ASSOCIATION INTERNATIONALE DE GEODESIE

BUREAU GRAVIMETRIQUE INTERNATIONAL

BULLETIN D'INFORMATION

N° 65

Décembre 1989

18, Avenue Edouard Belin

31055 TOULOUSE CEDEX

FRANCE

INFORMATIONS FOR CONTRIBUTORS

Contributors should follow as closely as possible the rules below :

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

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

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

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

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

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

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

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

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

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

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

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

BUREAU GRAVIMETRIQUE INTERNATIONAL

Toulouse

BULLETIN D'INFORMATION

Décembre 1989

N° 65

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ANNOUNCEMENT

INTERNATIONAL GRAVITY COMMISSION
13th MEETING

Toulouse, France. September 11-14, 1990

First Circular

TOPIC AND OBJECTIVES

See provisional program enclosed

ORGANIZING COMMITTEE

J. Tanner
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G. Balmino
BGI, Toulouse, France

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BGI, Toulouse, France

CONVENERS

G. Balmino, G. Boedecker, J. Faller, I. Groten, I. Marson, Ch. Poitevin, R. Rummel, J. Tanner
(Refer to program and list of addresses)

SPONSOR

IGC : International Gravity Commission

CO-SPONSOR

IAG : International Association of Geodesy

ORGANIZER

BGI : Bureau Gravimétrique International
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WORKING LANGUAGE

English

REGISTRATION FEES

550 French Francs

(Please return this form to the organizing committee immediately. The second circular will be mailed early 1990).

13th MEETING OF THE INTERNATIONAL GRAVITY COMMISSION
Toulouse, France. September 11-14, 1990
Preliminary Registration Form

Name : ....
Organization : ....
....
Address : ....
....
....
Telephone : ....
Telefax : ....
Telex : ....

Will you attend the meeting ?

☐ Yes ☐ No

☐ The following person (s) may be interested in the meeting ....

Do you intend to present a paper ?

☐ Yes ☐ No

If YES[1] : Subject or title : ....
....

Are you interested in an excursion on Saturday September 15 ?

☐ Yes ☐ No

If YES, mark preference

☐ Astronomical Observatory of Pic du Midi

☐ Albi (Toulouse-Lautrec Museum, Cathedral)

☐ Carcassonne (Medieval City)

☐ Other

Date : ....

Signature..........

1 Send also copy of this form to the appropriate convenor

13th MEETING OF THE INTERNATIONAL GRAVITY COMMISSION

(September 10-14, 1990)

PROVISIONAL PROGRAM

Monday, Sept. 10

Directing Board Meeting : attendance restricted to Directing Board members, presidents of Sub-Commissions and chairmen of Working Groups.

(p.m. : registration of participants to I.G.C.)

Tuesday, Sept. 11

a.m.	9.00	Opening	G. Balmino
	9.05	Administrative session. Introduction	Chairman : J. Tanner
	9.15	Technical Reports of the Working Groups	
	10.15	Break	
	10.40	Technical Reports of the Working Groups (cont.)	
	11.00	Report of BGI	
	11.30	Reports of Sub-Commissions	
	12.30	Lunch	
p.m.	14.00-17.00	Intercomparison of Absolute Gravimeters	Convener : I. Marson

Wednesday, Sept. 12

a.m.	9.00-12.30	Absolute Measurements and IAGBN	Convener : G. Boedecker
p.m.	14.00-17.00	New Regional Gravity Maps (North America gravity map, AGP, SAGP, others) - some space will be provided to display maps	Conveners : J. Tanner, G. Balmino

Thursday, Sept. 13

a.m.	9.00-12.30	High Precision Relative Gravity Measurements : (1) Instrumental Techniques	Convener : I. Groten
p.m.	14.00-17.00	High Precision Relative Gravity Measurements : (2) Environmental Problems and Applications	Convener : Ch. Poitevin

Friday, Sept. 14

a.m.	9.00-12.30	Non Newtonian Gravity Experiments	Convener : J. Faller
p.m.	14.00-17.00	Dynamic Gravimetry and Gradiometry	Convener : R. Rummel
	17.15	Adjourn	

Part I

INTERNAL MATTER

filtatt_saut (1)

```
      program redresse
      logical chgt,finva,finv
      dimension alu(4),a(4),apre(4),aprelu(4)
      dimension pente(4)
      dimension tsaut(4,100),cor(4,100),corcum(4),ic(4)

      integer rate
      integer start
      integer finish
      real seconds
! temps debut execution
      call system_clock(COUNT_RATE=rate)
      call system_clock(COUNT=start)

      epsdif=1.e-6
! mode iverb=1 verbose, iverb=0 noverbose
      iverb=0
! duree max trou comble
      dtmax=120.
! valeurs initiale gradient quaternions
      pente(:)=0.
      pente_seuil = 0.004
!
      open(1,file='nomatt',access='sequential',form='formatted')
      open(2,file='nomattsaut',access='sequential',form='formatted')
      open(3,file='/tmp/nomattcor',access='sequential',form='formatted')
      ic(:)=0
      chgt=.false.
      read(1,*,end=9)tpre,aprelu
      apre(:)=aprelu(:)
!      write(2,*)tpre,aprelu
      nt=1

    1 read(1,*,end=9)t,alu
      dec=alu(1)-aprelu(1)
      if(abs(dec).gt.0.3)then
        write(2,*)'saut t=',t
        if(.not.chgt)then
          chgt=.true.
        else
          chgt=.false.
        endif
      endif
      if(chgt)then
        do i=1,4
          a(i)=-alu(i)
        enddo
      else
        do i=1,4
          a(i)=alu(i)
        enddo
      endif
!     print *,nt,a(1),chgt
      do i=1,4
        if(abs(a(i)-apre(i)-pente(i)).gt.0.004)then     ! détection saut   [0.004 → pente_seuil]
          write(2,*)t,i,a(i)-apre(i)-pente(i)
          ic(i)=ic(i)+1
          tsaut(i,ic(i))=t
          cor(i,ic(i))=a(i)-apre(i)
          print *,'sauts:',i,tsaut(i,ic(i)),cor(i,ic(i))
        endif
      enddo

      tpre=t
      apre(:)=a(:)
```

$$\hat{\omega} = \frac{z^2 - \frac{z * z}{np}}{np + 1}$$

GENERAL INFORMATIONS

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

1. HOW TO OBTAIN THE BULLETIN

The Bulletin d'Information of the Bureau Gravimétrique International 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 everyfour years, a special issue contrains (solely) 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 (65 have been issued as December 1, 1989, 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 ROMMENS
CNES/BGI
18, Avenue Edouard Belin
31055 TOULOUSE CEDEX - FRANCE

Bulletins are sent on an exchange basis (free of charge) for individuals, institutions which currently provide informations, data to the Bureau. For other cases, the price of each number is as follows :

- 65 French Francs without map,

- 75 French Francs with map.

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 reach you by mail only !

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 charges. 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

They can be requested :

(a) *either from the CGDF (Compressed Gravity Data File). the list and format of the informations provided are the following :*

CGDF RECORD DESCRIPTION

70 CHARACTERS

Col. 1	*Classification code - 0 if not classified*
2- 8	*B.G.I. source number*
9- 15	*Latitude (unit = 1/10 000 degree)*
16- 23	*Longitude (unit = 1/10 000 degree)*
24	*Elevation type* *1 = Land* *2 = Subsurface* *3 = Ocean surface* *4 = Ocean submerged* *5 = Ocean Bottom* *6 = Lake surface (above sea level)* *7 = Lake bottom (above sea level)* *8 = Lake bottom (below sea level)* *9 = Lake surface (above sea level with lake bottom below sea level)* *A = Lake surface (below sea level)* *B = Lake bottom (surface below sea level)* *C = Ice cap (bottom below sea level)* *D = Ice cap (bottom above sea level)* *E = Transfer data given*
25- 31	*Elevation of the station (0.1 M)* *This field will contain depth of ocean positive downward) if col. 24 contains 3, 4 or 5.*
32- 36	*Free air anomaly (0.1 mgal)*
37- 38	*Estimation standard deviation free air anomaly (mgal)*

39-43	*Bouguer anomaly (0.1 mgal)* *Simple Bouguer anomaly with mean density of 2.67 - N_o terrain correction*
44-45	*Estimation standard deviation Bouguer anomaly (mgal)*
46	*System of numbering for the reference station* *1 = IGNS 71* *2 = BGI* *3 = country* *4 = DMA*
47-53	*Reference station*
54-56	*Country code*
57	*1 : measurement at sea with no depth given* *0 : otherwise*
Col. 58	*Information about terrain correction* *0 = no information* *1 = terrain correction exists in the archive file*
59	*Information about density* *0 = no information or 2.67* *1 = density ≠ 2.67 given in the archive file*
60	*Information about isostatic anomaly* *0 = no information* *1 = information exists but is not stored in the archive file* *2 = information exists and is included in the archive file.*
61	*Validity* *0 = no validation* *1 = good* *2 = doubtful* *3 = lapsed*
62-70	*Station number in the data base.*

(b) *or from the Archive file. The list and format of the informations provided are the following :*

ARCHIVE FILES

RECORD DESCRIPTION

160 CHARACTERS

Col. 1-7	*B.G.I. source number*
8-12	*Block number* *Col. 8-10 = 10 square degree* *Col. 11-12 = 1 square degree*
13-19	*Latitude (Unit : 1/10 000 degree)*
20-27	*Longitude (unit : 1/10 000 degree) (- 180 to + 180 degree)*
28	*Accuracy of position* *The site of the gravity measurement is defined in a circle of radius R* *0 = no information on the accuracy* *1 = R <= 20 M (approximately 0'01)* *2 = 20 < R <= 100* *3 = 100 < R <= 200 (approximately 0'1)* *4 = 200 < R <= 500* *5 = 500 < R <= 1000* *6 = 1000 < R <= 2000 (approximately 1')* *7 = 2000 < R <= 5000* *8 = 5000 < R* *9 ...*

29 *System of position*
0 = unknown
1 = Decca
2 = visual observation
3 = radar
4 = loran A
5 = loran C
6 = omega or VLF
7 = satellite
9 = solar/stellar (with sextant)

30-31 *Type of observation*
A minus sign distinguishes the pendulum observations from the gravimeter ones.
0 = current observation of detail or other observations of a 3 rd or 4th order network
1 = observation of a 2nd order national network
2 = observation of a 1st order national network
3 = observation being part of a nation calibration line
4 = individual observation at sea
5 = mean observation at sea obtained from a continuous recording
6 = coastal ordinary observation (Harbour, Bay, Sea-side...)
7 = harbour base station

32 *Elevation type*
1 = Land
2 = Subsurface
3 = Ocean surface
4 = Ocean submerged
5 = Ocean bottom
6 = Lake surface (above sea level)
7 = Lake bottom (above sea level)
8 = Lake bottom (below sea level)
9 = Lake surface (above sea level with lake bottom below sea level)
A = Lake surface (below sea level)
B = Lake bottom (surface below sea level)
C = Ice cap (bottom above sea level)
D = Ice cap (bottom above sea level)
E = Transfer data given

33-39 *Elevation of the station (0.1 M)*
This field will contain depth of ocean (positive downward) if col. 32 contains 3, 4 or 5

40 *Accuracy of elevation (E)*
0 = unknown
1 = E < = 0.1 M
2 = .1 < E < = 1
3 = 1 < E < = 2
4 = 2 < E < = 5
5 = 5 < E < = 10
6 = 10 < E < = 20
7 = 20 < E < = 50
8 = 50 < E < = 100
9 = E superior to 100 M

41-42 *Determination of the elevation*
= no information
0 = geometrical levelling (bench mark)
1 = barometrical levelling
3 = data obtained from topographical map
4 = data directly appreciated from the mean sea level
5 = data measured by the depression of the horizon (marine)
Type of depth (if Col. 32 contains 3, 4 or 5)
1 = depth obtained with a cable (meters)
2 = manometer depth
4 = corrected acoustic depth (corrected from Mathew's tables, 1939)
5 = acoustic depth without correction obtained with

sound speed 1500 M/sec. (or 820 Brasses/sec)
6 = acoustic depth obtained with sound speed 800 Brasses/sec (or 1463 M/sec)
9 = depth interpolated on a magnetic record
10 = depth interpolated on a chart

