanographic Institution, LAGSN77 : Latin American Gravity Standardization Net 1977

5.2. Use of Satellite Altimetry

Satellite altimetry derived geoid heights have been used on several occasions in various research activities in co-operation with several groups in the BGI supporting french agencies.

- A combine Geos 3 and Seasat altimetric geoid (derived from an adjusted mean sea surface and a model of the mean ocean circulation) was especially produced and used to derive a quasi-global oceanic set of 15' x 15' free-air gravity anomalies (Balmino et al., 1987).

Attempts at combining satellite derived data with measured gravity were also done over the North-Algerian Marge, the Aegeen trench, and around the Reunion Island. Deviations of the vertical have also been computed on request from these data.

- Simultaneous use of GEOSAT, ERS1 and TOPEX POSEIDON altimetry derived geoid heights to compute mean gravity anomalies in the North Atlantic, North Sea, Arctic Ocean and in the part of the Pacific and Indian Oceans in the context of large regional projects (cf. 6).

5.3. Geoid Computations

At the time the International Service for the Geoid did not exist, a number of requests were made to BGI to help in the computation of the geoid over limited areas (Balmino, 1986 b). These determinations were made using the classical Stokes integral (regularised at origin and with respect to a high degree spherical harmonic model of the geopotential), sometimes also by the collocation method (Balmino, 1982 and 1986 c). For example :

- the geoid over and around Madagascar was computed from a combination of gravity and Seasat altimetry data, and from a 180 x 180 spherical harmonics reference field (Rakotoary, 1986).

- the gravimetric geoid over the straight of Gibraltar and over most Morocco was determined in the context of the fixed link project and at the request of the Morocco government (Balmino et al., 1989). Geoid heights were in good agreement with satellite Doppler and survey derived quantities at control points.

- in the framework of a geophysical project supported by ICSU, BGI computed a gravimetric geoid over Jordania, based on a 360 x 360 reference field provided by the Ohio State University and on gravity measurements specifically available for the project.

- a 3' x 5' gravimetric geoid over France has been in preparation for many years. The project involves about 400 000 gravity measurements over France (provided by BRGM) and about 100 000 in neighbouring countries and oceanic areas. After an attempt (Deloménie, 1987) which showed some defects in the methodology (no terrain corrections had been applied) but also in the data (there were still large gaps and data were poorly validated), the activity was frozen for some time due to manpower constraints and other priorities. It started again in 1992 (Balma et al., 1992) with a complete analysis of the various stages and of the operational questions (including existing software) and continues in collaboration with IGN and BRGM, which expressed their interest of continuing the support to BGI in the realisation of this project.

5.4. Participation in the ICL/CC5 Activities

The Co-ordinating Committee Number 5 of the International Committee for the Lithosphere asked the help of BGI to compile an index of all centers archiving gravity, topographic, magnetic, seismic, and other data. This was achieved in 1988 and resulted in a catalogue published by CC5. The Director of the Bureau continues to represent the International Gravity Commission on CC5.

5.5. Participation in RGIA

The Bureau contributes to the activities in the project : "Réseau Géodésique Intégré sur l'Afrique", in which the establishment of new gravity networks, the making of absolute measurements, and questions of data densification are discussed.

5.6. Activities Related to Digital Terrain Models

- Digitisation of the worldwide bathymetry :

BGI was engaged in the digitisation of the GEBCO 5th Edition Bathymetric Charts between 1982 and 1991, with the help of the GEBCO Sub-Committee on Digital Bathymetry, the Canadian Hydrographic Service and the Institut Géographique National.

The main steps involved in such a work were :

- (a) automatic numerization of the contours (by a scanner) - performed at IGN, France.
- (b) interactive correction of the digitised level curves.
- (c) constitution of a data base for future updating of the GEBCO maps.
- (d) computation of analytical terrain models and production of grid values.

Step (b) was the BGI responsibility and was by far the most difficult and demanding in manpower and software. It was completely reanalyzed in 1984 after it was discovered that the previously developed package was very incomplete and inadequate. A new and quite sophisticated software was then developed and proved to be very efficient operationally.

Five maps were digitised (5-13, 5-14, 5-15, 5-16, 5-18) in 1986 and 1987. One person was assigned in 1987 by IGN to work full time on it. BGI completed the Northern Europe sheet (5-01) in 1987, the North Atlantic (5-04), Central Atlantic (5-08), and North Polar sheet (5-17) in 1988. The course of this effort was interrupted in 1989 for priority reasons and restarted in October 1990. Then the two sheets for the North and Central Indian oceans (5-05 and 5-09) were produced in 1991. The contribution of the Bureau and IGN to the project therefore consists in eleven files (out of eighteen) and is considered to be terminated. There remains the software which could be used for other similar applications (Toustou, 1985).

- A new DTM project :

The International Service for the Geoid and BGI have in mind to build up a data base of DTMs for a variety of uses, but obviously with major applications in geodesy and geophysics.

After a short period of excitement on the french space agency side (one of the supporting organisations of BGI), the enthusiasm cooled down for it appears now that the agency interest for the project is not so great or at least too diluted in something else (links with IGBP*) of which the future is not so certain.

Nevertheless, it was decided to go ahead, though slowly, and to first set up a limited DTM base around the Western Mediterranean, in relationship with other projects over this area. Main activities will consist in :

- . collecting existing (gridded) DTMs, probably with variable resolution.
- . creating DTMs from the BGI gravity data base (height information).

* International Geosphere Biosphere Program

- . comparing these two types of DTMs.
- . providing the best possible grids over limited areas.

6. PARTICIPATION OF BGI IN RECENT REGIONAL GRAVITY PROJECTS

6.1. African Gravity Project (AGP)

This project was formulated in 1985 by geophysicists D. Fairhead of the University of Leeds (U.K.) and A. Watts of Lamont Doherty Geological Observatory. The goal was the compilation of all available private and public domain gravity data for Africa to derive a map of the gravity field of the African continent and its continental margins. The project was managed by the University of Leeds Industrial Services (ULIS) and sponsored by 16 oil companies. The Bureau participated in 1986-87 by bringing its data base over that region. It is now also responsible for the archival of all the AGP data and received in addition the files of the produced grid values of free-air, Bouguer anomalies and elevations at 5' resolution both in longitude and latitude, for internal use in validating future acquisitions of data from Africa. Maps are being sold since early 1991 and the grids should be in the public domain in 1988.

6.2. South American Gravity Project (SAGP)

BGI was involved with the same group at the Leeds University in their South American gravity compilation project on the same basis as the African project in 1985-88. In addition, BGI brought its expertise and validated the initial data set (about 70 000 gravity observations) over this continent. The project terminated in June 1991, but final products were produced later, in the course of 1992 : 5' x 5' of free air and Bouguer anomalies, and of topography ; atlas of maps. BGI is a depository of these products which are used internally, but are not freely available - except over local areas in the context of special studies or for lower resolution data sets (e.g. 30' x 30' obtained by the Ohio State University).

6.3. Other Regional Gravity Projects (SEAGP, WEEGP)

ULIS made new plans in 1990 for projects similar to the ones above mentioned, in South-East Asia (SEAGP) and in Europe, including the ex-Eastern countries and ex-USSR, up to Ural (WEEGP). BGI is also involved in these activities. Both projects started in mid 1991. Of special interest is WEEGP since it is in some way combined with the efforts of the Sub-Commission for the Geoid in Europe (of the International Commission for the Geoid). Great emphasis is put on WEEGP due to the new situation in this part of the world ; specifically, Russia is going to provide gridded data at the resolution of 4 km x 4 km. SEAGP is facing insuperable problems with India and China ; Indian authorities are keeping all recent gravity data and Chinese authorities refuse to provide any kind of gravity information (apart from a poor resolution map with contour lines at 25 mgal interval).

7. MEETINGS

One of BGI's role is obviously to foster all programs aimed at improving our knowledge of the geopotential (Balmino, 1988 and 1989).

Besides organising the meetings of IGC, which take place every four years (1986 and 1990 in Toulouse, France ; 1994 in Graz, Austria - jointly with the International Commission for the Geoid), BGI therefore tries to be present on the world geodetical and geophysical scene : IUGG and IAG general assemblies , symposia and workshops. For instance in the past year, BGI participated in the following :

- European Geoid Workshop (Prague, May 1992), with one paper.
- WEEGP-SEAGP Workshop (Toulouse, Oct. 1992), with four papers.
- Workshop on Marine Gravity Data validation (Toulouse, Oct. 1992) with 3 technical papers by BGI staff, including a report on a test case distributed for comparison to participants (proceedings appeared in Bulletin d'Information n°71).

8. PROGRAM OF ACTIVITIES FOR THE NEXT YEARS

- Continue data collection, archiving and distribution : emphasis will be on those countries which have not, or seldom, contributed to the BGI data bank. First priority will be given to careful data evaluation ;
- Continue the publication of the Bulletin d'Information ;
- Assist IGC in setting up the International Absolute Gravity Base Station Network (IAGBN), and assist in the inter comparisons of instruments ;
- Support projects aimed at acquiring new absolute gravimeters in the context of WG1 (IAGBN) and WG5 activities ; for instance the joint venture between Belgium, France and Luxembourg to obtain the financing of such an instrument from European and national sources ;
- Establish simple procedures for the collection and archiving of absolute measurements ;
- Link with the Commission for the Geoid in data preparation in view of geoid computations and evaluations to be performed by the International Service for the Geoid ;
- Assist in promoting satellites techniques to improve our global knowledge of the Earth's gravity field : satellite-to-satellite tracking, satellite gradiometry, etc ...

9. THE BGI STAFF

The staff of the Bureau is composed of the following, as of January 1993 :

Position	Supporting Institute	Percentage of time spent in BGI activities (%)	Name
Director	CNES	30	G. Balmino
Secretary	CNRS	30	N. Rommens
Secretary	CNRS (under contract)	30	M. Barriot
Engineer	CNES	100	M. Sarrailh
Engineer	CNES	20	B. Moynot
Analyst/Prog.	IGN	100	D. Toustou
Technician	IGN	100	G. Balma

Acronyms :
 CNES : Centre National d'Etudes Spatiales
 CNRS : Centre National de la Recherche Scientifique
 IGN : Institut Géographique National

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FIRST EXPERIENCE OF TIDE RECORDING USING MODIFIED QUARTZ GRAVIMETER

by

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ABSTRACT

Fundamental investigations of the earth-tide gravity changes are especially important in Russia due to the small oceanic influence. Unfortunately there is no LCRs in Russia. That is why we have transformed two quartz field gravimeters Sodin-T NN 208 and 209 into recording ones with the help of specially developed digital registration systems based on CCD-scale and IBM lap-top microcomputer. First record of one month duration have been obtained in Baksan geodynamical laboratory in Northern Caucasus, Russia. The standard deviation of hourly values is about $1.6 \mu\text{Gal}$, drift rate is $5 \mu\text{Gal/day}$. According to the harmonic analysis made using the ETERNA program of Pr. Wenzel, δ -factors for M2 and O1 have been determined with a relative precision of 0.5 %.

1. INTRODUCTION

Tide gravity investigations are of fundamental importance for the modern planetary geodynamics. The urgent problems of tide gravimetry now are 1) to confirm the Wahr-Dehant model of body tides (Dehant, Ducarme, 1987) and 2) to test the hypothesis about the correlation between tide gravity residual vector and heat flow anomalies (Melchior, Ducarme, 1991 ; Rydelek et al., 1992), both on a global scale on the base of careful experiments (Baker et al., 1989). The principal difficulties are 1) precise (0.1 %) calibration of recording gravimeters and 2) precise correction for the ocean tides influence. That is why one should prefer to locate the tide gravity stations far from oceans (thousands of kilometers) and apply much efforts to the calibration.

Russian territory seems extremely attractive from this point of view. It is practically void in the sense of gravity tide studies - only old Askania devices were employed at several stations in 1960s-1980s. There is no LCR gravimeters in Russia up to now. That is why we have decided to transform common Sodin quartz field gravimeters into recording ones. Important by-product could be principally new tide-registering system, metrologically independent on LCR and Askania devices, that could contribute somehow to the solution of calibration problems.

2. DESCRIPTION OF GRAVIMETER

Sodin gravimeter represents a standard field quartz device with sensitive system similar to the Sharp. Its accuracy in field conditions is about $10\text{-}20 \mu\text{Gal}$, in laboratory - about $3\text{-}5 \mu\text{Gal}$ (Kopaev et al., 1990).

3. DESCRIPTION OF REGISTRATION SYSTEM

The registration system provides the photoelectrical detection of the gravimeter beam motions. It is based on a CCD-scale with $0.5 \mu\text{m}$ resolution that produces linear digital output signal. The CCD-scale together with servicing electronic circuits is located inside of the small metal box that is

rigidly fixed on the top panel of the gravimeter in such a way that the CCD is located in the focal plane of the gravimeter object-lens (the ocular is replaced). The IBM-AT lap-top is used as a data logging system. As a light source we use a specially selected quartz lamp that is located outside the gravimeter and is connected with it optically using an optical fibre (in order to prevent additional non-uniform heating). A special power supply block has been developed which switches to the spare battery automatically in case of AC failures. Two identical sets of such a registering system have been manufactured for our Sodin-T's NN 208 and 209.