43-44 *Mathews' zone*
When the depth is not corrected depth, this information is necessary.
For example : zone 50 for the Eastern Mediterranean Sea

45-51 *Supplemental elevation*
Depth of instrument, lake or ice, positive downward from surface

52-59 *Observed gravity (0.01 mgal)*

60 *Information about gravity*
1 = gravity with only instrumental correction
2 = corrected gravity (instrumental and Eotvos correction
3 = corrected gravity (instrumental, Eötvös and cross-coupling correction)
4 = corrected gravity and compensated by cross-over profiles

61 *Accuracy of gravity (e)*
When all systematic corrections have been applied
0 = E < = 0.05
1 = .05 < E < = 0.1
2 = 0.1 < E < = 0.5
3 = 0.5 < E < = 1.
4 = 1. < E < = 3.
5 = 3. < E < = 5.
6 = 5. < E < = 10.
7 = 10. < E < = 15.
8 = 15. < E < = 20.
9 = 20. < E

62 *System of numbering for the reference station*
This parameter indicates the adopted system for the numbering of the reference station
1 = for numbering adopted by IGSN 71
2 = BGI
3 = Country
4 = DMA

63-69 *Reference station*
This station is the base station to which the concerned station is referred

70-76 *Calibration information (station of base)*
This zone will reveal the scale of the gravity network in which the station concerned was observed, and allow us to make the necessary corrections to get an homogeneous system

77-81 *Free air anomaly (0.1 mgal)*

82-86 *Bouguer anomaly (0.1 mgal)*
Simple bouguer anomaly with a mean density of 2.67 - No terrain correction

87-88 *Estimation standard deviation free air anomaly (mgal)*

89-90 *Estimation standard deviation bouguer anomaly (mgal)*

91-92 *Information about terrain correction*
Horizontal plate without bullard's term
0 = no topographic correction
1 = CT computed for a radius of 5 km (zone H)
2 = CT 30 km (zone L)
3 = CT 100 km (zone N)
4 = CT 167 km (zone 02)
11 = CT computed from 1 km to 167 km
12 = CT 2.5 167
13 = CT 5.2 167

93-96 *Density used for terrain correction*

97-100 *Terrain correction (0.1 mgal)*
Computed according to the previously mentioned radius (col. 91-92) & density (col. 93-96)

101-103	*Apparatus used for the measurements of G* *0.. pendulum apparatus constructed before 1932* *1.. recent pendulum apparatus (1930-1960)* *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* *4.. Metal spring gravimeters for ground measurements* *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* *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* *7.. Gravimeters for measurements on the sea surface or at small depth (submarines..)* *70 = Graf-Askania* *72 = Lacoste-Romberg* *73 = Lacoste-Romberg (on a platform)* *74 = Gal and Gal-F (used in submarines) Gal-M* *75 = AMG (USSR)* *76 = TSSG (Tokyo Surface Ship Gravity meter)* *77 = GSI sea gravity meter*
104	*Conditions of apparatus used* *1 = 1 gravimeter only (no precision)* *2 = 2 gravimeters (no precision)* *3 = 1 gravimeter only (without cross-coupling correction)* *4 = 2 gravimeters (influenced by the cross-coupling effect) with the same orientation* *5 = 2 gravimeters (influenced by the cross-coupling effect) in opposition* *6 = 1 gravimeter (compensated for the cross-coupling effect)* *7 = 1 gravimeter non subject to cross-coupling effect* *8 = 3 gravimeters*
105	*Information about isostatic anomaly* *0 = no information* *1 = information exists but is not stored in the data bank* *2 = information exists and is included in the data bank*
106-107	*Type of the isostatic anomaly* *0.. Pratt-Hayford hypothese* *01 = 50 km including indirect effect (Lejay's tables)* *02 = 56.9 km* *03 = 56.9 km including indirect effect*

04 = 80 km including indirect effect
05 = 96 km
06 = 113.7 km
07 = 113.7 km including indirect effect
1.. Airy hypotheses (equality of masses or pressures)
10 = T = 20 km (Heiskanen's tables, 1931)
11 = T = 20 km including indirect effect
(Heiskanen's tables 1938 or Lejay's)
12 = T = 30 km (Heiskanen's tables, 1931)
13 = T = 30 km including indirect effect
14 = T = 40 km
15 = T = 40 km including indirect effect
16 = T = 60 km
17 = T = 60 km including indirect effect
6......
65 = Vening Meinesz hypothesis "modified Bouguer anomaly" (Vening Meinesz, 1948)

108-112	*Isostatic anomaly a (0.1 mgal)*
113-114	*Type of the isostatic anomaly B*
115-119	*Isostatic anomaly B*
120-122	*Velocity of the ship (0.1 knot)*
123-127	*Eötvös correction (0.1 mgal)*
128-131	*Year of observation*
132-133	*Month*
134-135	*Day*
136-137	*Hour*
138-139	*Minute*
140-145	*Numbering of the station (original)*
146-148	*Country code (B.G.I.)*
149	*Validity*
150-154	*Original source number (ex. DMA code)*
155-160	*Sequence number*

Whenever given, the theoretical gravity (gO), 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 :

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

where ϕ is the geographic latitude.

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

Formulas used in computing free-air and Bouguer anomalies

Elev Type	Situation	Formulas
1	Land Observation	FA = g + 0.3086*H - gO BO = FA - 0.1119*H
2	Subsurface	FA = g + 0.2238*D2 + 0,3086*(H-D2) BO = FA - 0.1119*H
3	Ocean surface	FA = g - gO BO = FA + 0.06886*H (H = depth of ocean positive downward from surface)
4	Ocean submerged	FA = g - gO BO = FA + 0.06886*H (D2 = depth of instrument positive downward) (H = depth of ocean positive downward)
5	Ocean bottom	FA = g + 0.3086*H - gO BO = FA + 0.06886*D1 (D1 = depth of ocean positive downward)
6	Lake surface (above sea level)	FA = g + 0.3086*H - gO BO = FA - 0.04191*D1 - 0.1119*(H-D1) (D1 = depth of lake positive downward)
7	Lake bottom (above sea level)	FA = g + 0.08382*D1 + 0.3086*(H-D1) - gO BO = FA - 0.04191*D1 - 0.1119*(H-D1)
8	Lake bottom (below sea level)	FA = g + 0.08382*D1 + 0.3086*(H-D1) - gO BO = FA - 0.04191*D1 - 0.06999*(H-D1)
9	Lake surface (above sea level with bottom below sea level)	FA = g + 0.3086*H - gO BO = FA - 0.04191*H - 0.06999*(H-D1)
A	Lake surface (below sea level)	FA = g + 0.3086*H - gO BO = FA - 0.1119*H + 0.06999*D1
B	Lake bottom (surface below sea level)	FA = g + 0.3086*H - 0.2248*D1 - gO BO = FA - 0.1119*H + 0.06999*D1 (D1 = depth of lake positive downward)
C	Ice cap (bottom below sea level)	FA = g + 0.3086*H - gO BO = FA - 0.03843*H - 0.07347*(H-D1) (D1 = depth of ice positive downward)
D	Ice cap (bottom above sea level)	FA = g + 0.3086*H - gO BO = FA - 0.03843*D1 - 0.1119*(H-D1) (D1 = depth of ice)

2.6. Satellite Altimetry Data

BGI has access to the Geos 3 and Seasat data base which is 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 B.G.I.

(b) Requests for the full altimeter measurement 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 unlabeled 9-track tape (s) with a fixed block size. The exact physical format will be indicated in each case.

3. USUAL SERVICES B.G.I. 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 are effective January 1, 1989 and will 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*
** 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°x 20° 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).

. 5 F/100 points to be screened.

. 100 F minimum charge.

3.1.4. Gridding

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

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

. minimum charge : 150 F

. maximum area : 40°x 40°

3.1.5. Contour Maps of Bouguer or Free-Air Anomalies

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

. 250 F minimum charge

. maximum area : 40°x 40°

3.1.6. Computation of Mean Gravity Anomalies

(Free-air, Bouguer, isostatic) over ΔxΔ' area : 10 F/$\Delta\Delta'$ per degree square.

. minimum charge : 150 F

. maximum area : 40°x 40°

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 in the polygon.*

3.2.3. Data Screening

. 1 F per screened point

. 250 F minimum charge

3.2.4. Gridding

Same as 2.1.4.

3.2.5. Contour Maps of Bouguer or Free-Air Anomalies

Same as 2.1.5.

3.2.6. Computation of Mean Gravity Anomalies

Same as 2.1.6.

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 be returned)

3.3.2. 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) 1985 200 FF

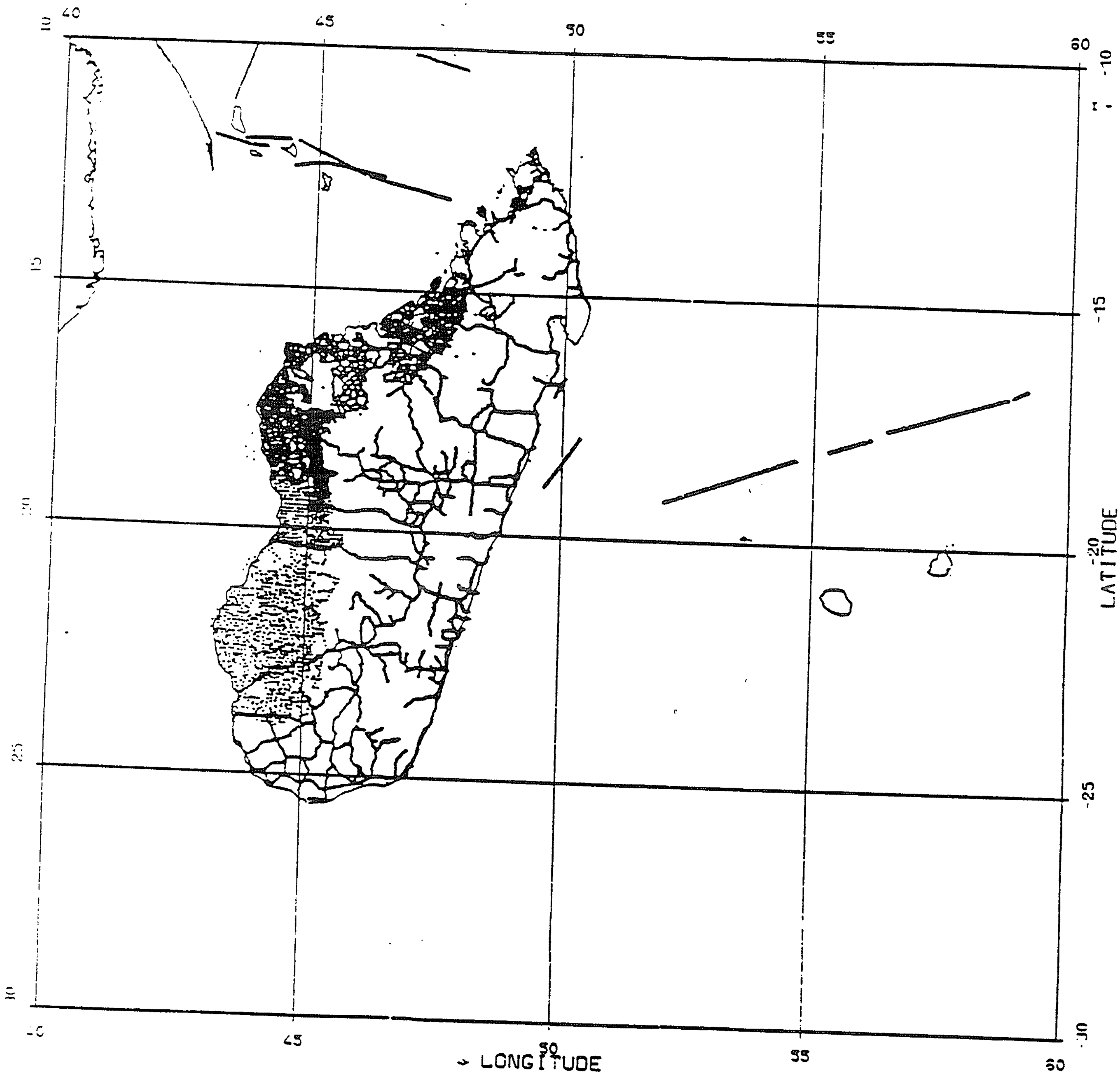
THE UNIFICATION OF THE GRAVITY NETS
OF AFRICA (Vol. 1 and 2) 1979 150 FF

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

. Colour copy : price according to specifications of request.

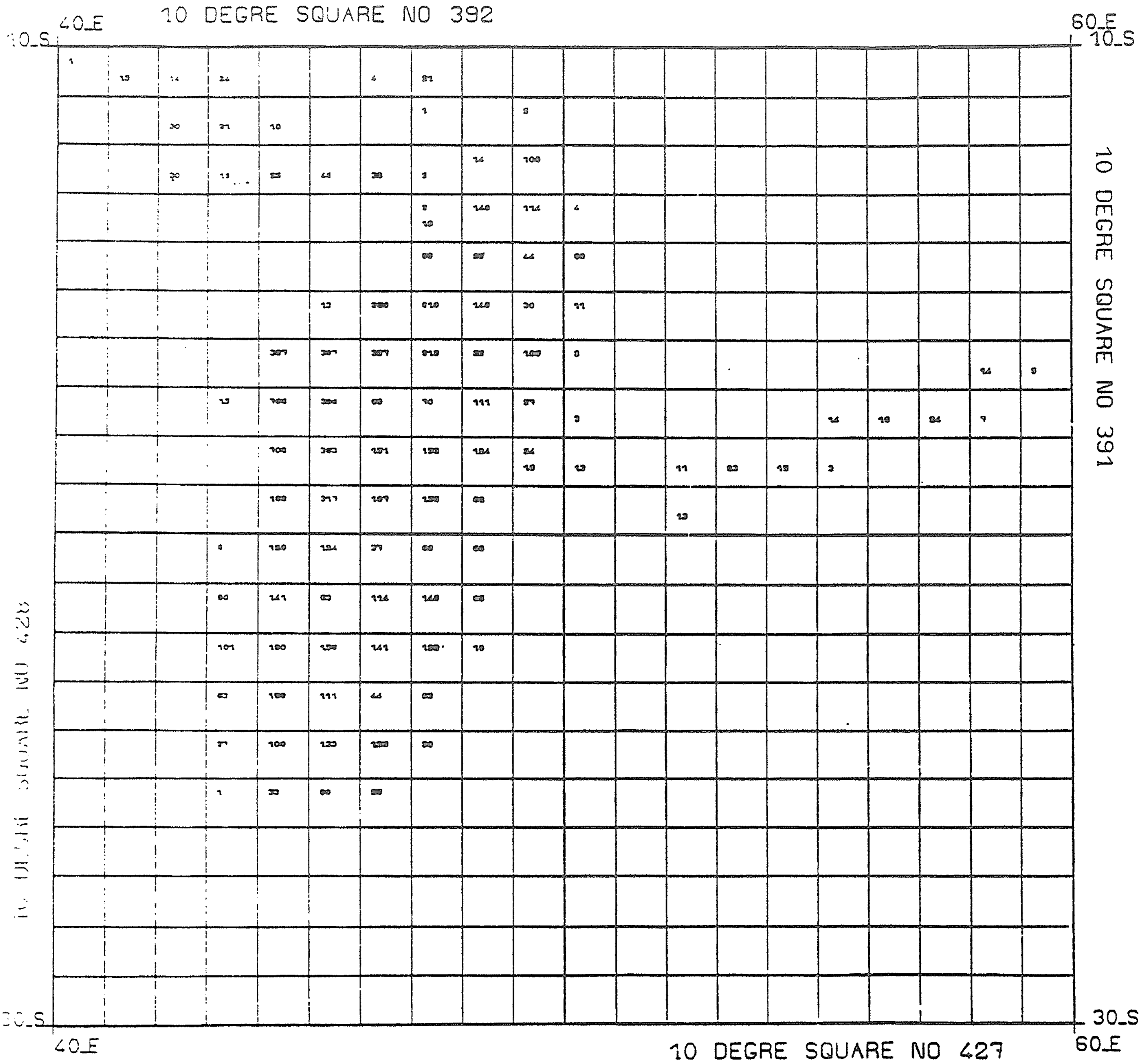
Mailing charges will be added for air-mail parcels when "Air-Mail" is requested)

Map 1. Example of data coverage plot



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

REPRESENTATION OF EARTH AND SEA GRAVIMETRIC STATIONS



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)[1]
   . for water stations : water depth.

2. *Measured (observed) gravity, corrected to eliminate the periodic gravitational effects of the Sun and Moon, and the instrumental drift*[2]

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.

. 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 unlabeled tapes (if possible), with no password, and formated records of possibly fixed length and a fixed blocksize, too. Tapes are returned whenever specified, as soon as they are copied.

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1 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 wheter 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.

2 For marine gravity stations, gravity value should be corrected to eliminate effects of ship motion, or this effect should be provided and clearly explained.

Part II

INTERNATIONAL GRAVITY COMMISSION
Special Meeting

Saturday August 5, 1989
Edinburgh, U.K.

An administrative meeting of the International Gravity Commission was held in Edinburgh (U.K.) on the 5th of August 1989.

The main purpose of it was to review the progress made in data collection and validation (activities of the Bureau Gravimétrique International), in establishing IAGBN (the responsibility of W.G. 2), in preparing the next intercomparison of absolute gravimeters (to take place in the fall of 1989 at BIPM), also to see how the newly created working groups (5, 6 and 7) were operating.

Unfortunately, most presidents of the sub-commissions could not attend it, nor the WG 1 and 6 chairmen, which somewhat limited the depth of discussions in some sessions.

We give hereafter the summary program of the session as it was run and reproduce the texts of the presentation which were made available.

In addition to this, the Directing Board of BGI met for one hour on the 8th of August ; the discussion was restricted to setting up the list of the sessions of the 13th meeting of the commission, which will take place in Toulouse, France, in the second week of september 1990 (see special announcement and preliminary program in this bulletin).

I.G.C., Aug. 5, 1989

PROGRAM

9.00 :	Opening, Adoption of Agenda	J.G. Tanner
9.10 :	I.G.C. Report	J.G. Tanner
9.30 :	Reports of the Sub-Commissions	
	- S.C. Western Europe	I. Marson
	- S.C. North Pacific Region	I. Nakagawa
10.10 :	Status of reference networks in the world	C. Morelli G. Boedecker G. Balmino I. Nakagawa
10.40 :	Absolute Apparatuses - Results and Plans	G. Boedecker W. Torge A. Sakuma
11.30 :	Discussions	...
14.30 :	Reports of Working Groups	
	WG 2	G. Boedecker
	WG 5	Ch. Poitevin
	WG 7	H.G. Wenzell
15.30 :	New terms of reference for the Working Groups	Discussion
16.00 :	IAGBN - Review and Discussion	G. Boedecker
16.15 :	Announcement : IGC meeting in Toulouse	J.G. Tanner

16.30 : Adjourn

REPORT OF THE INTERNATIONAL GRAVITY COMMISSION TO THE GENERAL MEETING OF THE INTERNATIONAL ASSOCIATION OF GEODESY

Edinburgh, Scotland
August 3-12, 1989

INTRODUCTION

In 1971, the General Assembly in Moscow adopted the International Gravity Standardization Net, 1971 as the recommended world absolute gravity standard and the reference system to be used by the international geodetic and geophysical community to determine observed gravity values for the purpose of computing gravity anomalies. This network has served the international community well as a global absolute gravity standard and even to-day stands up well to comparisons with recent results obtained by the newer transportable absolute apparatuses. However, new construction for the purpose of economic development has led to the known or suspected destruction of many of its sites - to the extent that concerns have been raised about its status, particularly in Africa, Asia and South America. The International Gravity Commission will complete a review of the situation with respect to access to IGSN sites at Edinburgh with the aim, if necessary, of formulating a plan that will enable absolute standards to be readily accessible to countries of the developing world.

The General Assembly of 1979 in Sydney saw the removal of the International Gravity Bureau from Paris to Toulouse with a revised mandate to act as the operational arm of the International Gravity Commission. Among its responsiilities are the management of a global data base of gravity anomalies and its distribution to the international geodetic and geophysical communities. This has proved to be a difficult task for the Bureau because of limited staff and unexpected turnover of key personnel. Discussion within the Directing Board of the BGI has led to the establishment of an ordered set of priorities for the workload of the Bureau. Some difficulties still remain, however, and other mechanisms to ease the workload of the Bureau must be considered.

ACTIVITIES

(a) Directing Board

The Directing Board of the International Gravity Bureau (BGI) has met once since the last General Assembly (in Paris in conjunction with a meeting of Working Group 5 called by Pr. Boulanger to organize the next comparison of absolute apparatuses). This meeting, which took place in June of 1988, covered a wide range of topics with the working groups and their terms of reference, the proposed International Absolute Gravity Base Station Network (IAGBN) and management of the global data base receiving the bulk of the attention over the two days of the meeting.

At the time of the restructuring of the BGI at Canberra, four working groups were created to provide advice and assistance to the Bureau in meeting its heavy workload. In the discussions at Paris a decision was taken to cancel Working Groups 3 and 4, concerned with world gravity maps and prediction of mean gravity anomalies respectively. Their cancellation was offset by revising the terms of reference of the remaining two working groups and creating three new working groups. The new working group structure of the International Gravity Commission is :

(i) WG1 - Data Processing
R.K. McConnell (Canada) - Chairman

(ii) WG2 - World Gravity Standards
G. Boedecker (FRG) - Chairman

(iii) WG5 - Monitoring of Non-Tidal Gravity Variations
Ch. Poitevin (Belgium) - Chairman

(iv) WG6 - Comparison of Absolute Gravimeters
Yu.D. Boulanger (USSR) - Chairman

(v) WG7 - Computation of Mean Gravity Anomalies
H.G. Wenzel (FRG) - Chairman

Working Group n° 7 was tentative in the sense that the meeting believed there should be discussion with the President of the International Commission for the Geoid before formally adopting the terms of reference. New terms of reference were discussed for the four other working groups (in the case of Working Group 1 (Data Processing) and Working Group 2 (World Gravity Standards) the terms of reference were revised) and will eventually be published in the Bulletin d'Information.

The discussion of IGSN 71 arose near the end of the meeting when some members of the Board expressed strongly their concern for the status of this important international gravity standard in the developing countries, particularly Asia, Africa and South America. This led to the decision to make another attempt through the regional sub-commissions to carry out a detailed assessment of the status of as many stations as possible in this reference system. The Board was also aware that there was a recommendation from Working Group 2, then chaired by Pr. Uotila, that no attempt should be made to re-adjust or re-build ISN 71 because transportable absolute apparatuses could provide a more practical method of maintaining a global reference standard (in time they would undoubtedly replace IGSN 71). WG 2 did recommend, however, that new absolute measurements be tied into IGSN 71 whereever possible.

The Director of the BGI reported the Bureau still experienced difficulties in getting the global data base fully operational because of staff turnover and that the limited number of staff under his direction was having difficulty in meeting its objectives in a timely fashion. The Board re-confirmed that the data base had the highest priority, but recognized that the need for the Bureau to establish and maintain a complete set of data files on each absolute measurement would place an even greater load on the staff. The Board agreed to a meeting in Toulouse to be organized by the Chairmen of WG 1 and 7 to discuss ways of standardizing the approach to evaluating data within the Bureau and to develop and make available to the Bureau software to assist in this function. This meeting was scheduled for 1989, but to date has not taken place.

(b) Working Groups

The reports of the Working Groups are being circulated at this meeting by their respective chairmen. A brief summary only of the salient points of the discussion in Paris is given here for completeness.

WG1 reported delays in its plans to produce a world gravity map using the data base of the BGI, but will try to produce a preliminary version prior to the quadrennial meeting of the IGC in Toulouse during September, 1990.

WG2 has been extremely active in its effort to get the IAGBN underway. Draft standards have been written for IAGBN and a suggested format for presentation of the results of all absolute measurements to the BGI recently circulated. According to the information available at the time of writing observations at recommended sites of IAGBN have already been carried out in Europe, North America and South America.