4. DESCRIPTION OF BAKSAN TIDE STATION

The preliminary testing of one of our systems with the Sodin T-209 gravimeter has been carried out in Baksan geodynamical laboratory of the Astronomical Institute of Moscow University, which is located in Northern Caucasus, near the Mt. Elbrus ($\varphi = 43^{\circ}20'$, $\lambda = 42^{\circ}72'$, $H = 1702$ m), in an underground tunnel of the Baksan neutrino observatory of Russian Academy of Sciences. The laboratory has no thermal isolation (daily changes of temperature are 0.5 - 1.0° C) and no barocontrol.

5. PRELIMINARY METROLOGICAL STUDIES

The Sodin T-209 gravimeter has been calibrated with a relative precision better than 0.1% using special tilting installation. The scale factor has been determined roughly before the one-month-duration record by means of steps method with a relative precision of about 2% only. The instrumental phase lag has been determined simultaneously, as in Richter and Wenzel (1992), and equals roughly $0.14^{\circ} \pm 0.01^{\circ}$ for diurnal wave groups and $0.27^{\circ} \pm 0.01^{\circ}$ for semi-diurnal ones.

6. RESULTS OF HARMONIC ANALYSIS

A first test record of 28.5 days duration (fig. a) has been analysed using the ETERNA program of H.-G. Wenzel with 51-hour Pertsev filter and Tamura tidal potential development. The pre-processing included the least-squares fitting of the 1-min values on a 10 min interval centered on each hour mark by a 3-degree polynomial for getting hourly values.

The results of the ETERNA application are the following :

- mean drift value is only $5 \mu\text{Gal/day}$ (fig. b),
- relative precision of δ -factors for O1 and M2 waves is 0.5% ,
- standard deviation of 1-hour value is $1.6 \mu\text{Gal}$ (from residuals, see fig. c),
- noise level in diurnal and semi-diurnal bands is about $0.2 \mu\text{Gal}$.

After applying ocean corrections according to Pertsev calculations, the δ -factors for the O1 and P1S1K1 groups agree with the Wahr-Dehant model (see Table 1), but for the M2 and S2K2 groups the discrepancies are $+2.0 \pm 0.4\%$ and $6.0 \pm 0.8\%$ respectively.

7. DISCUSSION

If we take into account the calibration error of 2% and the very short observation period, these discrepancies seem to be statistically insignificant. Anyhow, its averaged value for all the four wave groups (O1, P1S1K1, M2, S2K2) is $+2.1 \pm 2.2\%$.

Besides the rough calibration, our preliminary result could also be affected by the modification of the scale factor due to the tilts in the beam plane (we plan to use Nakai procedure for the pre-processing), also due to the ocular scale non linearity (that is now under careful investigation).

In any case we cannot install feedback into quartz devices without :

- availability of stable pillars
- frequent calibration with record shifting in the center of the ocular scale (at least, once a month).

Nevertheless our instrumentation seems to be working well, in spite of the metrological problems that are the same for the LCRs in recording mode without feedback. Moreover, the internal accuracies of δ -factors and phase lags practically coincide with those values for LCRs without feedback (Sato, 1977). It is not surprising after recent results (Elstner et al, 1992), according to which there are no significant discrepancies between quartz devices and LCRs in field works. As had been mentioned in Melchior (1966), fused quartz is very useful for the stationary recording of tidal tilts due to its high elasticity, and it should be true also for tidal gravity. We hope that after some metrological developments, our instrumentation could be useful for the large scale investigation of tidal gravity. The very low cost of the system is especially of interest for Russia these days..

CONCLUSION

Carefully selected and tested quartz Sodin gravimeters could be applied successfully for the stationary gravity tides recording using our CCD-registration system. It could be valid also for another quartz devices - Wordens and Sharps. It could produce a lot of recording gravimeters from the old quartz devices that are out of work in many organisations.

9. ACKNOWLEDGEMENTS

We are very thankful to Prof. H.-G. Wenzel for providing us with his ETERNA Program and valuable comments and to Profs. Yu. Boulanger and B. Pertsev for their attention.

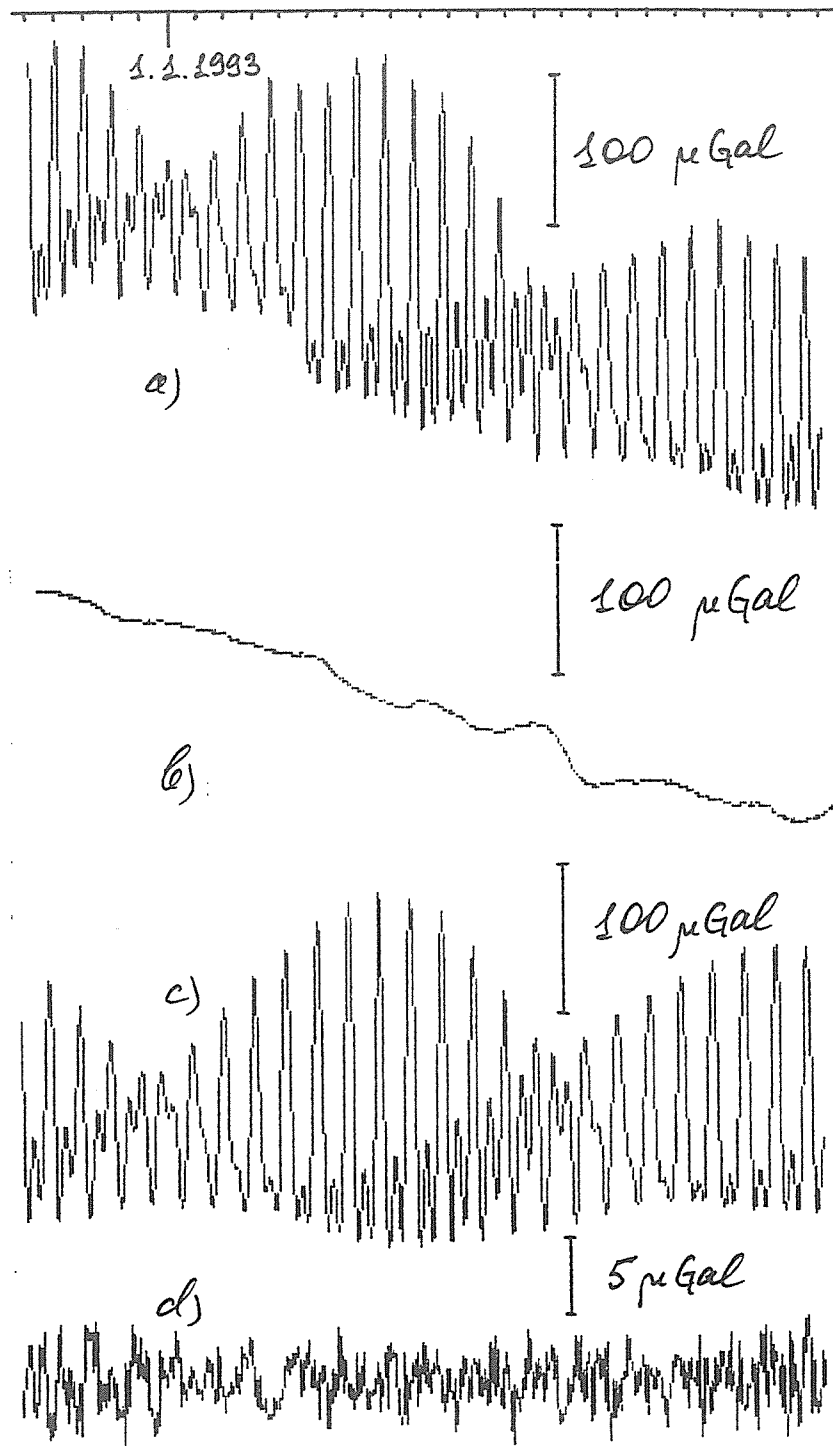
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Table 1. Results of δ -factor determination

Wavegroup	01	P1S1K1	M2	S2K2
Signal/noise ratio	163	231	234	112
Delta-factor, corr. for oceans	1.152 + 0.006	1.142 + 0.004	1.183 + 0.005	1.230 + 0.009
Discrepance with Wahr-Dehant model %	- 0.2 + 0.5	+ 0.7 + 0.4	+ 2.0 + 0.4	+ 6.0 + 0.8
Phase lag, corr. for oceans, deg.	- 0.2 + 0.4	- 0.2 + 0.3	- 0.3 + 0.3	- 4.9 + 0.5

Fig. 1. Results of harmonic analysis
(a, b, c, d, see text)



GRAVITY IN THE BANDA SEA

The Snellius II Expedition in Indonesia, 1985.

Govert L. Strang van Hees
University of Technology
Delft, The Netherlands.

Introduction.

Gravity measurements were carried out from 25 March to 11 April 1985 in the Banda Sea. On 25 March the ship cruise started from Timor. The main objective was to cross the Banda Arc perpendicular at 4 places. These were called the Transects I, II, III, IV (see figure 1). Close to the coast of Irian Jaya a dense network of lines was measured. This area was of special interest because of expected fractures in the crust (figure 2). Besides gravity also magnetic and seismic measurements were carried out.

The gravimeter used was the Askania-Bodensee Gravimeter KSS5, owned by the University of Technology in Delft, The Netherlands. This instrument was renewed and improved in the Bodensee-Werke in Germany in 1978 and 1984. The sensor has a horizontal beam which means that it is sensitive for the cross-coupling effect. This effect is dependent on the weather conditions. During this cruise however the weather was excellent so this effect was negligible.

Processing of the observations.

The computation of the gravity anomalies is based on three datasets:

1. Gravimeter output.
2. Positions of the ship.
3. Depth.

On board the ship the measuring data were registered by paper-recording. The datasets are made by digitizing the recordings later on. The three recordings were digitized independently and coupled by time. The main problem in the computation was to compute a reliable value for the Eötvös correction. One milligal corresponds to a speed of 0.13 knots or 0.067 m/s.

To achieve this precision very accurate positioning was necessary. However the navigation system of the ship was mainly based on Doppler Satellite Navigation. This gives a fix at rather irregular time intervals depending on the satellites available. Besides there were some radar fixes to the coast in coastal areas. The ships' log and compass gave dead-reckoning positions in the intermediate points.

The original dataset of fix-points contained exact 1000 positions. After carefully checking all the positions, 271 positions, had to be rejected. The remaining positions still contained some noise. As the Eötvös correction is dependent on the speed and course of the ship it depends on the relative position accuracy of successive fixes. Random noise in these positions may cause errors in the Eötvös correction. Therefore the positions had to be smoothed. A sophisticated computer program was used to compute smoothed splines through the position fixes. This program was developed by Reinsch, München.

The advantage of this method is that it computes a continuous curve through the points and its derivatives. This has 3 advantages:

1. Smoothing. Random noise in the positions can be smoothed. The degree of smoothing can be chosen. After several trials a realistic smoothing parameter was chosen.
2. Interpolation. As the position fixes are at rather irregular time intervals, the spline gives interpolated positions at regular intervals. A time-interval of 6 minutes (0.1 hour) is chosen for the interpolation and for the computation of the anomalies.
3. Differentiation. The spline computes automatically the derivatives of the function at the interpolated points. This is the change in latitude and longitude per unit time interval. These quantities are directly related to the speed, course and the Eötvös correction. The Eötvös correction is computed by

$$E = 2\omega v \sin \alpha \cos \varphi = 2\omega N \cos^2 \varphi \frac{\Delta \lambda}{\Delta t}$$

E = Eötvös correction

ω = rotation of the earth

v = speed

α = course

φ = latitude

N = radius of curvature in east direction of the earth-ellipsoid

$\Delta\lambda$ = longitude change

Δt = time interval.

In this way it was possible to compute the Eötvös corrections as good as possible with the given positions.

The datasets of the gravimeter recordings and depth had also to be interpolated in order to get values on the fixed time intervals of 6 minutes. This was also done by the spline program, however the smoothing parameter has been set to a low value, because these datasets contain very low random noise. Finally the three datasets are combined to one dataset containing all observed quantities.

Computation of the gravity anomalies.

The gravity values are computed by the following formula:

$$g = S(R + \frac{dR}{dt} \cdot \tau) + E + D \cdot t + H \quad (1)$$

g = gravity.

S = calibration constant of the gravimeter.

R = reading of the gravimeter.

$\frac{dR}{dt}$ = change of reading per line unit, computed from the spline program.

τ = time-constant of the gravimeter, 200 seconds.

E = Eötvös correction.

D = drift of the gravimeter, computed from harbour connection before and after the measurements in Timor and Ambon respectively.

t = time since beginning of cruise.

H = harbour connection.

H is computed from the gravity value in the harbour, the gravimeter reading in the harbour and the height difference between the harbour gravity station and the water level. This correction reduces the computed gravity values to the height of the water level.