WG5 reported that its membership has been established and general agreement has been reached on the nature of its activities. Co-ordination with WG2 during the observation of IAGBN was agreed.

WG6 held a special meeting to discuss the forthcoming comparison of absolute gravimeters in Sèvres during the fall of 1989. Pr. Boulanger has reported on the results elsewhere, but to summarize there will be 10 different instruments at five sites during the two campaign. Precise connections will be made between the five sites by colleagues from Europe using several gravimeters to provide a basis for comparing the final results of all instruments. Unsatisfactory results at previous sites, usually the result of poor location, led to the replacement of three of them.

Discussion in connection with WG7 was confined to its terms of reference pending input from the President of the International Commission for the Geoid.

FUTURE ACTIVITIES

The Directing Board will continue to meet every year as agreed at Vancouver. The next meeting will take place at the time of the quadrennial meeting of the IGC during the second week of September, 1990.

The program for the 1990 meeting of the Commission will be discussed in Edinburgh and its agenda published in the Bulletin d'Information in December, 1989. This meeting promises to be both interesting in terms of its technical content and critical in the continued development of the activities of the commission. In this latter context we hope to discuss with the international community the results of our efforts to seek additional help for the International Gravity Bureau. The management of the global data bases under its control is the key to the success of the Bureau within the international community and we can spare no efforts in meeting our commitment to make it the important gravity reference library for the world geoscience community.

J. Tanner
President, I.G.C.

REPORT OF THE SUB-COMMISSION FOR THE NORTH PACIFIC REGION

(Pr. I. Nakagawa)

The president of the Sub-Commission presented a detailed account of the activities of the community in this part of the world :

- international gravimetric connections along the circum-pacific region.
- Japan-China international gravimetric connections.
- the gravity stations of JGSN 75.

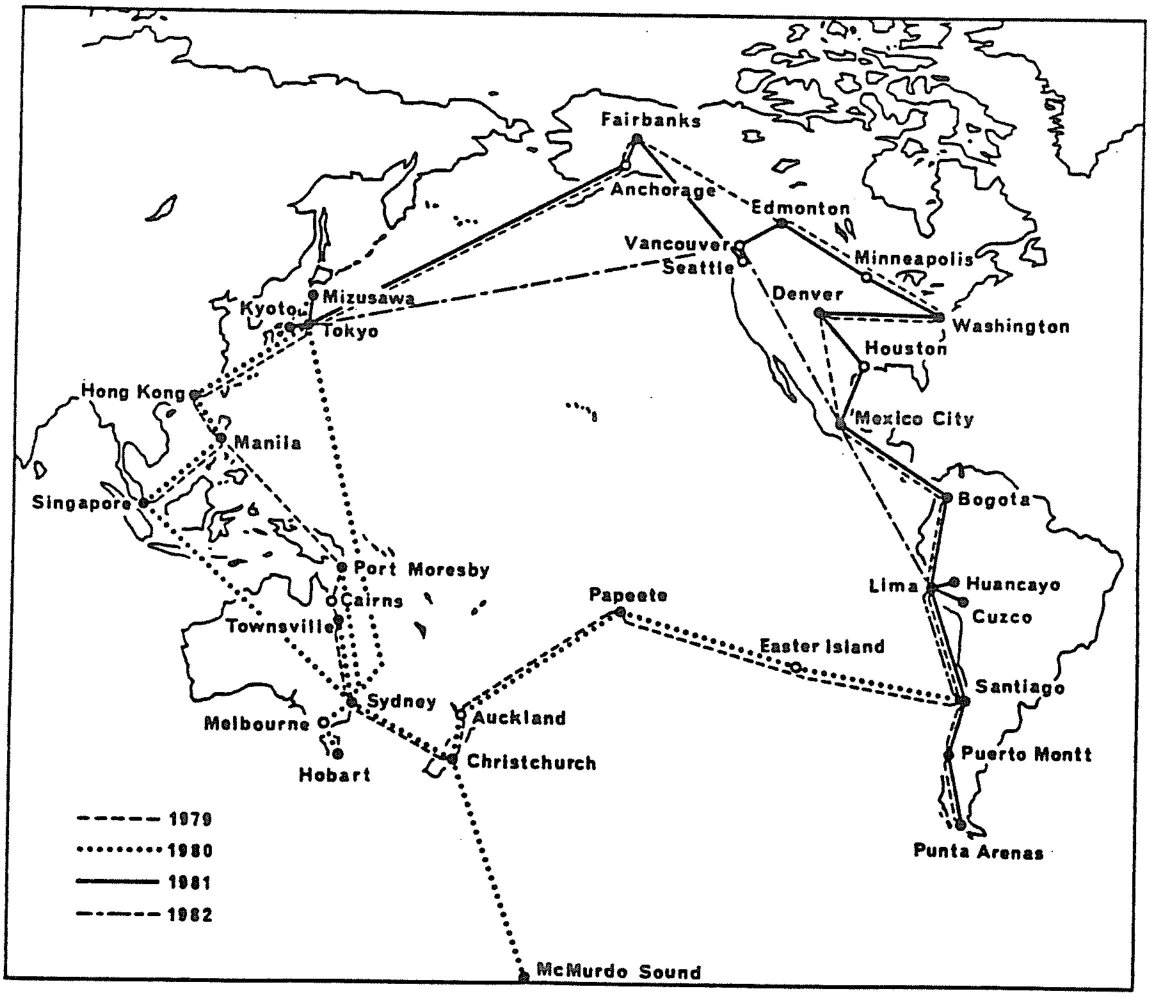
Copies of the hand-outs are reproduced hereafter.

INTERNATIONAL GRAVIMETRIC CONNECTION ALONG THE CIRCUM-PACIFIC REGION

(1979-1982)

			Number of stations	
		IGSN 71	Total stations measured	IGSN 71 stations measured
Tokyo	13159	14	7	3
Mizusawa	13091	0	3	0
Kyoto	13155	2	3	2
Hong Kong	09724	10	4	1
Manila	06050	16	5	1
Singapore	02613	14	7	2
Port Moresby	34697	1	7	3
(Cairns)	38265	3	2	2
Townsville	38296	6	5	5
Sydney	45331	8	6	6
(Melbourne)	45474	17	1	1
Hobart	49027	1	4	4
Christchurch	48732	5	4	1
(Auckland)	45164	4	2	2
Tahiti	37579	10	7	1
(Easter Island)	40779	0	1	0
(Anchorage)	23119	5	3	0
Fairbanks	23147	9	8	4
(Seattle)	15772	10	2	0
(Vancouver)	15793	12	1	1
Edmonton	19233	16	7	4
(Minneapolis)	15443	3	1	0
Washington	11687	22	10	7
Denver	11994	14	8	3
(Houston)	08295	10	1	0
Mexico City	04699	10	8	2
Bogota	00844	5	5	5
Lima	36827	10	8	4
Cuzco	36831	0	3	0
Huancayo	36825	0	6	0
Santiago	44030	4	12	2
Puerto Montt	47612	3	4	1
Punta Arenas	51230	5	7	3
McMurdo Sound	59676	5	6	4
Total		254	168	74

Cities in parentheses show those where gravity measurements were carried out taking the opportunity of transit or technical stopover times of aircraft so far as circumstances permitted.

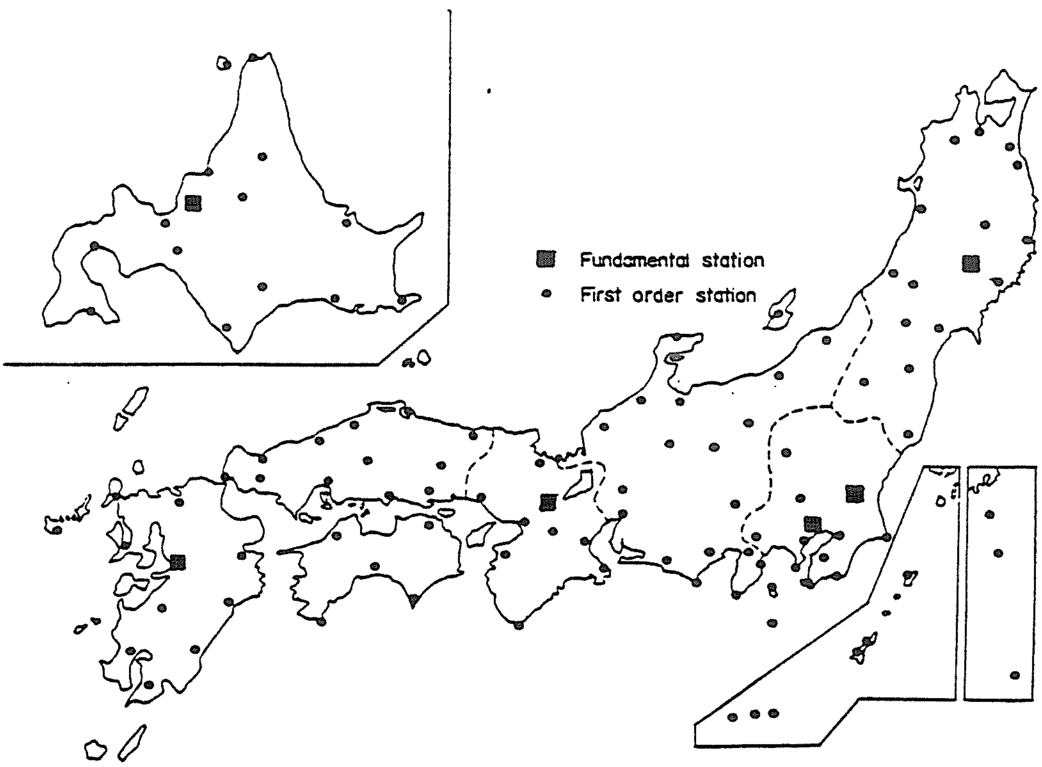


Fairbanks
Anchorage
Edmonton
Vancouver
Seattle
Minneapolis
Denver
Washington
Houston
Mexico City
Bogota
Lima
Huancayo
Cuzco
Santiago
Puerto Montt
Punta Arenas
Easter Island
Papeete
Mizusawa
Kyoto
Tokyo
Hong Kong
Manila
Singapore
Port Moresby
Cairns
Townsville
Sydney
Melbourne
Hobart
Auckland
Christchurch
McMurdo Sound
1979
1980
1981
1982

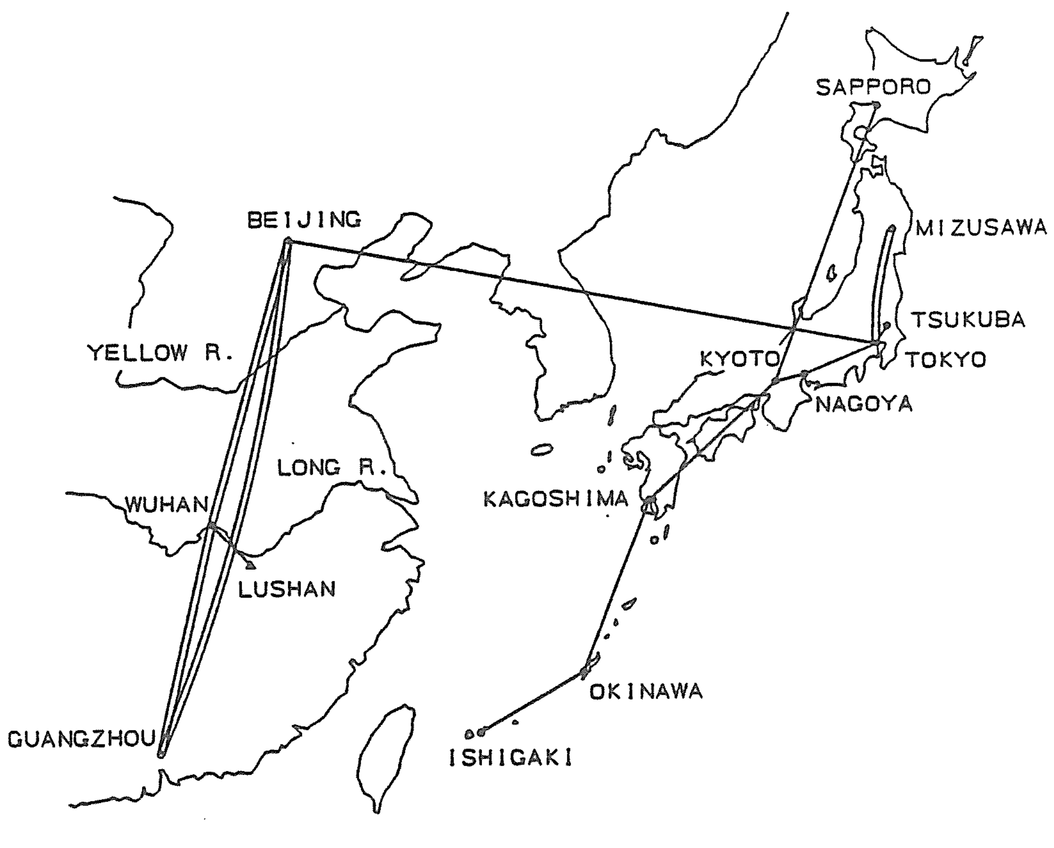
JAPAN-CHINA INTERNATIONAL GRAVIMETRIC CONNECTION

(1985-1986)

		Number of stations	
		Total stations measured	IGSN 71 stations measured
Tokyo	13159	8	3
Mizusawa	13091	5	0
Kyoto	13155	5	4
Tsukuba	13060	2	0
Nagoya	13156	3	0
Sapporo	16631	3	1
Kagoshima	13110	5	1
Okinawa	09667	4	0
Ishigaki	09644	2	0
Beijing	13396	4	0
Wuhan	13304	5	0
Guangzhou	09733	6	0
Lushan	09796	24	0
Total		76	9



Gravity stations of the JGSN 75.


SAPPORO
MIZUSAWA
BEIJING
TSUKUBA
YELLOW R.
KYOTO
TOKYO
NAGOYA
LONG R.
WUHAN
KAGOSHIMA
LUSHAN
OKINAWA
GUANGZHOU
ISHIGAKI

BUREAU GRAVIMETRIQUE INTERNATIONAL

Activity Report

for the period June 1988 - July 1989

(presented by the Director. IGC meeting, Edinburgh - August 5, 1989)

This is an update of the report of activities presented at the June 1988 meeting of the Directing Board of BGI, in Paris.

(a) Data Base Software Development

New Cyber 990 was installed at CNES at the end of 1987. Changeover from NOS/BE to NOS/VE operating system required major softwares to be rewritten. This work was completed in October 1988. The data base and its system were again re-installed on a newer CYBER 992 in December 1988. The graphic language change requires to rewrite many pieces of software, which has been completed for most of it.

The Bureau is looking at the possibility of developing (in house) a new software for the data base management. The main purpose is to allow a faster merging of new sources and to ensure better protection against loss of operational continuity.

(b) Data Collection

The data base to-day contains some 3.6 million point gravity values. The main new sources acquired are listed in Annex 1. It remains more than a quarter million points to be added ; as said above, this is a very slow process due to the characteristics of the present software.
New catalogues have been produced and are available on request :
. General coverage of gravity data per 20 x 20 degrees area
. Index catalogue of data distribution : statistics per degree square, mean value, standard deviation.

(c) African Gravity Project (see Annex 2)

With respect to the African Gravity Project of the University of Leeds, to which BGI contributed, a 5'x5' grid was produced and will be made publicly available in 2 years. Point values will not be released for 10 years but BGI will have access to them for use in validating future acquisitions of data from Africa.

(d) South American Gravity Project

BGI is also involved with the University of Leeds in their South American gravity compilation project on the same basis as the African project. BGI validated with its new validation software (see below) about 60 000 gravity observations over this continent and provided them to the project (to end in spring 1991).

(e) Data Validation (see Annex 3)

An automated software (PFATES) was received from Prof. Wenzell (Univ. of Karlsruhe - previously at IFE, Hannover) which allows a fast first stage editing.
A sophisticated new system (DIVA) for finer data validation using statistical techniques and interactive graphics has been developed by Denis Toustou.
All previously validated data will be revalidated using these two systems.
Data over South America, Spain, Morocco have already been processed.

(f) Requests

The bureau has received 95 requests for data and services over the past year. 32 requests were received in the first six months of 1989. The complete statistics are given in Annex 4.

(g) GEBCO Project

One person had been assigned in 1987 by the Institut Géographique National (I.G.N.) to work on the GEBCO hydrographic project. In addition to the Northern Europe sheet (5-01) published in 1987, BGI has produced the North Atlantic sheet (5-04), the Central Atlantic sheet (5-08), the North Polar sheet (5-17).
The course of this effort is (again) frozen due to a decision by IGN to reduce the BGI staff by one person. The work will very likely be terminated at the IGN St Mandé premises.

(h) Bibliography

Compilation of the gravity bibliography continues. The digitization of the old bibliography, prior to 1980, has also been undertaken. A file is now available on floppy disk.

(i) Participation in ICL/CC5 Activities

The draft of the compilation of data bases and data centers, established by the Institute of Physics of the Earth (Moscow) with the help of BGI, was updated.
Balmino represents the International Gravity Commission on CC5.

(j) 5' x 5' Gravity Map of the World

The Bureau and WG1 members (at GSC) are preparing a 5' x 5' gravity map of the whole world. BGI has already produced the part of the basic grid over land areas (Bouguer anomalies) while GSC has prepared the oceanic part (free-air).

(k) Miscellaneous

- training of students and visitors : data validation procedures, graphics
- computation of a geoid over the straight of Gibraltar area (before the establishment of the International Geoid Service)
- compilation of absolute measurements : difficult (agencies do not answer to our request for data and facts).
- status of IGSN 71 stations : partially established, from reports of European and North-Pacific Sub-commissions (see Annex 5).

(l) Publications

Bulletin d'Information : Dec. 1988 (n° 63)
Bulletin d'Information : June 1989 (n° 64)

Technical Notes :

Barriot, J.P., "Méthodes d'intégration numérique de Cowell - Systèmes du 1er et 2ème ordre - Théorie et implémentation", Technical Note n° 9, March 1989.

Toustou, D., Sarrailh, M., "Chaîne de validation interactive de données gravimétriques DIVA", Technical Note n° 10, April 1989.

Balmino, G., "Enveloppes du champ couvert par un instrument d'observation d'un corps du système solaire (bords de fauchée et empreinte instantanée)", Technical Note n° 11, (in press).

Others :

Balmino G., D. Lamy, M. Sarrailh, D. Toustou, N. Valès : Calcul d'un géoide gravimétrique sur le détroit de Gibraltar, Int. Symp. on a fixed link over the Gibraltar straight, Proceedings, Madrid, 1989 (in press).

Toustou D., Numérisation de la carte GEBCO au Bureau Gravimétrique International, Bull. d'Information de l'IGN, n° 130, 1988.

G. BALMINO
Director, BGI
(July. 25, 1989)

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2. The Completion of the African Gravity Project
3. Data Validation Software
4. Statistics of Requests and Services Provided
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ANNEX 1

DATA COLLECTION (UPDATE)

NEW MAIN SOURCES (> 1000 PTS)

SOURCE:3035002 (2057 PTS)
D.E. AJAKAIYE
GRAVITY DATA IN NORTH-WEST NIGERIA
AHMADU BELLO UNIVERSITY OF ZARIA

SOURCE:3002002 (1425 PTS)
GRAVITY SURVEY IN SOUTH ANGOLA
INSTITUTO NACIONAL DE METEOROLOGIA E GEOFISICA, LISBOA

SOURCE:1999033 (7661 PTS)
ARGENTINA GRAVITY DATA
INSTITUTO GEOGRAFICO MILITAR

SOURCE:3009001 (12661 PTS)
GRAVITY DATA IN CHAD
O.R.S.T.O.M.

SOURCE:3529005 (7238 PTS)
GRAVITY DATA IN SWEDEN
LANTMATERIVERKET (NATIONAL LAND SURVEY)

SOURCE:3516005 (11210 PTS)
GRAVITY DATA IN NORTHERN IRELAND (SURVEY 1952, 1959, 1983)
BRITISH GEOLOGICAL SURVEY

SOURCE:3013004 (2965 PTS)
GRAVITY SURVEY IN BIR TARFANI AREA, EGYPT
UNIVERSITAT DER BUNDESWEHR MUNCHEN
1986

SOURCE:2500023 (1429 PTS)
H.J. GOTZE
GRAVITY DATA IN THE EASTERN ALPS
INSTITUT FUR GEOPHYSIK DER TECHNISCHEN UNIVERSITAT CLAUSTHAL
1981

SOURCE:6522005 (18108 PTS)
G. STRANG VAN HEES
NAVGRAV CRUISE IN NORTH SEA
TECHNISCHE HOGESCHOOL DELFT
1986

SOURCE:6522004 (21529 PTS)
G. STRANG VAN HEES
CRUISE IN NORTH SEA
TECHNISCHE HOGESCHOOL DELFT
1979

SOURCE:3043005 (1070 PTS)
GRAVITY SURVEY OF G.P.C. AREA, SUDAN
G.P.C. GENERAL ADMINISTRATION OF EXPLORATION AND PRODUCTION
1984

SOURCE:3043006 (1498 PTS)
BLOCK B GRAVITY DATA, SUDAN
CFP-TOTAL
1981

SOURCE:6313039 (2223 PTS)
CRUISE OF TAKUYO VESSEL IN THE WESTERN PART OF DAITO RIDGE, OCT-NOV, 1983
JAPAN OCEANOGRAPHIC DATA CENTER, TOKYO
1987

SOURCE:6313040 (2097 PTS)
CRUISE OF TAKUYO VESSEL IN THE EASTERN PART OF DAITO RIDGE
DEC 1983-JAN 1984
JAPAN OCEANOGRAPHIC DATA CENTER, TOKYO
1987

SOURCE:6313041 (1234 PTS)
CRUISE OF TAKUYO VESSEL OF DAITO RIDGE
JAPAN OCEANOGRAPHIC DATA CENTER, TOKYO
1987

SOURCE:6313042 (1515 PTS)
CRUISE OF TAKUYO VESSEL OF OKINAWA TROUGH, JUN-JULY, 1984
JAPAN OCEANOGRAPHIC DATA CENTER, TOKYO
1987

SOURCE:6313043 (4421 PTS)
CRUISE OF TAKUYO VESSEL OF THE NORTHERN PART OF OKINAWA TROUGH, OCT-NOV, 1984
JAPAN OCEANOGRAPHIC DATA CENTER, TOKYO
1987

SOURCE:6313044 (3903 PTS)
CRUISE OF TAKUYO VESSEL OF MINAMI KOHO SEAMOUNT
JAPAN OCEANOGRAPHIC DATA CENTER, TOKYO
1987

SOURCE:6313045 (3973 PTS)
CRUISE OF TAKUYO VESSEL, WEST OF KAZAN RETTO
JAPAN OCEANOGRAPHIC DATA CENTER, TOKYO
1987

SOURCE:3515009 (1021 PTS)
A. SCHLEUSENER - W. TORGE - H. DREWES
THE GRAVITY FIELD OF NORTHEASTERN ICELAND
JOURNAL OF GEOPHYSICS, VOL. 42, P. 27-45, 1976
1987

SOURCE:6508005 (5758 PTS)
O.B. ANDERSEN - K. ENGSAGER
SURFACE SHIP GRAVITY MEASUREMENTS IN DANISH WATERS 1970-1975
GEODAETISK INSTITUTS SKRIFTER 3. RAEKKE BIND XLIII, COPENHAGEN 1977
1987

SOURCE:6512012 (2533 PTS)
A. DEHGNANI
SEA GRAVITY OBSERVATIONS WITH KSS30 SEA GRAVITY METER ON BOARD OF SHIP VALDIVIA IN THE NORTH SEA, 1983
INSTITUT FUR GEOPHYSIK, UNIVERSITAT HAMBURG
1987

SOURCE:3206009 (17803 PTS)
D. BLITZKOW
GRAVITY DATA IN BRAZIL
INSTITUTO ASTRONOMICO E GEOFISICO, UNIVERSIDADE DE SAO PAULO
1985

SOURCE:6522008 (1829 PTS)
G.L. STRANG VAN HEES
SEA GRAVITY DATA AROUND INDONESIA FROM SNELLIUS II EXPEDITION
AFDELING DER GEODESIE, TECHNISCHE HOGESCHOOL DELFT
1985

SOURCE:3531013 (84361 PTS)
GRAVITY DATA IN ENGLAND AND WALES, SURVEY 1950-1983
BRITISH GEOLOGICAL SURVEY
1984

SOURCE:3031006 (1314 PTS)
A. BELLOT
ETUDE GRAVIMETRIQUE DU RIF PALEOZOIQUE : LA FORME DU MASSIF DES BENI-BOUSERA
CENTRE GEOLOGIQUE ET GEOPHYSIQUE, U.S.T.L. MONTPELLIER, FRANCE
1985

ANNEX 2

THE COMPLETION OF THE AFRICAN GRAVITY PROJECT

The African Gravity Project: Academic, Government and Commercial Data Integrated for New Map of Continent and Margins

The sedimentary basins of Africa appear to have a close spatial and temporal relation to the progressive break-up of the Gondwanaland supercontinent. The early Permo-Triassic to Jurassic basins of East and southern Africa relate to the opening of the Indian ocean; the Cretaceous to early Tertiary rifting of West and Central Africa relate to the differential opening of the Central and South Atlantic oceans; and the Tertiary to Recent rifting of East Africa relates to the embryonic oceanic opening of the Red Sea and Gulf of Aden. These intracontinental rift basins, together with the cratonic sag basins and the continental margin basins which were once intracontinental rifts, make Africa important for the study of extensional processes.