Strictly speaking the gravity values should also be reduced for tides, however this correction is usually smaller than 1 mgal and is neglected.

Harbour connection.

In Timor the gravity values obtained were:

date, time	= 25 March 1985, 1.00 UT
g (on jetty)	= 978 153.13 mgal
correction to water level	= 1.80 mgal
g on water level	= 978 154.93 mgal
gravimeter reading	= 3 022.0

In Ambon:

date, time	= 11 April 1985, 5.00 UT
g (on jetty)	= 978 165.10 mgal
correction to water level	= 0.60 mgal
g on water level	= 978 165.70 mgal
gravimeter reading	= 3 039.0

Gravity difference Timor-Ambon = 10.8 mgal.

Measured gravity difference = 1.060 (3039-3022) = 18.0 mgal.

Calibration factor = 1.060

Drift = 18.0 - 10.8 = 7.2 mgal in 17 days.

Remark: The gravimeter reading in Timor was less accurate, because the automatic levelling of the platform was defect and the gravimeter was levelled by hand. This defect was repaired shortly after departure. This less accurate reading in Timor may be the cause of the rather big drift.

The Free-air anomalies were computed by subtracting the normal gravity from the computed gravity. The Geodetic Reference system 1980 is used for the reduction, defined as:

$$\gamma = 978\,032.68 + 5185.96 \sin^2 \varphi - 5.74 \sin^2 2\varphi \quad (2)$$

and

$$\Delta g_{FA} = g - \gamma$$

The Bouguer anomalies were in first approximation computed by the simple Bouguer plate reduction. The Bouguer plate is an infinite flat plate with the thickness of the local depth and the density equal to the difference in density between the crust (2670 kg/m) and the seawater (1030 kg/m), so $\rho = 1640$ kg/m

$$\Delta g_{Bou} = \Delta g_{FA} + 2\pi G \rho D = \Delta g_{FA} + 0.0687 D \quad (3)$$

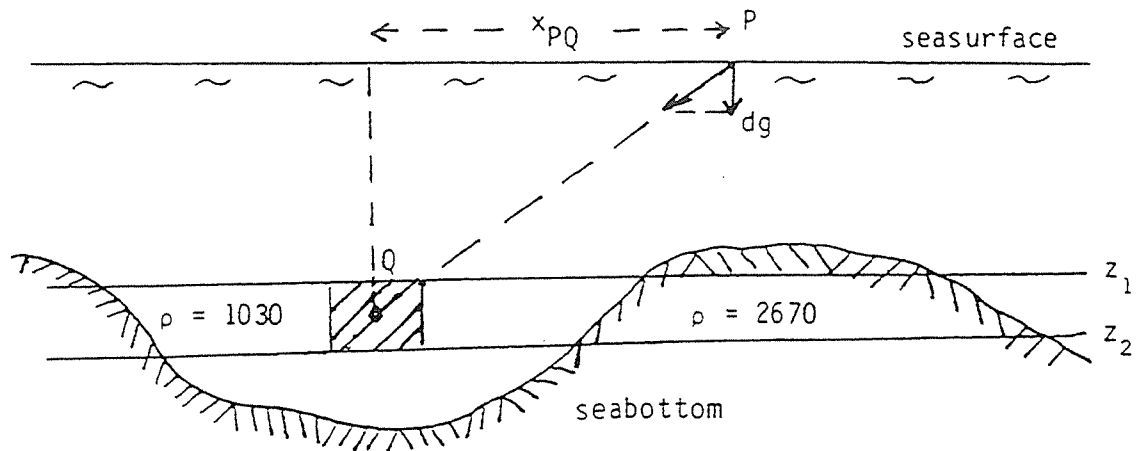
D is the depth in meter.

The simple Bouguer correction is only an acceptable approximation if the bottom of the ocean is rather flat. In Indonesia however, especially in the Banda Sea, the bottom topography is extremely rough. The depth varies between 500 m and 6500 m. Therefore topographic corrections should be applied.

These corrections are rather difficult to compute as they are an integral over the topography which should be computed for each gravity point. Secondly the bottom topography is only measured along the survey lines and not perpendicular to it.

As the survey lines are chosen such that they cross the geological structures perpendicular, it was reasonable to assume a depth profile along the line and assume a constant depth across the line. With this model the topographic corrections can be computed. However the computation of the integrals takes much computer time. A faster method is developed by G. Strang van Hees, using Fast Fourier Transforms (FFT). The principle of this method is as follows.

Devide the ocean into horizontal layers from surface to the maximal depth. The thickness of the layers and thus the number of layers can be chosen freely. More layers give more accurate results, but on the other hand take more computertime. The density of each volume unit in the layer is 1030 if it contains seawater, 2670 if it contains crust material and a proportional density if the sea bottom crosses the layer.



The vertical attraction dg in point P of a mass element $dv = dx dy dz$ of the layer is:

$$dg = G\rho(x_Q) \frac{z}{(x_{PQ}^2 + y_{PQ}^2 + z^2)^{3/2}} dx dy dz$$

a is the mean depth of the layer

x_{PQ} is the horizontal distance between P and Q along track and y_{PQ} across track.

As $\rho(x_Q)$

is assumed to be constant across track, ρ is only a function of x . The integration of y can be performed analytical.

$$dg_P = 2G \int_{-\infty}^{+\infty} \int_{z_1}^{z_2} \rho(x_Q) \frac{z}{x_{PQ}^2 + z^2} dx_Q dz$$

The integration over dz should be performed over the thickness of the layer between the depths z_1 and z_2 . This gives:

$$dg_P = G \int_{-\infty}^{+\infty} \rho(x_Q) \ln \left(\frac{x_{PQ}^2 + z_2^2}{x_{PQ}^2 + z_1^2} \right) dx_Q$$

This integral is a convolution type integral. It can be solved by multi-

plication of the spectra of $\rho(x_Q)$ and the response function: $\ln \left(\frac{x^2 + z_2^2}{x^2 + z_1^2} \right)$.

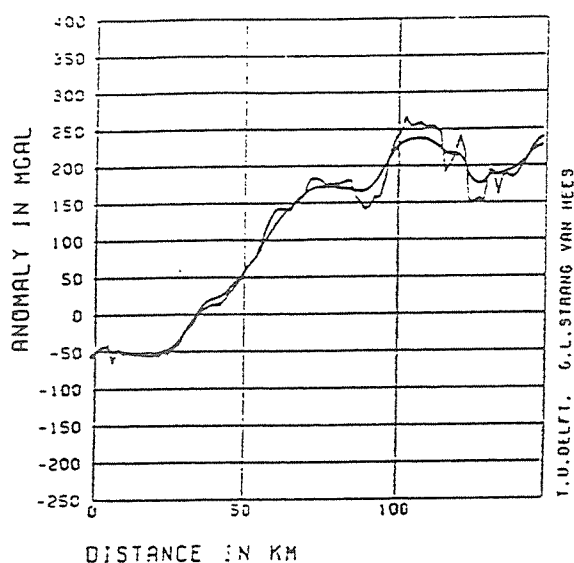
To avoid edge effects the depth profile should be longer than the actual measured line. Therefore the profile is extended at both ends with

the same depth as the last point of the measured line.

For each layer this integral is computed and the total effect of the attraction of the ocean is the sum of the layers.

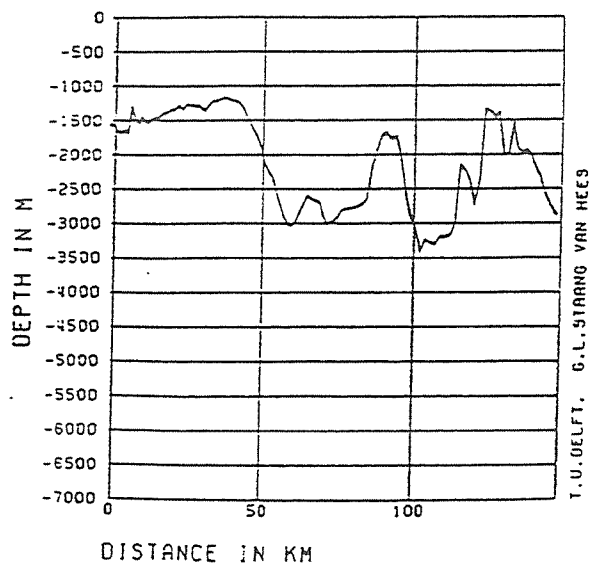
It is interesting to compare the simple Bouguer anomalies with the improved Bouguer anomalies. The difference can reach more than 40 mgal in cases of rough topography. This shows the importance to compute the Bouguer anomalies with the real depth profile and apply topographic corrections.

INDONESIA: GRAVITY ANOMALY



The figure shows the depth profile (below) and the corresponding simple Bouguer anomaly (irregular line) and the improved Bouguer anomaly (smooth line).

INDONESIA: DEPTH T1B



Some remarks on the results.

As I am not a geophysicist I will not give a geophysical interpretation of the gravity anomalies. However I will point your attention to some remarkable anomalies.

The most important lines are the transects across the island arc of the Banda Sea. These lines are called T1, T2, T3 and T4 and are subdivided into T1A, T1B, a.s.o.

Transect T1 crosses east of Timor. It shows a very irregular topography between 1000 and 3500 m depth. The Bouguer anomalies are about 50 mgal in the southern part and increase to + 300 mgal to the northern end.

Transect T2 passes across one of the deepest points of the Banda Sea, almost 7000 m depth. However the Bouguer anomaly remains rather constant. This means that this hole is only regional, isostatic compensated (graph T2A). This in contrast to transect T4A. The Bouguer anomaly is about 250 mgal.

More east on T2B the depth decreases from 5500 m to 700 m. In the middle of this slope a remarkable sharp anomaly is found of +150 mgal (graph T2B).

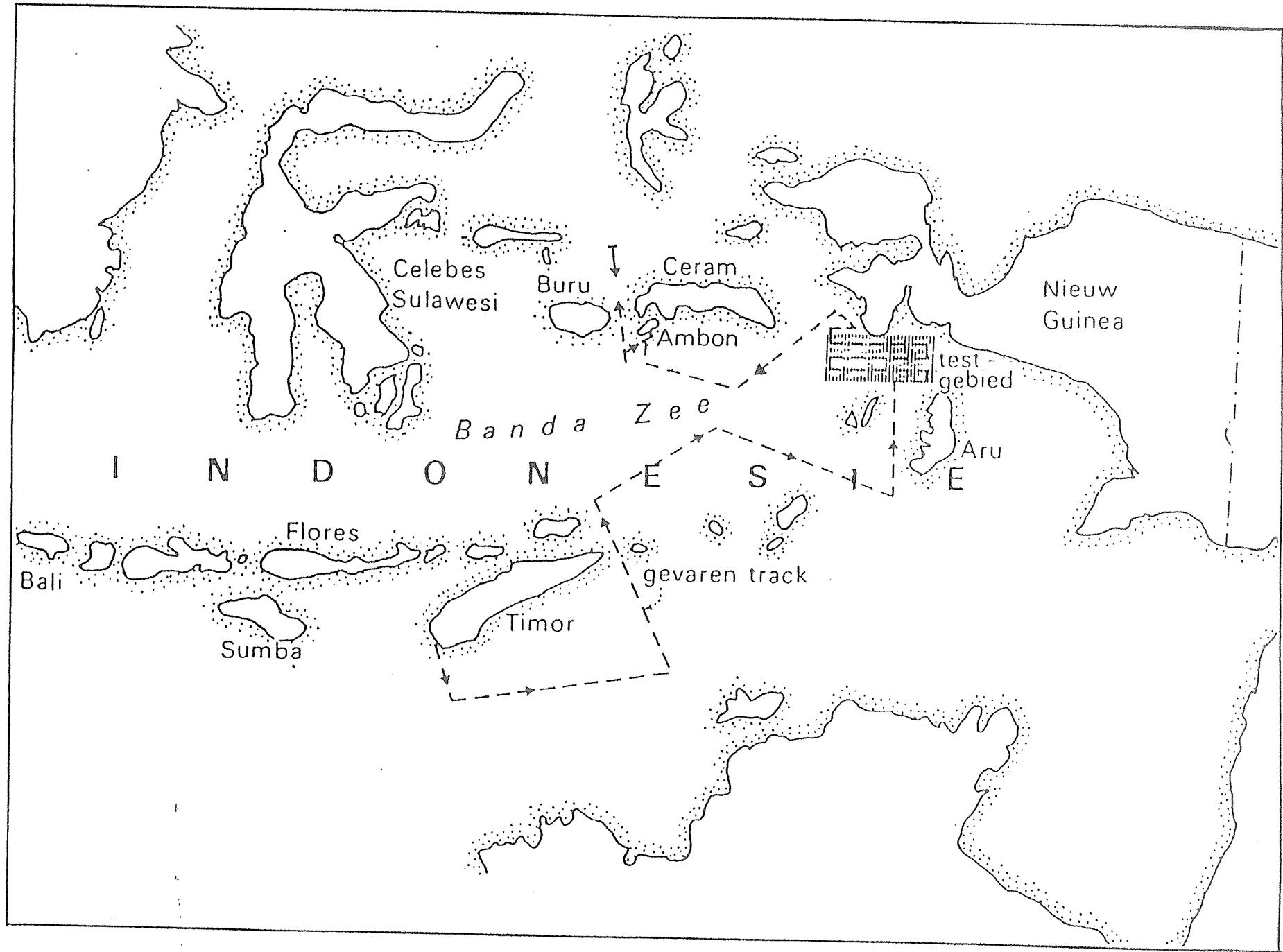
Position: latitude = $-6^{\circ}37'$, longitude = $131^{\circ}35'$.