The gravity field

The subtle variations of the Earth's gravity field have long been used as a tool to map the subsurface structure of sedimentary basins. Gravity is sensitive to changes in sedimentary thickness and lateral lithology as well as structural deformation within basins and the occurrence of diapiric salt structures—all features that are useful to map for the delineation of basin morphology and structural traps. On a larger scale, the gravity field is used to investigate the isostatic crustal response to the presence of the basin as well as understanding the flexural strength of the underlying lithosphere and the thermo-mechanical evolution of the basin.

The African Gravity Project (AGP) was formulated in mid-1985 by geophysicists Derek Fairhead of the University of Leeds (U.K.) and Tony Watts of Lamont. Despite the oil crisis of 1986, 16 companies finally joined the project.

All available private and public gravity data

The goal of AGP is 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 is managed by the University of Leeds Industrial Services (ULIS), Ltd. and it is headed up by Fairhead and Watts. Since gravity, along with aeromagnetics, provide a cost-effective means of preliminary evaluation of basins prior to seismic studies, the compilation is both opportune for the oil industry's exploration requirements and for advancing in a more academic way our understanding of how rift-type sedimentary basins evolve in a continental setting. Moreover, by studying Africa as a whole, rather than on a country by country basis, it will be possible to assess structures on a continent-wide scale.

The project has brought together the expertise of researchers in Leeds who have a long history of gravity acquisition within Africa with scientists at Lamont, who have extensive experience of marine gravity data acquisition offshore Africa. AGP initially utilized the extensive academic data bases compiled by the gravity groups at Lamont-Doherty and Leeds and integrated them with the data bases made available by the Defense Mapping Agency (DMA, U.S.A.), the Bureau Gravimetrique International (BGI, France) and the Institut Francais de Recherche Scientifique pour le Development en Cooperation (ORSTOM, France). These data were substantially augmented by proprietary data from sponsoring, non-sponsoring oil companies, national hydrocarbon groups in Africa and geophysical contractors.

Immense reprocessing task

The task of reprocessing these diverse data sets was immense. The land data benefited from a long history of establishing national and international gravity base station networks to which the

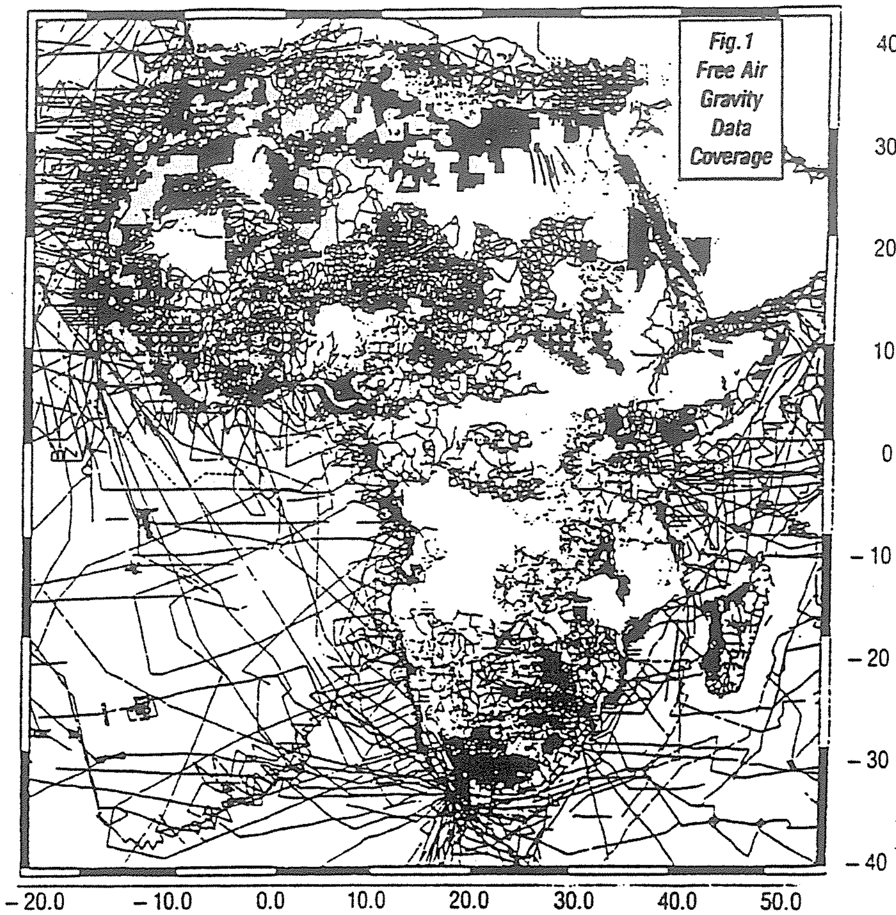


Fig. 1 Free Air Gravity Data Coverage

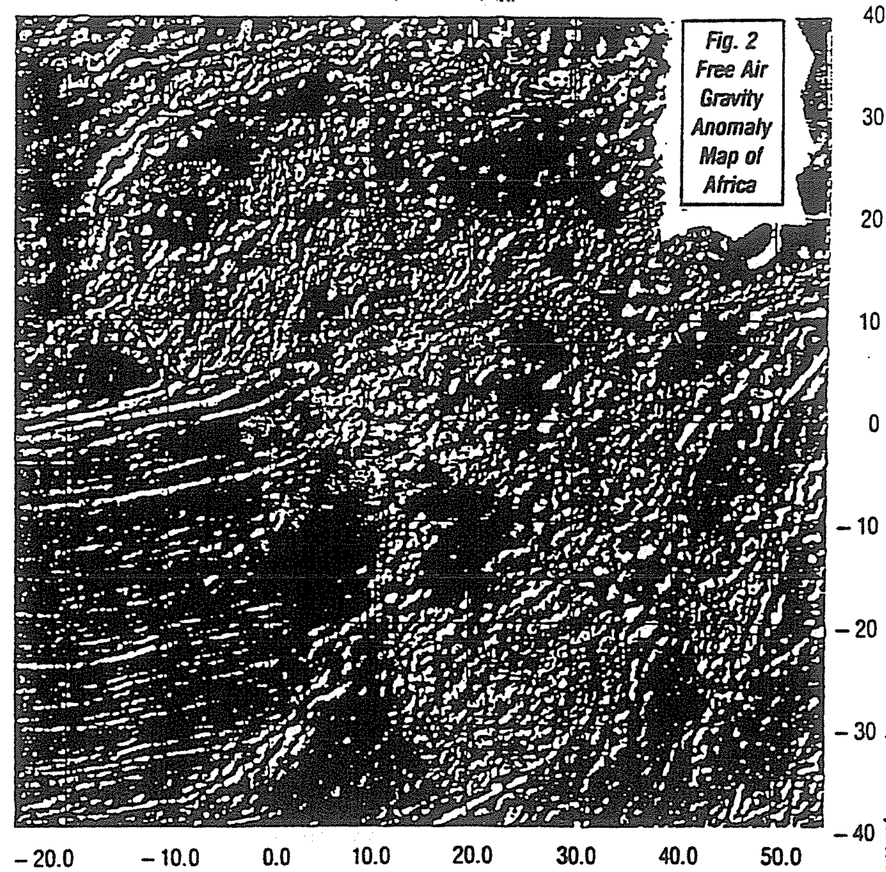
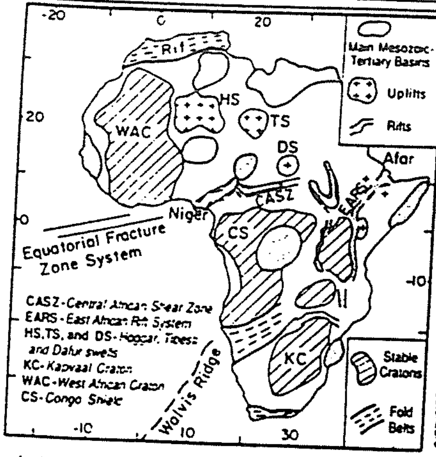


Fig. 2 Free Air Gravity Anomaly Map of Africa



Pat Calenzario

majority of surveys were tied. All data were reprocessed to the IGSN 71 datum and gravity anomaly field values derived using the IGF67. The marine data were reprocessed using the Lamont-Doherty shiptrack cross-over-error (COE) analysis software to correct surveys for base station misties (DC corrections) and time-dependent drift errors. To generate a regular 5′ by 5′ grid of gravity anomaly values for Africa, the weighted means position and value were determined within 2.5′ x 2.5′ "bins."

The data coverage (Fig. 1) was significantly improved by the inclusion of the commercial data, especially in the all near-shore regions of Africa as well as within Morocco, Algeria, Tunisia, Libya, Egypt, Sudan and Somalia.

Better understanding of tectonic history

The irregular spaced weighted values were then interpolated onto a regular 5′ x 5′ grid using the minimum curvature technique. For confidentiality reasons Fig. 2 shows a shaded relief contour map of the free air gravity anomaly field decimated to a 15′ x 15′ grid. This map can be expected to resolve features in the gravity field with wavelengths down to about 50 km with an accuracy of better than 1 mGal. While such a broad representation of the "point" gravity anomaly measurements may not be very useful for detailed studies of shallow structure in basins, it is useful for understanding the intermediate wavelength gravity field—especially the gravity anomalies associated with rifting and crustal separation, sedimentary loading, volcanism and mid-plate swell formation.

Coastline "edge effect"

A striking feature of the gravity anomaly map is the apparent delineation of the African coastline by the free-air gravity anomaly positive-negative couple. This "edge effect" anomaly has traditionally been interpreted as the result of a juxtaposition of thick continental crust against thin oceanic crust. However, the presence of other positive-negative couples sub-parallel to the main edge effect in Africa anomaly suggests a more complex structure. Off the Niger margin, where in Tertiary time a thick clastic wedge progrades seaward, the edge effect anomaly follows the trend of the thickest sediment accumulations. This observation can be explained if the positive of the edge effect is the result of sediment loading, with higher than usual values indicating a relatively cold, rigid, lithosphere and lower values a hot, weak lithosphere. The landward positive-negative anomaly couple in this case marks the edge of the basin in the absence of the sedimentary wedge—a sort of paleo shelf edge.

Fracture zone linked to rift systems

The edge effect appears to be cut by an ESE-WNW trending anomaly associated with the equatorial fracture zone and a link with the west and central African rift systems. The positive-negative anomaly of the fracture zones are interpreted by Watts and Fairhead as an isostatic edge effect that arises from the juxtaposition of relatively young and old oceanic lithosphere. The intense negative anomalies of the cental African rift, however, are interpreted as a down-dropping of crustal blocks in narrow pull-apart basins that formed as a result of shearing of the African continent. The age of the faulting along the rift is Cretaceous to early Tertiary in age and corresponds to a time of rapid sea-floor spreading between Africa and South America. The fact that the two belts of gravity anomalies appear continuous across the edge effect is intriguing and suggests that differential plate movements between the Central and South Atlantic oceans has influenced the stratigraphic development of basins in the continents. Geological and geophysical studies of these Cretaceous basins indicate a geometry of shear tectonics extending into Africa and terminating as extensional basins which are oriented perpendicular to the shear direction. The multi-phase development of these basins testifies to long and complex interaction with the opening evolution of the equatorial Atlantic.