Transect T3 shows an increase of the Bouguer anomaly from about 0 to + 300 mgal (graph T3A and B). The depth changes from 500 to 6400 m.

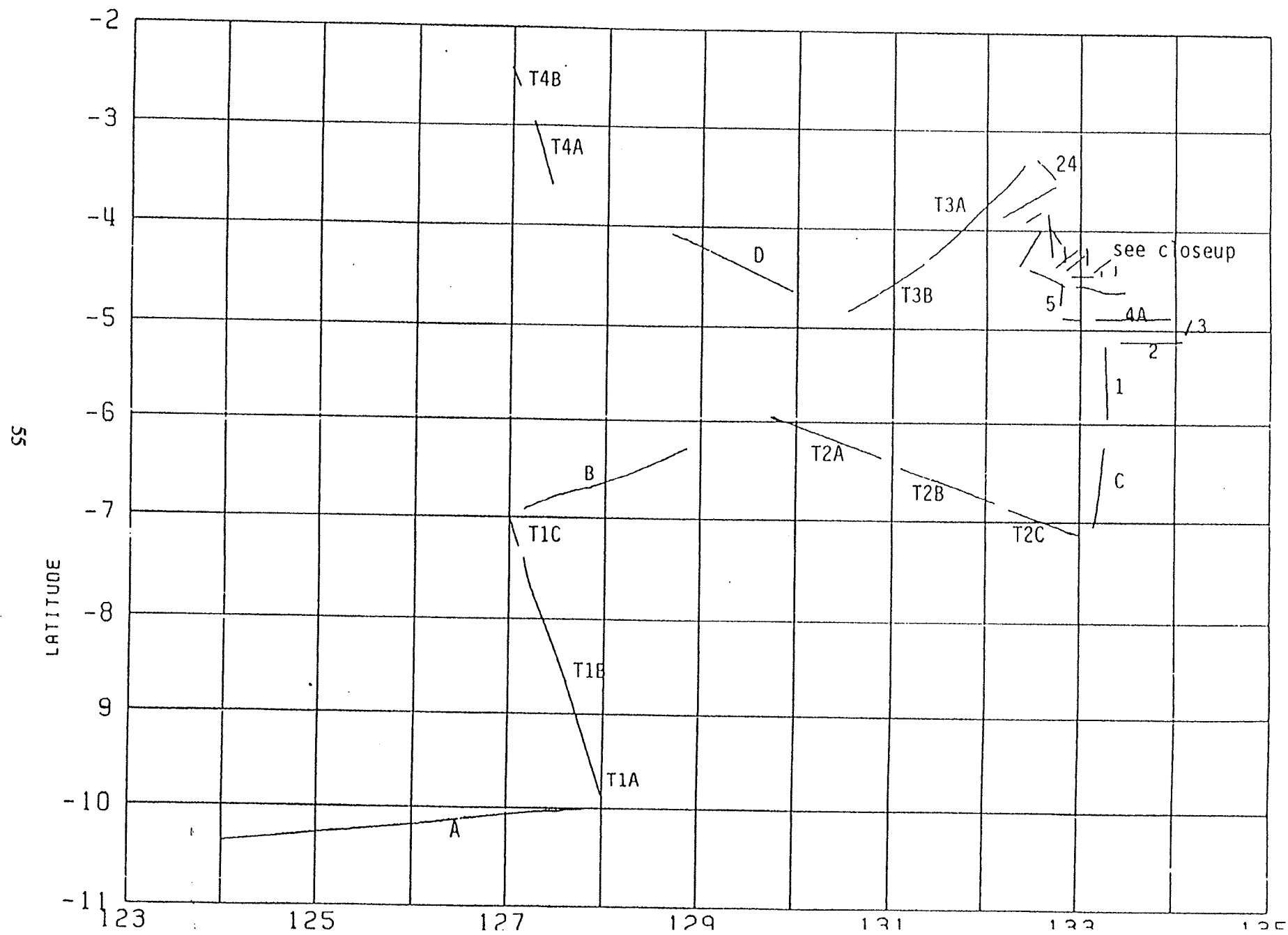
Transect T4 shows a change in the Bouguer anomaly from + 200 to +50 mgal corresponding to a change in depth from 4000 to 1000 m.

It is remarkable that the free air anomaly does not change very much although the depth changes by 3000 m. This indicates that this area is in good isostatic equilibrium (graph T4A). Note the difference with the slope of T2A.

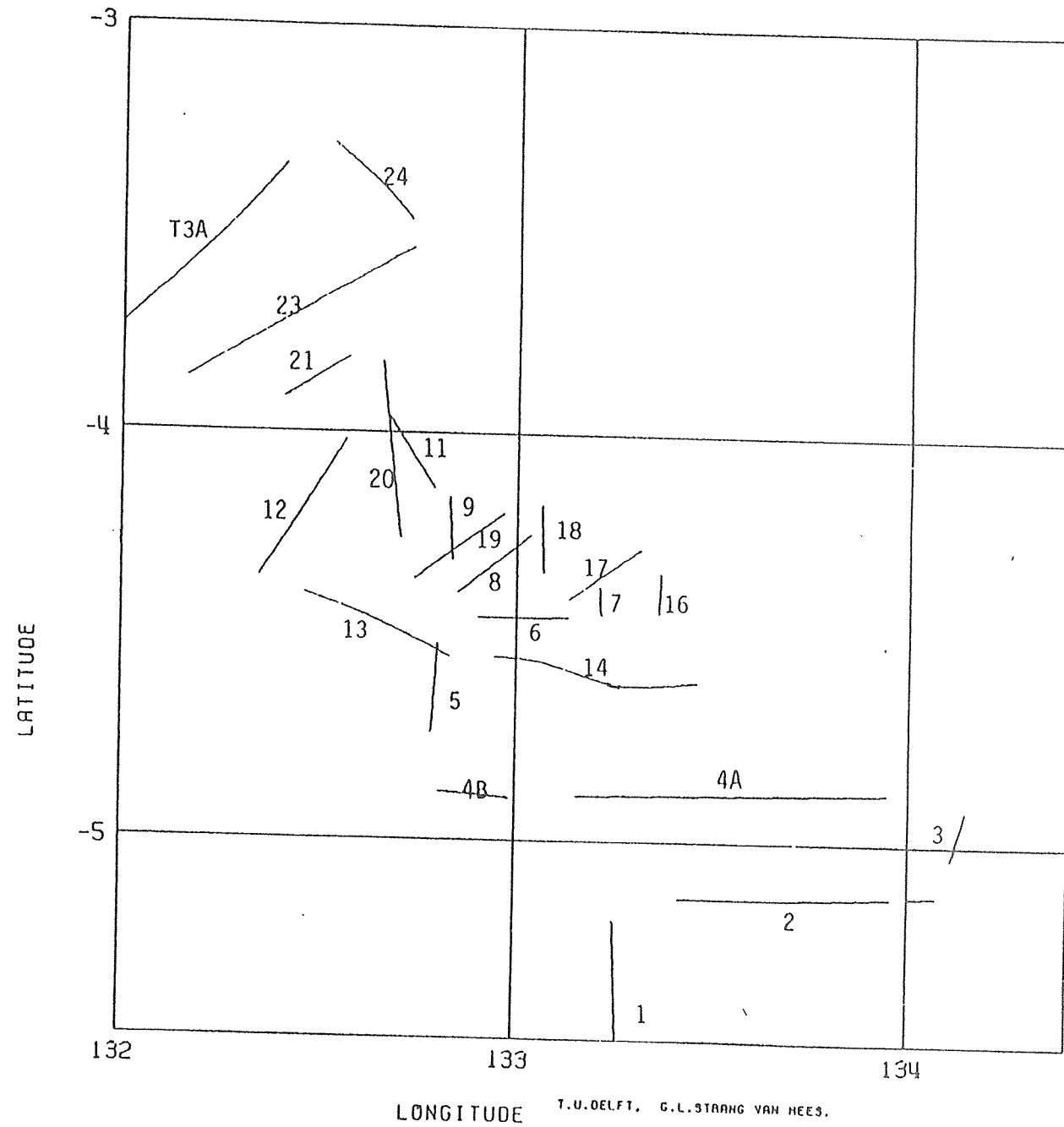
Line D passes a rather deep trench from 1000 to 4000 m depth. Most of it is reflected in the free air anomaly, which changes from +150 to 0 mgal. However the Bouguer anomaly shows also an increase from 200 to 275 mgal. This means that this trench is partly local isostatic compensated.



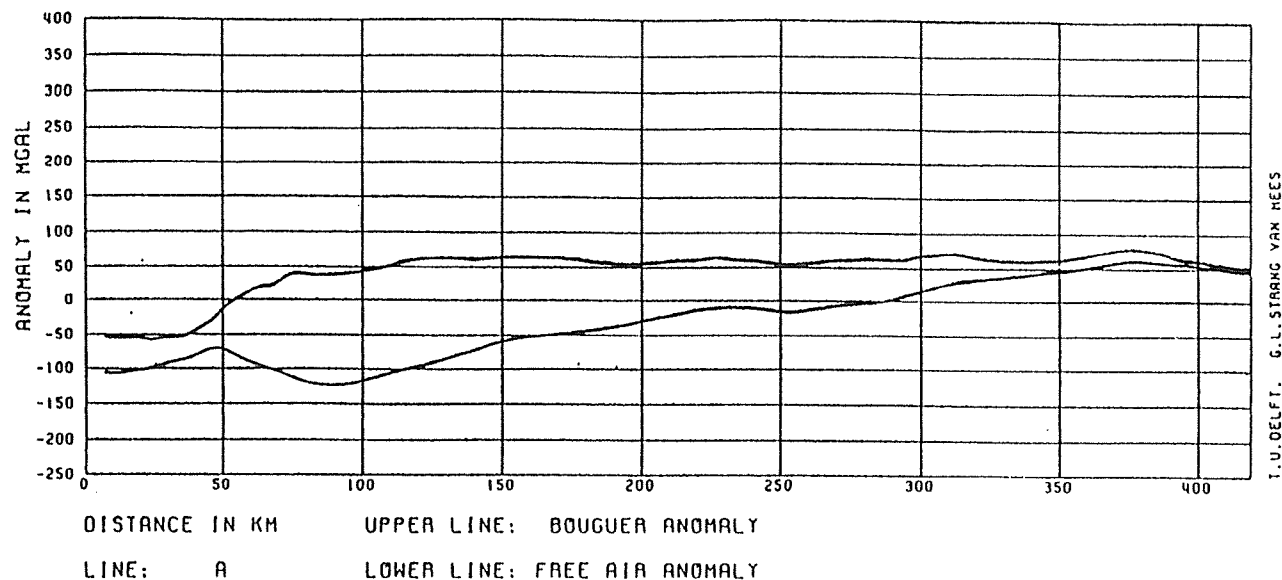
INDONESIA: GRAVITY LINES. SNELLIUS II, 1985.



INDONESIA: GRAVITY LINES. SNELLIUS II, 1985.



INDONESIA: GRAV. Y ANOMALY A

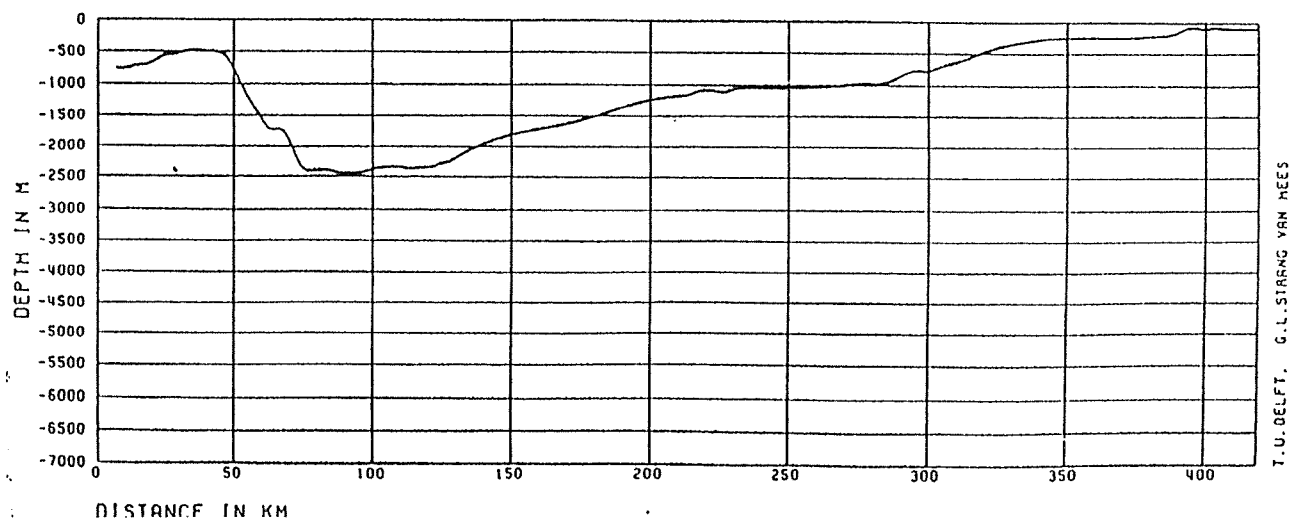


DATE: MARCH 25 1985

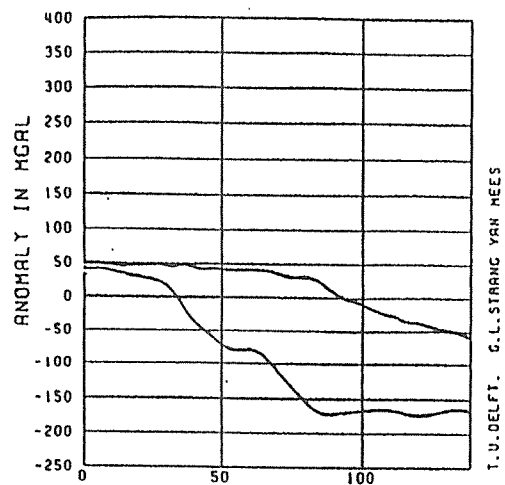
TIME	H.M.	START	FINISH
		19 53	16 41

GEOGRAPHICAL COORD.	LATITUDE:	LONGITUDE:
	-10.349	124.044
	-10.014	127.788

INDONESIA: DEPTH A



INDONESIA: GRAVITY ANOMALY T1A



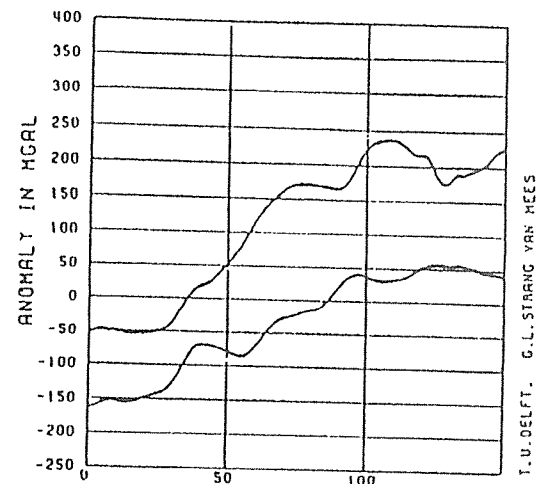
DISTANCE IN KM UPPER LINE: BOUGUER ANOMALY
LINE: T1A LOWER LINE: FREE AIR ANOMALY

DATE: MARCH 26 1985

TIME	H.M.	START	FINISH
		19 30	6 11

GEOGRAPHICAL COORD.	LATITUDE:	LONGITUDE:
	-9.863	-8.666
	127.989	127.597

INDONESIA: GRAVITY ANOMALY T1B



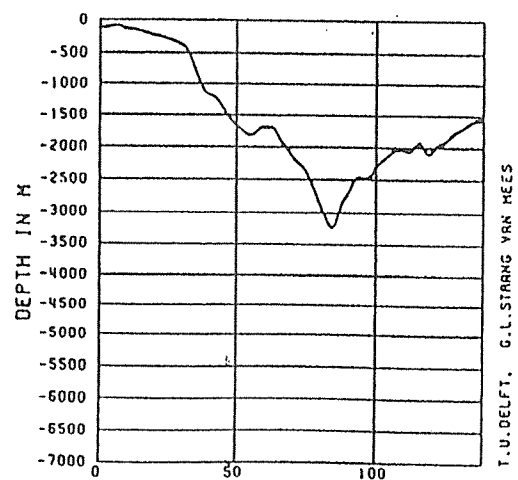
DISTANCE IN KM UPPER LINE: BOUGUER ANOMALY
LINE: T1B LOWER LINE: FREE AIR ANOMALY

DATE: MARCH 27 1985

TIME	H.M.	START	FINISH
		8 0	10 23

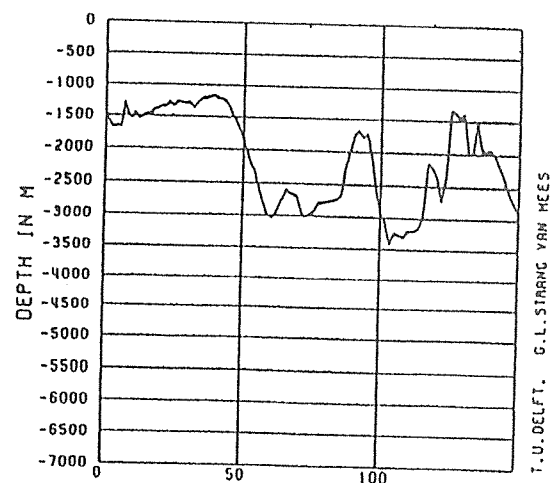
GEOGRAPHICAL COORD.	LATITUDE:	LONGITUDE:
	-8.667	-7.396
	127.609	127.151

INDONESIA: DEPTH T1A



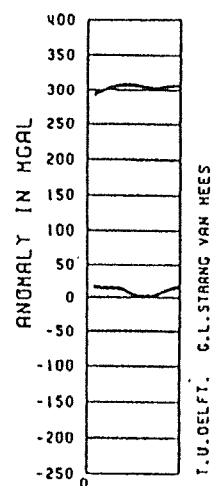
DISTANCE IN KM

INDONESIA: DEPTH T1B



DISTANCE IN KM

INDONESIA: GRAVITY ANOMALY TIC



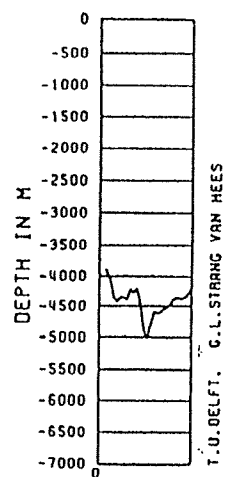
DISTANCE IN KM UPPER LINE: BOUGUER ANOMALY
LINE: TIC LOWER LINE: FREE AIR ANOMALY

DATE: MARCH 27 1985

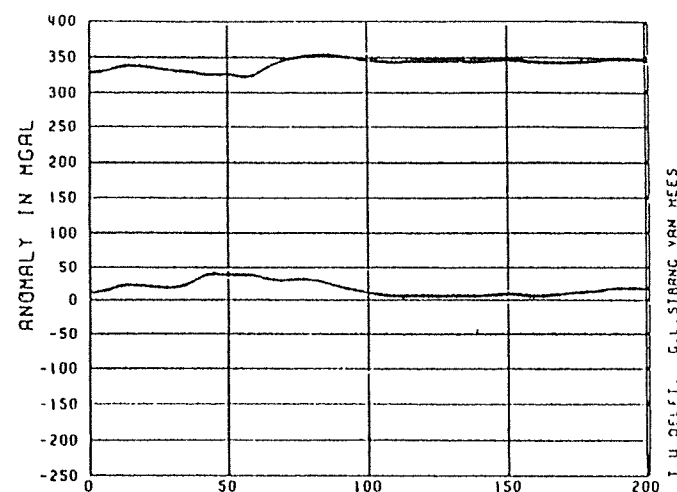
TIME	H.M.	START	FINISH
		21 11	23 36

GEOGRAPHICAL COORD. LATITUDE: -7.284 -7.018
 LONGITUDE: 127.092 127.005

INDONESIA: DEPTH TIC



INDONESIA: GRAVITY ANOMALY B



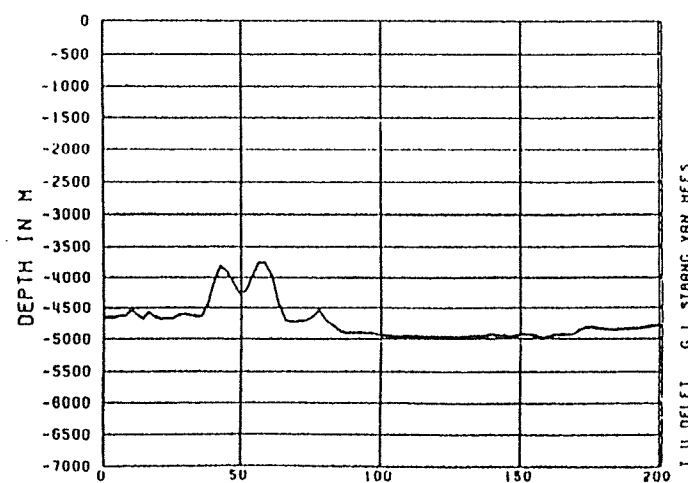
DISTANCE IN KM UPPER LINE: BOUGUER ANOMALY
LINE: B LOWER LINE: FREE AIR ANOMALY

DATE: MARCH 28 1985

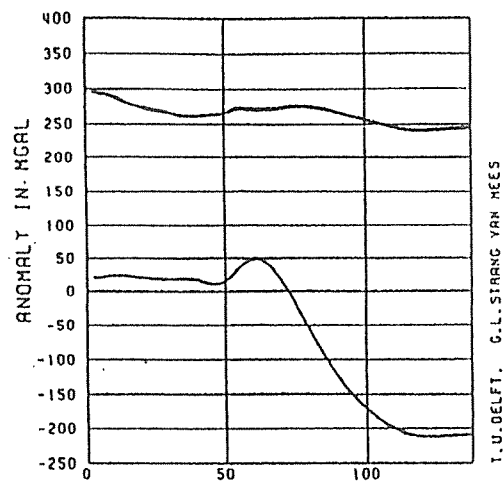
TIME	H.M.	START	FINISH
		0 48	9 36

GEOGRAPHICAL COORD. LATITUDE: -6.914 -6.286
 LONGITUDE: 127.150 128.050

INDONESIA: DEPTH B



INDONESIA: GRAVITY ANOMALY T2A

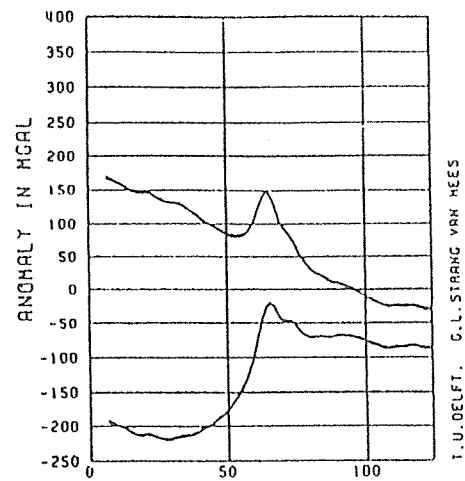


DISTANCE IN KM UPPER LINE: BOUGUER ANOMALY
LINE: T2A LOWER LINE: FREE AIR ANOMALY

DATE: MARCH 28 1985

	START	FINISH
TIME	15 11	0 41
GEOGRAPHICAL COORD. LATITUDE:	-5.950	-6.361
LONGITUDE:	129.732	130.685

INDONESIA: GRAVITY ANOMALY T2B

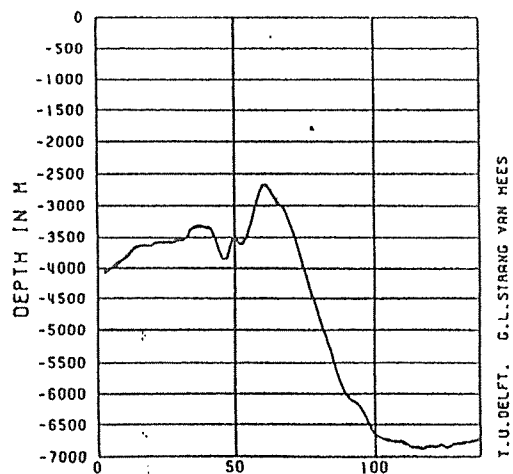


DISTANCE IN KM UPPER LINE: BOUGUER ANOMALY
LINE: T2B LOWER LINE: FREE AIR ANOMALY

DATE: MARCH 29 1985

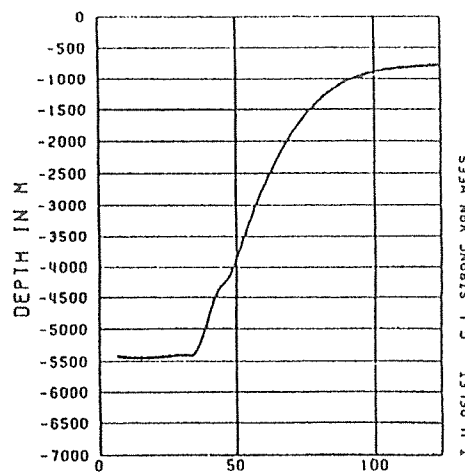
	START	FINISH
TIME	14 0	22 53
GEOGRAPHICAL COORD. LATITUDE:	-6.464	-6.806
LONGITUDE:	131.090	132.093