Gravity and topography

The topography of Africa is dominated by a "basin and swell" architecture which has been attributed by previous workers to dynamic effects in response to some form of convection in the underlaying mantle. In contrast to other cratons, Africa has remained relatively fixed with respect to the hot-spot frame of reference making it an ideal locality for the study of epeirogenic movements. A critical test is the relationship between gravity and topography over the Hoggar, Dafur and Tibetsi swells in north Africa. Preliminary studies of the data in Fig. 1 show that these features are associated with slopes in the gravity field of about −20 mgal/km which in other parts of the world has been attributed to some form of dynamic compensation.

"Side-driven" stresses

The African continent has clearly also been affected by "side driven" extensional and compressional stresses as evidenced in the intense gravity anomalies that are observed over Morocco and East Africa. The Tertiary to Recent East African rift system (Fig. 2) is delineated by the free air gravity anomaly where the negative anomaly resides over the rift basins and positive anomaly over the rift shoulders reflecting the topographic relief of the rift system. This anomaly relationship allows a clear delineation of the rift system extending into Africa from the Afar triple junction—the other two branches of which form the Gulf of Aden-Carlsberg ridge and Red Sea rift systems, which are at more advanced stages of oceanic basin development than the East Africa rift system. Over Morocco, on the other hand, the negative anomaly over the Rif foreland basin and the positive anomaly over the Rif mountains reflects the effects of flexural downwarping and emplacement of thrust/fold and buried loads that accompany compression. A similar positive-negative gravity anomaly couple occurs over the Betic mountains and Guadacuvila basin of southern Spain. Both belts of gravity anomalies follow the Betic-Atlas mountain belt which formed by convergence of the African and Eurasian plates during the Tertiary.

Thermal and mechanical evolution

The project has spawned a follow-up Basin Analysis of Africa Project. Although smaller in scope, this aims to examine the thermal and mechanical evolution of African basins. Because of the confidential nature of the commercial data used, the data cannot be immediately released into the public domain. However, the products of the project will be commercially available next year and the 5′ x 5′ grids will come into the public domain no later than 1998.□

The AGP is sponsored by Agip, Amoco, Arco, BHP, BP, Chevron, Conoco, Exxon, Mobil, Marathon, Phillips, Placid, Shell, Texaco, Total and Unocal.

ANNEX 3

DIVA
DIRECT INTERACTIVE VALIDATION
SOFTWARE OF GRAVITY DATA

D. TOUSTOU

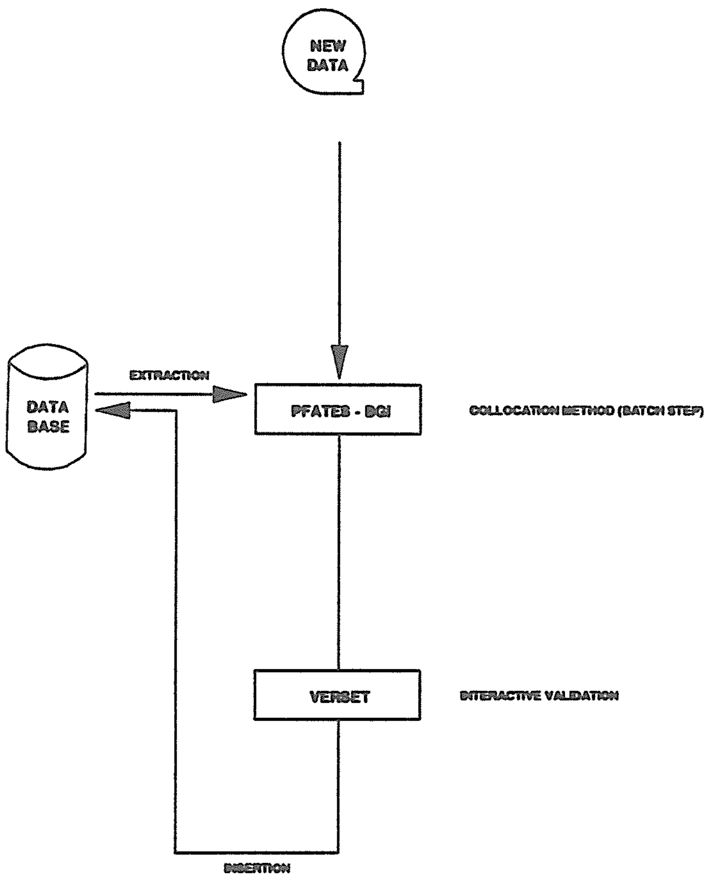
This software, created and written at BGI, is now completely operational.

With DIVA, any user, being guided step by step by interactive menus, can process any gravity data set.

This software runs in interactive mode on a Tektronix Intelligent Terminal (4125 or 4225) and makes extensive use of its high definition graphic capabilities. It is written in Fortran 77 (the code is 15 000 lines long) and is implemented on a CDC Cyber 992 ; the graphic library used is IGL/PLOT10 of Tektronix.

After a batch step (PFATES) which computes by collocation the predicted signal at each measurement point from the neighbouring data, a big interactive module (VERSET) allows to correct the data. This step requires the longest interactive session, but an experienced user usually can validate about 5000 to 7000 points per day.

General Scheme



First Step : Prediction by collocation (PFATES-BGI)

This program comes from the Institut für Erdmessung, University of Hannover (F.R.G.) ; it was designed by Dr. H.G. Wenzell who provided it to BGI.

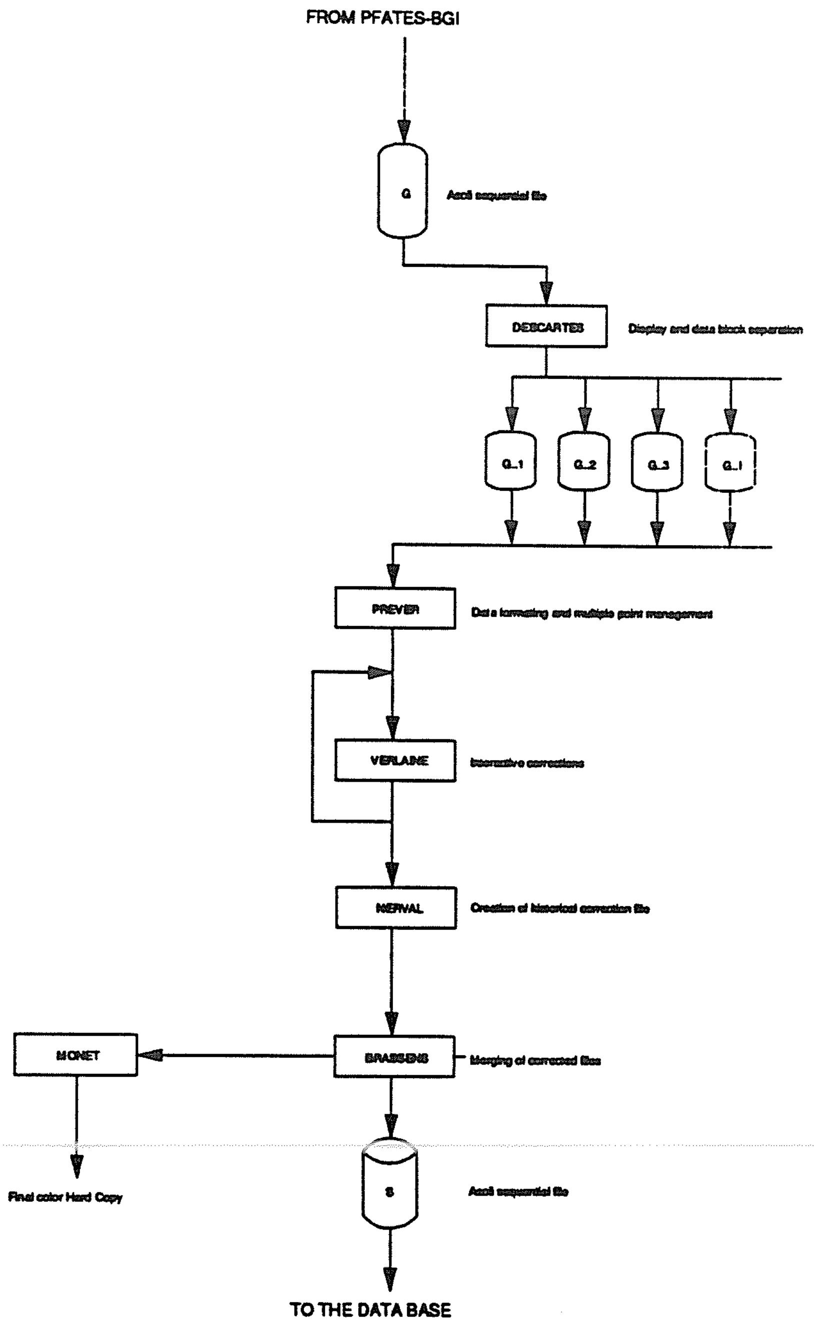
The program PFATES carries out a check of point gravity data by comparison of observed Bouguer anomalies with Bouguer anomalies predicted from surrounding sample points, and makes use of a collocation technique.

It consists of several steps : (1) A covariance function is derived from the data, or an empirical one is selected by the user ; (2) a trend is estimated by a moving coverage performed over a distance not larger than twice the correlation length ; (3) the closest points to each data location, up to a selected number, are used for the least squares prediction.

A point is declared doubtful if the difference between the observed and predicted values exceeds an error limit (usually fixed to 6 milligal) and twice the prediction error.

Second step : Interactive validation VERSET

Breakdown structure



The interactive validation softwares VERSET is built around the Verlaine module.

After a display of the gravity observations coverage and an interactive block decomposition of the data set for better performances (it is better to work on 1000 to 1500 points at a time) - which is performed by the module Descartes, the data are reformatted through the module Prever. The Verlaine module puts at the user's disposal by means of a menu, four interactive tools.

MAIN MENU		
SHADED COVERAGES	(1)	Geographical display upon selection of various functions of the data (e.g. anomaly) with colored histogram. Apart from longitude and latitude, all the station parameters can be corrected.
POINT CLUSTER	(2)	Simultaneous displays of the point cluster of which base parameters have been chosen by the user, and geographical representation, so as to study correlations (by interactive definiton of polygons). Validation flags can be changed.
LEVEL AND TRIANG.	(3)	After triangulation, display of colored maps with contour lines and stations. Possibility to change the validation flag of points with new display and new partial prediction around the modified points.
GRADIENT & TRIANG.	(4)	Same as above, but colors are assigned depending on the gradient.
DATA COVERAGE	(5)	Display of the data coverage with different symbols for each source and list of source references.
END OF CORRECTIONS	(6)	