INDONESIA: DEPTH T2A



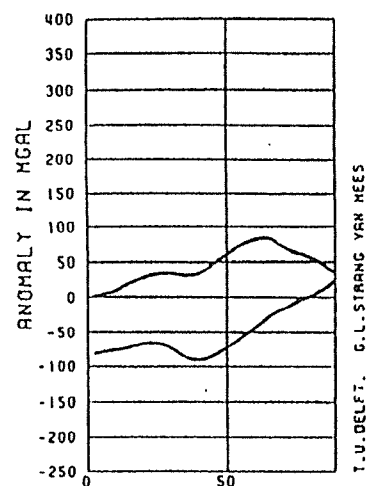
DISTANCE IN KM

INDONESIA: DEPTH T2B



DISTANCE IN KM

INDONESIA: GRAVITY ANOMALY T2C

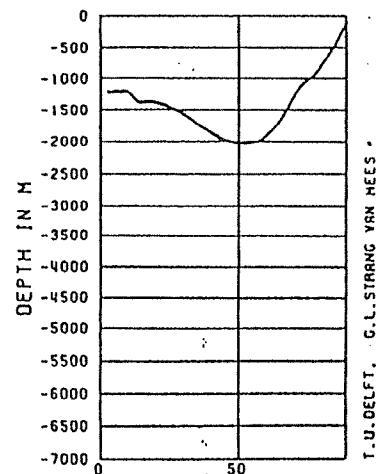


DISTANCE IN KM UPPER LINE: BOUGUER ANOMALY
 LINE: T2C LOWER LINE: FREE AIR ANOMALY

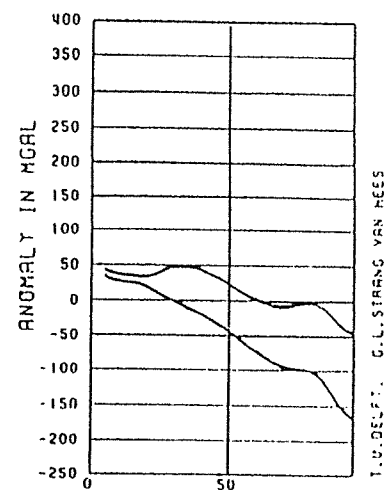
DATE: MARCH 30 1985

TIME	H.M.	START	FINISH
		1 11	7 23
GEOGRAPHICAL COORD. LATITUDE:		-6.873	-7.127
LONGITUDE:		132.248	132.980

INDONESIA: DEPTH T2C



INDONESIA: GRAVITY ANOMALY C

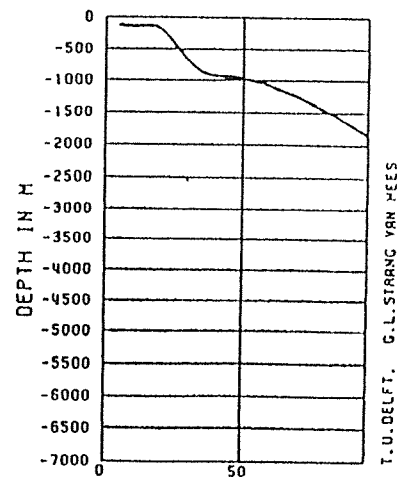


DISTANCE IN KM UPPER LINE: BOUGUER ANOMALY
 LINE: C LOWER LINE: FREE AIR ANOMALY

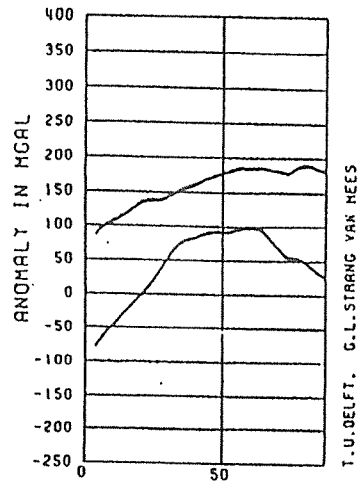
DATE: MARCH 30 1985

TIME	H.M.	START	FINISH
		9 18	13 23
GEOGRAPHICAL COORD. LATITUDE:		-7.052	-6.246
LONGITUDE:		133.137	133.249

INDONESIA: DEPTH C



INDONESIA: GRAVITY ANOMALY 1



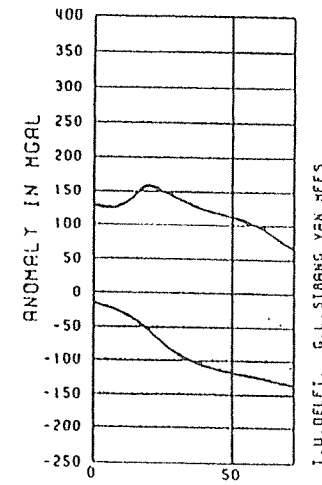
UPPER LINE: BOUGUER ANOMALY
 LINE: 1
 LOWER LINE: FREE AIR ANOMALY

DATE: MARCH 30 1985

TIME	H.H.	START	FINISH
		15 30	21 53

GEOGRAPHICAL COORD.	LATITUDE:	LONGITUDE:
	-5.944	133.284
		-5.195
		133.255

INDONESIA: GRAVITY ANOMALY 2



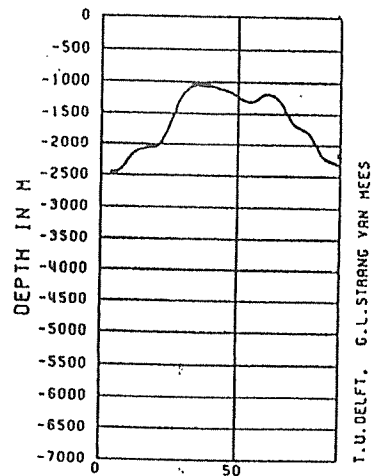
UPPER LINE: BOUGUER ANOMALY
 LINE: 2
 LOWER LINE: FREE AIR ANOMALY

DATE: MARCH 31 1985

TIME	H.H.	START	FINISH
		2 0	6 53

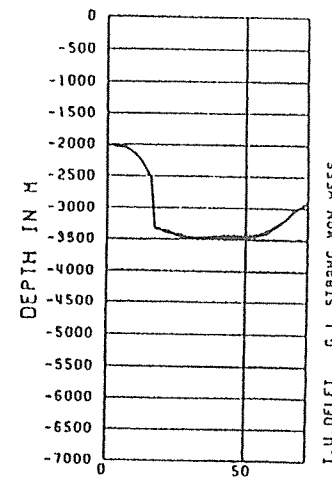
GEOGRAPHICAL COORD.	LATITUDE:	LONGITUDE:
	-5.136	133.419
		-5.124
		134.070

INDONESIA: DEPTH 1



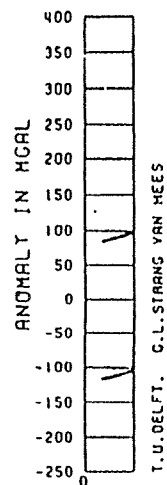
DISTANCE IN KM

INDONESIA: DEPTH 2



DISTANCE IN KM

INDONESIA: GRAVITY ANOMAL 3



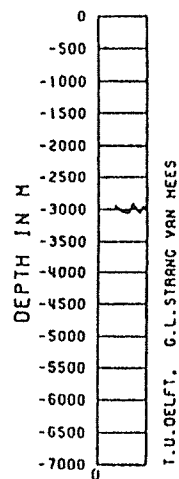
DISTANCE IN KM UPPER LINE: BOUGUER ANOMALY
 LINE: 3 LOWER LINE: FREE AIR ANOMALY

DATE: MARCH 31 1985

TIME	H.M. :	START	FINISH
		0 0	0 53

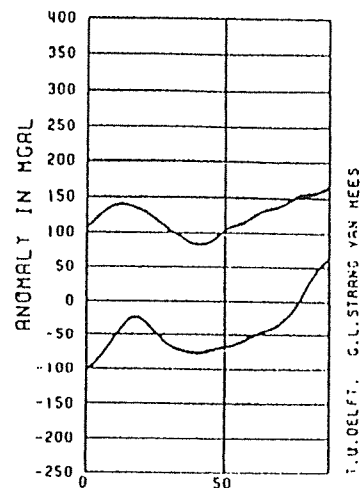
GEOGRAPHICAL COORD. LATITUDE: -5.013 -4.914
 LONGITUDE: 134.113 134.143

INDONESIA: DEPTH 3



DISTANCE IN KM

INDONESIA: GRAVITY ANOMALY 4A



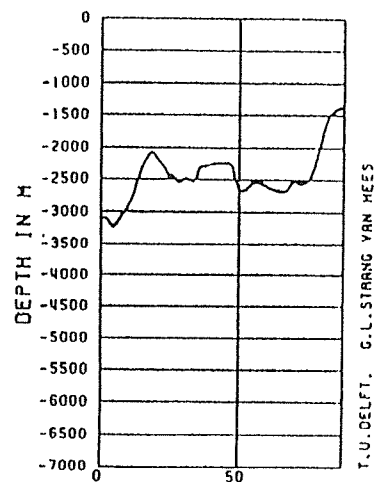
DISTANCE IN KM UPPER LINE: BOUGUER ANOMALY
 LINE: 4A LOWER LINE: FREE AIR ANOMALY

DATE: MARCH 31 1985

TIME	H.M. :	START	FINISH
		15 30	22 40

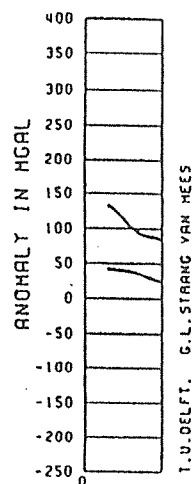
GEOGRAPHICAL COORD. LATITUDE: -4.875 -4.889
 LONGITUDE: 133.946 133.155

INDONESIA: DEPTH 4A



DISTANCE IN KM

INDONESIA: GRAVITY ANOMALY 4B



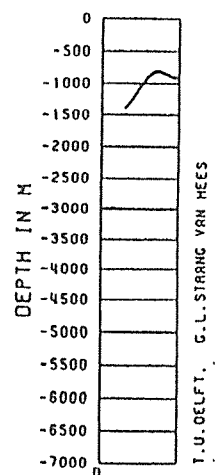
DISTANCE IN KM UPPER LINE: BOUGUER ANOMALY
LINE: 4B LOWER LINE: FREE AIR ANOMALY

DATE: APRIL 1 1985

TIME	H.M.	START	FINISH
		1 41	3 18

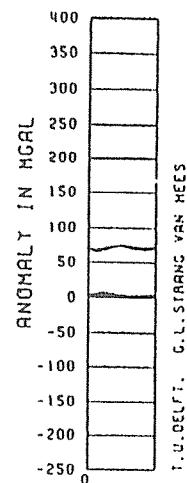
GEOGRAPHICAL COORD. LATITUDE: -4.895 -4.882
LONGITUDE: 132.985 132.809

INDONESIA: DEPTH 4B



DISTANCE IN KM

INDONESIA: GRAVITY ANOMALY 5



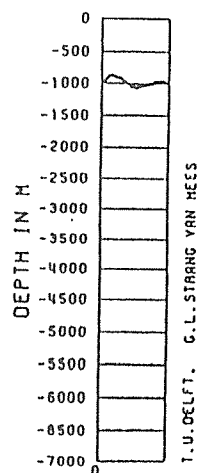
DISTANCE IN KM UPPER LINE: BOUGUER ANOMALY
LINE: 5 LOWER LINE: FREE AIR ANOMALY

DATE: APRIL 1 1985

TIME	H.M.	START	FINISH
		4 30	6 18

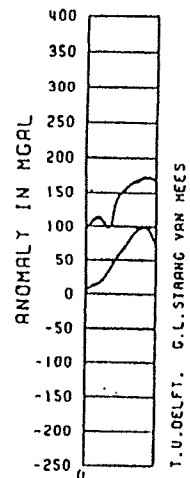
GEOGRAPHICAL COORD. LATITUDE: -4.742 -4.519
LONGITUDE: 132.789 132.803

INDONESIA: DEPTH 5



DISTANCE IN KM

INDONESIA: GRAVITY ANOMALY 6

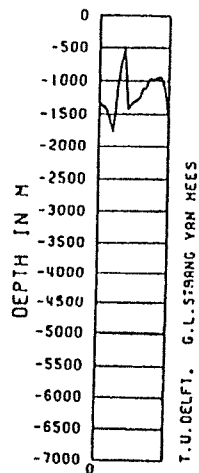


DISTANCE IN KM UPPER LINE: BOUGUER ANOMALY
LINE: 6 LOWER LINE: FREE AIR ANOMALY

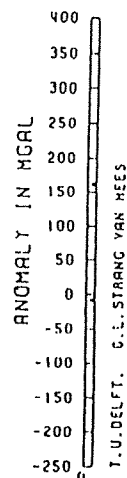
DATE: APRIL 1985

TIME	H.M.	START	FINISH
		7 30	9 23
GEOGRAPHICAL COORD.			
LATITUDE:		-4.451	-4.450
LONGITUDE:		132.902	133.131

INDONESIA: DEPTH 6



INDONESIA: GRAVITY ANOMALY 7

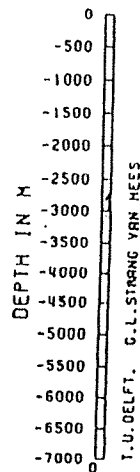


DISTANCE IN KM UPPER LINE: BOUGUER ANOMALY
LINE: 7 LOWER LINE: FREE AIR ANOMALY

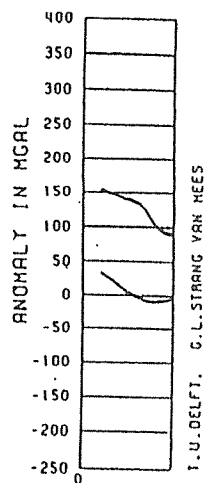
DATE: APRIL 1985

TIME	H.M.	START	FINISH
		11 23	12 0
GEOGRAPHICAL COORD.			
LATITUDE:		-4.440	-4.390
LONGITUDE:		133.218	133.212

INDONESIA: DEPTH 7



INDONESIA: GRAVITY ANOMALY 8



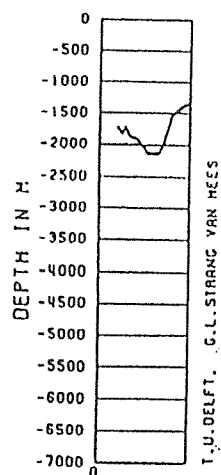
DISTANCE IN KM
 LINE: 8
 UPPER LINE: BOUGUER ANOMALY
 LOWER LINE: FREE AIR ANOMALY

DATE: APRIL 1985

TIME	H.M.	START	FINISH
		15 0	16 53

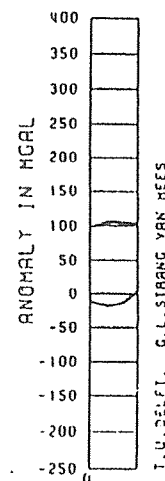
GEOGRAPHICAL COORD. LATITUDE: -4.243 -4.308
 LONGITUDE: 133.036 132.053

INDONESIA: DEPTH 8



DISTANCE IN KM

INDONESIA: GRAVITY ANOMALY 9



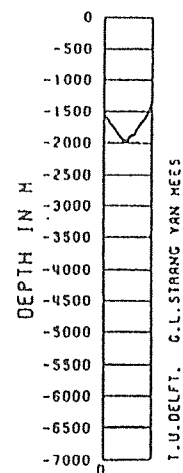
DISTANCE IN KM
 LINE: 9
 UPPER LINE: BOUGUER ANOMALY
 LOWER LINE: FREE AIR ANOMALY

DATE: APRIL 1985

TIME	H.M.	START	FINISH
		10 0	19 23

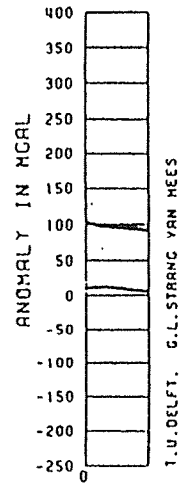
GEOGRAPHICAL COORD. LATITUDE: -4.308 -4.153
 LONGITUDE: 132.039 132.031

INDONESIA: DEPTH 9



DISTANCE IN KM

INDONESIA: GRAVITY ANOMAL 11



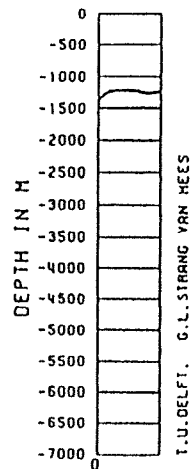
DISTANCE IN KM UPPER LINE: BOUGUER ANOMALY
 LINE: 11 LOWER LINE: FREE AIR ANOMALY

DATE: APRIL 2 1985

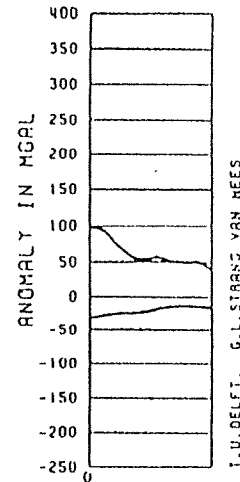
TIME	H.M. :	START	FINISH
		5 30	7 30

GEOGRAPHICAL COORD. LATITUDE: -4.129 -3.961
 LONGITUDE: 132.791 132.676

INDONESIA: DEPTH 11



INDONESIA: GRAVITY ANOMALY 12



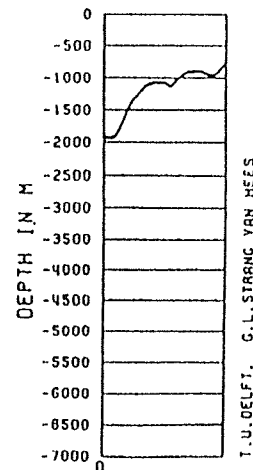
DISTANCE IN KM UPPER LINE: BOUGUER ANOMALY
 LINE: 12 LOWER LINE: FREE AIR ANOMALY

DATE: APRIL 2 1985

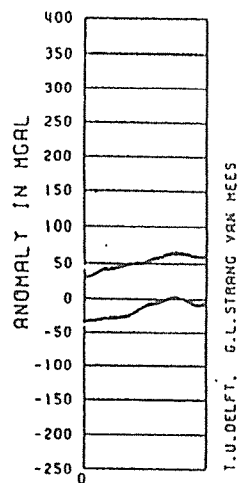
TIME	H.M. :	START	FINISH
		9 0	12 48

GEOGRAPHICAL COORD. LATITUDE: -4.018 -4.353
 LONGITUDE: 132.569 132.350

INDONESIA: DEPTH 12



INDONESIA: GRAVITY ANOMALY 13

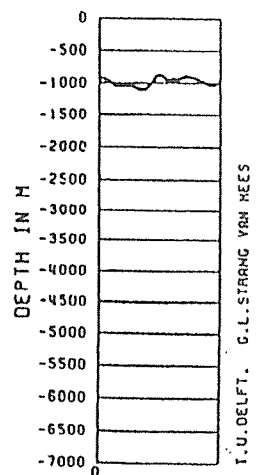


DISTANCE IN KM UPPER LINE: BOUGUER ANOMALY
LINE: 13 LOWER LINE: FREE AIR ANOMALY

DATE: APRIL 2 1985

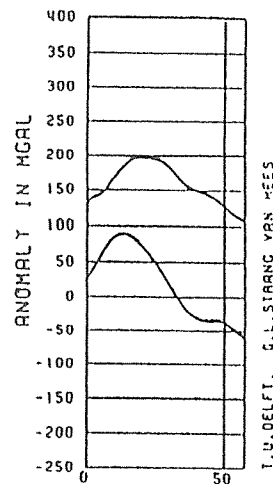
TIME	H.M.	START	FINISH
		14 0	17 53
GEOGRAPHICAL COORD.	LATITUDE:	-4.393	-4.549
	LONGITUDE:	132.467	132.833

INDONESIA: DEPTH 13



DISTANCE IN KM

INDONESIA: GRAVITY ANOMALY 14

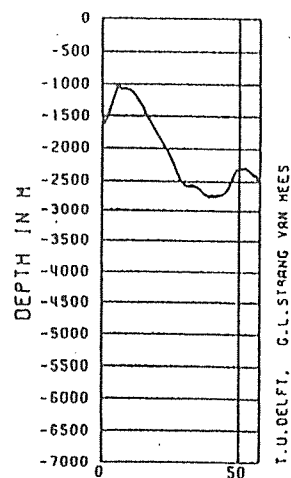


DISTANCE IN KM UPPER LINE: BOUGUER ANOMALY
LINE: 14 LOWER LINE: FREE AIR ANOMALY

DATE: APRIL 2 1985

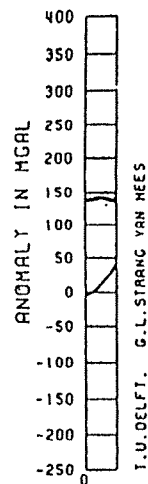
TIME	H.M.	START	FINISH
		19 0	22 48
GEOGRAPHICAL COORD.	LATITUDE:	-4.550	-4.607
	LONGITUDE:	132.944	133.462

INDONESIA: DEPTH 14



DISTANCE IN KM

INDONESIA: GRAVITY ANOMALY 16



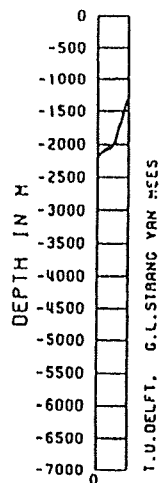
DISTANCE IN KM UPPER LINE: BOUGUER ANOMALY
 LINE: 16 LOWER LINE: FREE AIR ANOMALY

DATE: APRIL 3 1985

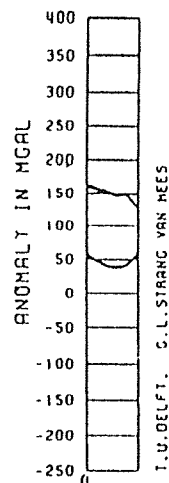
TIME	H.M. :	START	FINISH
		2 30	3 23

GEOGRAPHICAL COORD. LATITUDE: -4.437 -4.335
 LONGITUDE: 133.361 133.366

INDONESIA: DEPTH 16



INDONESIA: GRAVITY ANOMALY 18



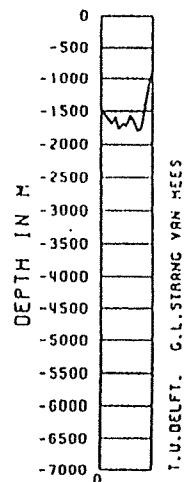
DISTANCE IN KM UPPER LINE: BOUGUER ANOMALY
 LINE: 18 LOWER LINE: FREE AIR ANOMALY

DATE: APRIL 3 1985

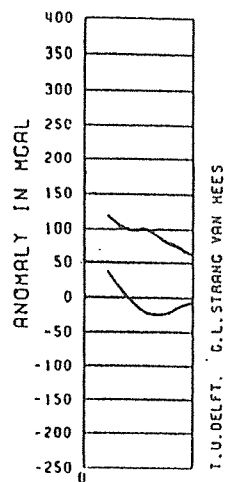
TIME	H.M. :	START	FINISH
		8 30	9 53

GEOGRAPHICAL COORD. LATITUDE: -4.337 -4.168
 LONGITUDE: 133.069 133.063

INDONESIA: DEPTH 18



INDONESIA: GRAVITY ANOMALY 19



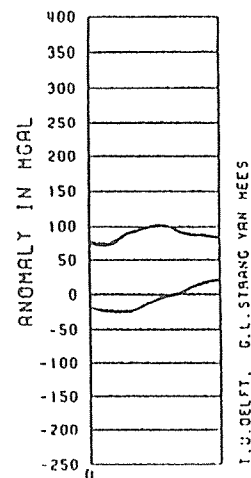
DISTANCE IN KM, UPPER LINE: BOUGUER ANOMALY
LINE: 19 LOWER LINE: FREE AIR ANOMALY

DATE: APRIL 3 1985

TIME	H.M. :	START	FINISH
		11 18	13 23

GEOGRAPHICAL COORD. LATITUDE: -4.190 -4.358
LONGITUDE: 132.965 132.743

INDONESIA: GRAVITY ANOMALY 20



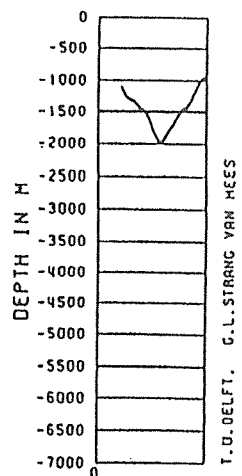
DISTANCE IN KM UPPER LINE: BOUGUER ANOMALY
LINE: 20 LOWER LINE: FREE AIR ANOMALY

DATE: APRIL 3 1985

TIME	H.M. :	START	FINISH
		14 30	16 18

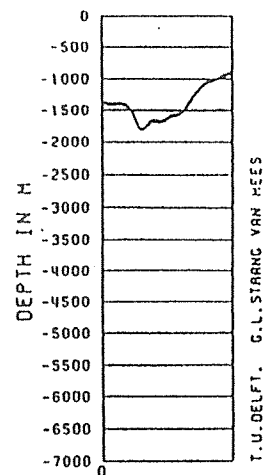
GEOGRAPHICAL COORD. LATITUDE: -4.256 -3.832
LONGITUDE: 132.708 132.658

INDONESIA: DEPTH 19



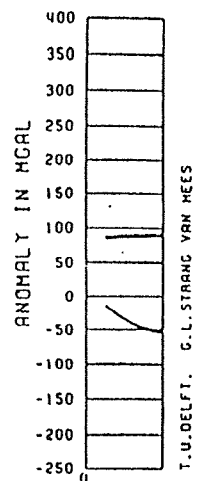
DISTANCE IN KM

INDONESIA: DEPTH 20



DISTANCE IN KM

INDONESIA: GRAVITY ANOMALY 21



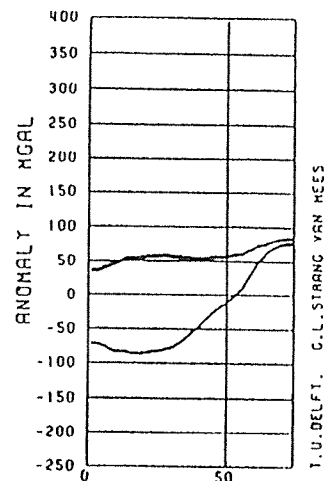
DISTANCE IN KM UPPER LINE: BOUGUER ANOMALY
 LINE: 21 LOWER LINE: FREE AIR ANOMALY

DATE: APRIL 3 1985

TIME	H.M. :	START	FINISH
		19 36	21 23

GEOGRAPHICAL COORD. LATITUDE: -3.821 -3.916
 LONGITUDE: 132.576 132.419

INDONESIA: GRAVITY ANOMALY 23



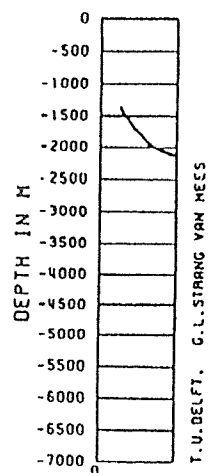
DISTANCE IN KM UPPER LINE: BOUGUER ANOMALY
 LINE: 23 LOWER LINE: FREE AIR ANOMALY

DATE: APRIL 4 1985

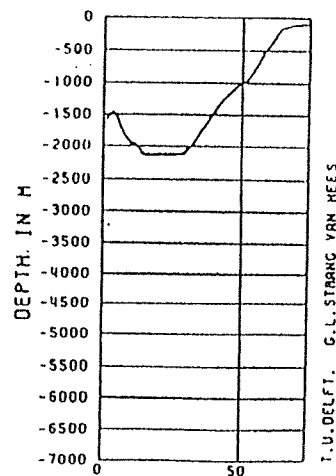
TIME	H.M. :	START	FINISH
		1 6	6 48

GEOGRAPHICAL COORD. LATITUDE: -3.873 -3.552
 LONGITUDE: 132.165 132.734

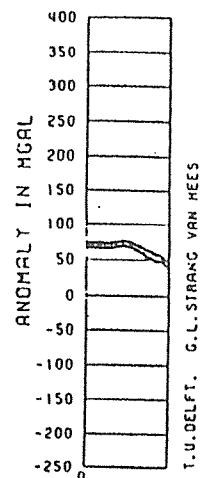
INDONESIA: DEPTH 21



INDONESIA: DEPTH 23



INDONESIA: GRAVITY ANOMAL 24

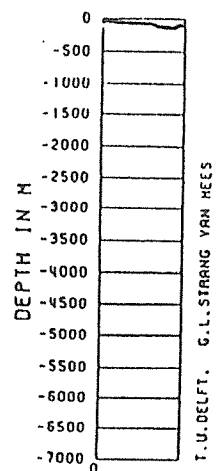


DISTANCE IN KM UPPER LINE: BOUGUER ANOMALY
 LINE: 24 LOWER LINE: FREE AIR ANOMALY

DATE: APRIL 4 1985

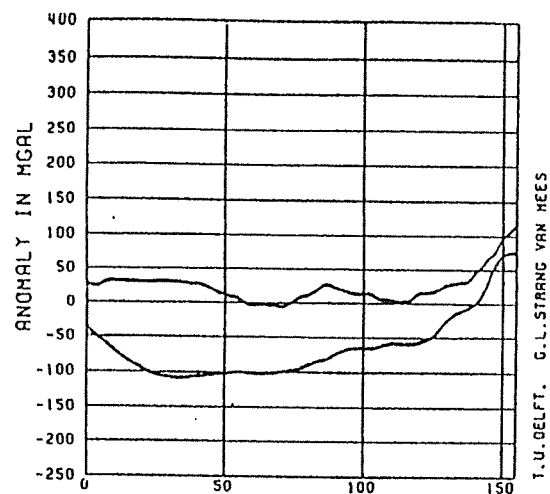
TIME	H.M.	START	FINISH
		8 0	10 53
GEOGRAPHICAL COORD.	LATITUDE:	-3.480	-3.291
	LONGITUDE:	132.729	132.532

INDONESIA: DEPTH 24



DISTANCE IN KM

INDONESIA: GRAVITY ANOMALY T3A



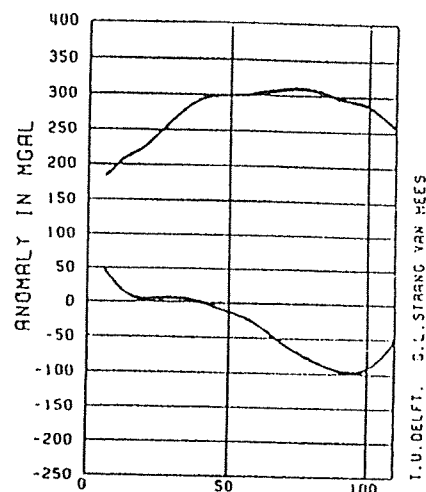
DISTANCE IN KM UPPER LINE: BOUGUER ANOMALY
 LINE: T3A LOWER LINE: FREE AIR ANOMALY

DATE: APRIL 4 1985

TIME	H.M.	START	FINISH
		12 30	0 48

GEOGRAPHICAL COORD. LATITUDE: -3.344 -4.294
 LONGITUDE: 132.408 131.381

INDONESIA: GRAVITY ANOMALY T3B



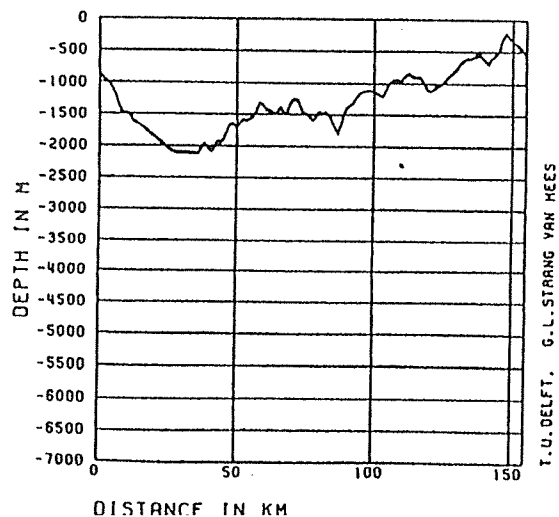
DISTANCE IN KM UPPER LINE: BOUGUER ANOMALY
 LINE: T3B LOWER LINE: FREE AIR ANOMALY

DATE: APRIL 5 1985

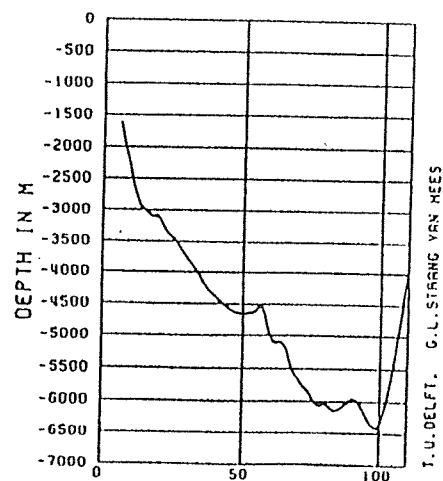
TIME	H.M.	START	FINISH
		2 30	10 48

GEOGRAPHICAL COORD. LATITUDE: -4.344 -4.825
 LONGITUDE: 131.324 130.520

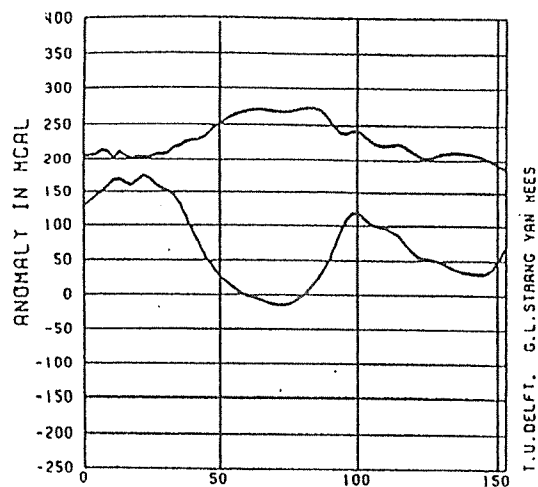
INDONESIA: DEPTH T3A



INDONESIA: DEPTH T3B



INDONESIA: GRAVITY ANOMALY



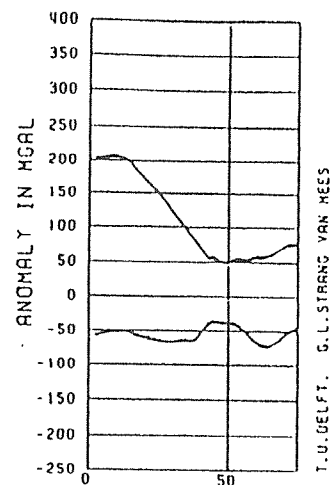
DISTANCE IN KM UPPER LINE: BOUGUER ANOMALY
 LINE: D LOWER LINE: FREE AIR ANOMALY

DATE: APRIL 5 1985

74

TIME	H.M.	START	FINISH
		14 0	20 41
GEOGRAPHICAL COORD.	LATITUDE:	-4.627	-4.070
	LONGITUDE:	129.951	128.686

INDONESIA: GRAVITY ANOMALY T4A

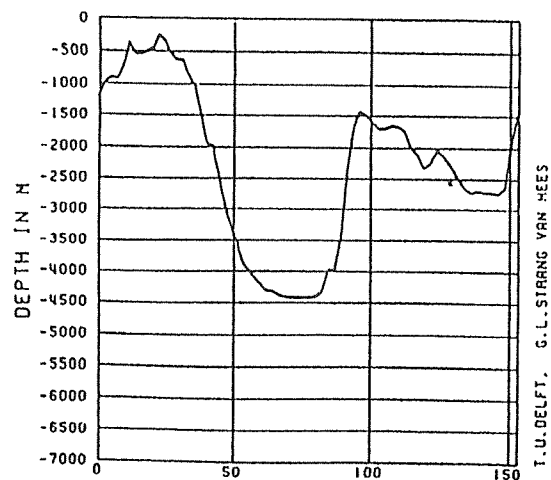


DISTANCE IN KM UPPER LINE: BOUGUER ANOMALY
 LINE: T4A LOWER LINE: FREE AIR ANOMALY

DATE: APRIL 6 1985

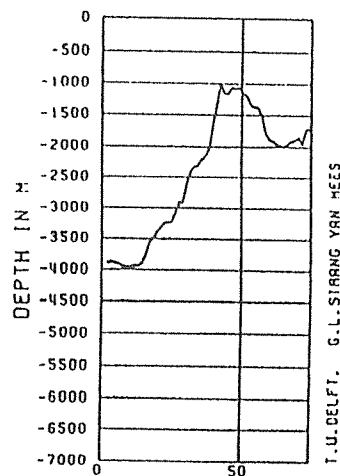
TIME	H.M.	START	FINISH
		11 41	17 6
GEOGRAPHICAL COORD.	LATITUDE:	-3.587	-2.959
	LONGITUDE:	127.418	127.222

INDONESIA: DEPTH D



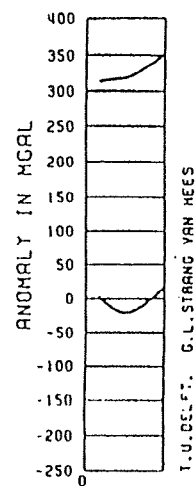
DISTANCE IN KM

INDONESIA: DEPTH T4A



DISTANCE IN KM

INDONESIA: GRAVITY ANOMALY T4



DISTANCE IN KM UPPER LINE: BOUGUER ANOMALY
 LINE: T4B LOWER LINE: FREE AIR ANOMALY

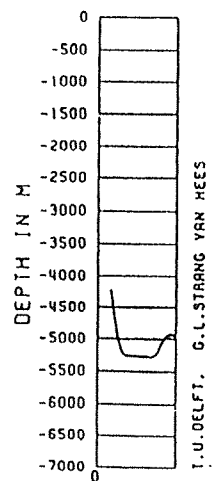
DATE: APRIL 6 1985

TIME	H.M.	START	FINISH
		22 23	0 18

GEOGRAPHICAL COORD. LATITUDE: -2.590 -2.398
 LONGITUDE: 127.070 126.983

75

INDONESIA: DEPTH T4B



DISTANCE IN KM