ANNEX 4

STATISTICS OF REQUESTS AND SERVICES PROVIDED

1988 BGI DATA RETRIEVAL - SUMMARY OF EXTERNAL REQUESTS

G-DATA SETS Requesting org./XX (XX = MT or DK)**	INDIVIDUAL G-Values p = point m = mean	SATELLITE ALTIMETRY DATA				TOPO. DATA MEAN ALT. (GRIDS)	MAPS CATALOGUES	IGSN71 Microfiches	Miscellaneous
		Obs.	Grid	Mean Val.	Misc. + Bath				
BANDA (SP)/1MT	ANTOINE (SA) m/1MT	HAXBY (USA)/1MT				BONVALOT (F)/1MT	AGIP (IT)	COKER (NIG)	BENOIT (F)
BONVALOT (F)/1MT	ABG. SEMCA (F)/p	D'OUZOUVILLE (FIDJI)/2MT				ORSTOM (F)	COBBOLD (F)	DALADIER (F)	BGS (UK)
CHEVRON (USA)/1MT	DARE (UK) m/1MT					RAPP (USA)	RAPP (USA)	EGLOFF (FRG)	BOULANGER (USSR)
CONNARD (USA)/1MT	LGIT (F) p							ESNOULT (F)	CHEVALIER (UK)
DODO (CH)/1MT	LIETARD (F) p							FOURGASTIE (F)	EXXON (USA)
HEHL (FRG)/2MT	MERCIER (F) m/1MT							GENAVIR (F)	IGN (SP)
HUCH (FRG)/1MT	POUPINET (F) p							GEOL.SURV. DPT (NIG)	JONES (UK)/1MT
KADIR (USA)/1MT								HUGILL (UK)	LEGOUIC (F)
KLEYVEGT (SA)/1MT								JOLIVET (F)	LEVALLOIS (F)
LAHMEYER (CH)/1MT								LEVALLOIS (F)	LHUILLIER (F)
LYON-CAEN (F)/1MT								MAKRIS (FRG)	PAULSON (UK)
PLAUMANN (FRG)/1MT								RVS (UK) 4	PLAUMANN (FRG)
TORRES (POR)/1MT								TOTAL (F)	RAPP (USA)
VIGNERESSE (F)/1DK									RICARD (F)
WARSI (KUW)/1MT									UNNIKRISHNAN (IND)
ZILINSKI (USA)/1MT									USNAVY (USA)
									VONSTROKRICH (AUST)
									WARSI (KUW)
16 requests (15 MT, 1 DK)	7 requests (3MT)	2 requests (3 MT)				3 requests (1 MT)	3 requests	13 requests	19 requests (1 MT)

TOTAL : 63 REQUESTS (24 MT and 1 DK)

**MT : Magnetic Tape, DK : Diskette

1989 BGI DATA RETRIEVAL - SUMMARY OF EXTERNAL REQUESTS
January to July 1989

G-DATA SETS Requesting org./XX (XX = MT or DK)*	INDIVIDUAL G-Values p = point m = mean	SATELLITE ALTIMETRY DATA				TOPO. DATA MEAN ALT. (GRIDS)	MAPS CATALOGUES	IGSN71 Microfiches	Miscellaneous
		Obs.	Grid	Mean Val.	Misc. + Bath				
BYAMUNGU (SA)/1MT	LARROQUE (F) m	BRETTERBAUER (RFA)/ 1MT				DIAMENT (F)/2MT	LEWIS (USA)	BOUVIER (F)	CHEVALIER (UK)
FLEITOUT (F)/1MT	OLIVIER (CM) m	WEBER (F)					MORRIS (UK)	CHENOT (F)	DELFRATE (F)
HEIN (RFA)/1MT	PLAUMANN (RFA) m						KIENIEWICZ (USA)	HOEL (UK)	Div. Topo RABAT (MAR)/1DK
LEGELEY (F)/1DK	ZBINDEM (F) p						THOMAS (RFA)	JOKAT (RFA)	MARCHAC (F)
LE PICHON (F)/1MT							TOUZOT (F)	KLETSAS (UK)	MOYNOT (F)
								LARROQUE (P)	PALMIERI (IT)
								LOOWICK (AUST.)	ROBRES (UK)
								MELCHIOR (BEL)	
5 requests (4 MT, 1 DK)	4 requests	1 request (1 MT)				1 request (2 MT)	5 requests	9 requests	7 requests

TOTAL FOR 6 MONTHS : 32 REQUESTS (7 MT and 2 DK)

*MT : Magnetic Tape, DK : Diskette

ANNEX 5

IGSN 71 : A PARTIAL STATUS REPORT

STATUS OF IGSN71 STATIONS ESTABLISHED BY THE SUB-COMMISSION FOR WESTERN EUROPE

COUNTRIES	O.K.	O.K. but DOUBTFUL	OBSOLETE	DESTROYED	CANCELLED (reconstruction)	CANCELLED	TOTAL
ITALY		1	5	18			24
BELGIUM	2		1				3
SWEDEN	13				2	3	18
DENMARK	1						1
TOTAL	16	1	6	18	2	3	46

STATUS OF IGSN71 STATIONS ESTABLISHED BY THE SUB-COMMISSION FOR THE NORTH-PACIFIC REGION

COUNTRIES	O.K.	O.K. but DOUBTFUL	OBSOLETE	DESTROYED	CANCELLED (reconstruction)	CANCELLED	TOTAL
JAPAN	13	1	1	18			33
HOBART (AUSTRALIA)	1						1
PORT MORESBY (PAP.N.GUIN)				1			1
CHRISCHURCH (NEW ZEAL)	1			3			4
PUNTA ARENAS (CHILE)	3	2		3			8
MAC MUROOSOUND (ANTARTICA)	5						5
BOGOTA (COLOMBIA)	6			1			7
ANCHORAGE (U.S.A.)	3						3
PAPEETE (TAHITI)		1					1
SINGAPORE	2			12			14
MALACCA (MALAYSIA)	1						1
MANILLA (PHILIPINES)	7	1		3			11
MEXICO CITY	4	3		2			9
HONG KONG	5	3		1			9
FAIRBANKS (U.S.A.)	4	1					5
HOUSTON (U.S.A.)	5	1					6
WASHINGTON (U.S.A.)	10						10
VANCOUVER (CANADA)	4	1					5
EDMONTON (CANADA)	8		1				9
LIMA (PERU)	8		1				9
CAIRNS (AUSTRALIA)	3						3
TOWNSVILLE (AUSTRALIA)	4		1	1			6
PUERTO MONA (CHILE)	2			2			4
SANTIAGO (CHILE)	3	1		1			5
VALPARAISO (CHILE)	1	1		1			3
AUCKLAND (AUSTRALIA)	2		2				4
MELBOURNE (AUSTRALIA)	7		9				16
SIDNEY (AUSTRALIA)	4	1		3			8
28 COUNTRIES	114	19	16	52			201

Status Report on the "International Absolute Gravity Basestation Network"

by G. Boedecker, Chairman IGC - WG2

This is the continuation of the Status Report 1986 (BOEDECKER/FRITZER 1986).

The possibility of a new absolute world gravity network was discussed at the beginning of the 1980s within IGC-WG2 under its chairman Prof. Uotila. From 1983 to 1987 additionally SSG 3.87 investigated this subject. One result was the above mentioned report. At the General Assembly of the International Association of Geodesy in 1987 the activities of SSG 3.87 were summarized in a report (BOEDECKER 1987). As a result of this investigation, the IAG recommended to realize the 'International Absolute Gravity Basestation Network (IAGBN)' on the basis of the studies of SSG 3.87; cf. resolution no. 5 (AIG 1988). The activities of SSG 3.87 ceased and the resolution requested the ICG to coordinate the works. The IGC made it part of the duties of WG2, cf. "Terms of Reference BGI WG2 - World Gravity Standards" as of June 1988 (BGI 1988).

Since 1987 WG2 performed the following activities with respect to IAGBN:

In the course of standardization, "Absolute Gravity Observations Data Processing Standards and Station Documentation" were developed and published (WG2 1988). These cover rules for station documentation and absolute observations data processing standards such as light travel time correction, earth tides reduction, earth rotation changes (including polar motion) reduction, air pressure reduction, height reference.

Recently, since 1988, a discussion is underway among the members of WG2 and BGI on "Absolute Gravity Observation Documentation Standards", that are also of importance for the observations at IAGBN stations. The discussion is in its final stage and the resulting guidelines will be published soon.

Most important at this stage was the preparation of IAGBN (A) station sites. Included in this report are the station descriptions of the following stations:

Penticton (Canada)
Yellowknife (Canada)
Shefferville (Canada)
Tucson (USA)
Fort Davis (USA)
International Falls (USA)
Rolla (USA)
Great Falls (USA)
Nuuk (Godthåb) (Greenland)
Sta. Elena Uairen (Venezuela)
Brasilia (Brazil)
Tandil (Argentina)
Sodankylä (Finland)
Wettzell (Fed. Republic of Germany)
Antananarivo (Madagascar)
Nanning (China)
Beijing (China)

All station sites are generally close to the locations originally proposed and have been selected after local reconnaissance. As to the US stations, these have to be considered as a preliminary selection out of the US national net. At all of these stations, sites have been prepared and absolute gravity observations have been carried out with at least one instrument.

Of the originally proposed station list quite a number have also been observed or are in different stages of preparation:

Madrid (Spain): Station site has been selected at the geodynamic station of "Valle del los Caídos" and observations have been carried out. Station description will be available soon.

Bamako (Mali) and Tamanrassat (Algeria): Local reconnaisance has started.

Moscow - Ledovo (USSR): Station existing and observations performed, release of description sheet announced.

Perth/Yaragadee (Australia): Local reconnaissance started.

Alice Springs (Australia): Local reconnaissance ready.

Orroral (Australia): Station site prepared.

Syowa (Antarctica): Station site under preparation.

Stations which will be very difficult to achieve include those in remote Sibiria, Kerguelen, Midway and Arabia; for the rest there are slight indications that they may be realized within the next years, but still need strong efforts.

The primary goals of WG2 with respect to IAGBN to be promoted in the near future are:

- preparation of remaining station sites
- absolute instruments comparisons at IAGBN (A) stations
- synchronization of observations
- connection of IAGBN stations to other gravity reference stations in the area like IGSN71
- geometric control by space methods.
- guidelines for observation data bank
- collection of station descriptions for IAGBN (B)
- observation data flow to BGI

Literature

AIG: IAG-Resolution no. 5, Bull. Geod. vol. 62, no. 3,2 (The Geodesist's Handbook 1988), pp. 280/281; Paris 1988

BGI: Terms of Reference BGI Working Group 2 - World Gravity Standards, as revised June 24, 1988, BGI - Bulletin d'Information, no. 63, p. 29; Toulouse 1988

Boedecker, G.: Report on the Activities of SSG 3.87, Development of a New World Absolute Gravity Network. Travaux de l'AIG, tome 28, pp. 288 - 290, Paris 1988

Bodecker, G., Fritzer, T.: Int. Ass. of Geodesy, SSG 3.87, International Absolute Gravity Basestation Network Status Report March 1986, Veröffentlichungen der Bayer. Kommission f. d. Internationale Erdmessung, Astronom.-Geod. Arbeiten Nr. 47, München 1986

WG2: International Absolute Gravity Basestation Network (IAGBN) - Absolute Gravity Observations Data Processing Standards & Station Documentation, BGI - Bulletin d'Information no. 63, pp. 51 - 57, Toulouse 1988

International Absolute Gravity Basestation Network (IAGBN)

Station Location: Penticton, BC	Country: CANADA

φ = 49.3208°N	λ = 240.3811°	H = 562 m	g = 980.7650216 Gal

Overview / Access / Outside View / Topo Map

See attached

Access can be by road to Penticton or by air. The station is then 20 km South of the city.

Remarks / Station Identity / Contact

Station number 990988

Detailed Sketch (North? Station Marker?) / Photograph

See attached.

A "brass screw" marks the location of absolute gravity observation.

Date / Author

STATION NO.

9909-88

NUMERO DE STATION

CANADIAN GRAVITY STANDARDIZATION NET
RESEAU CANADIEN DE NORMALISATION GRAVIMETRIQUE

REVISED

08/88

REVISE

NAME
NOM PENTICTON

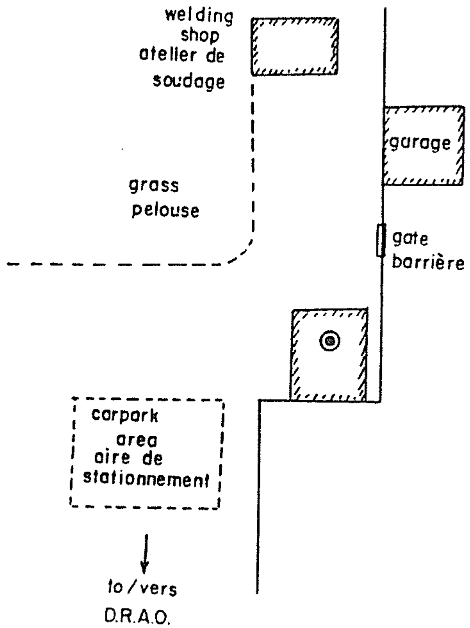
PROVINCE BRITISH COLUMBIA
COLOMBIE-BRITANNIQUE

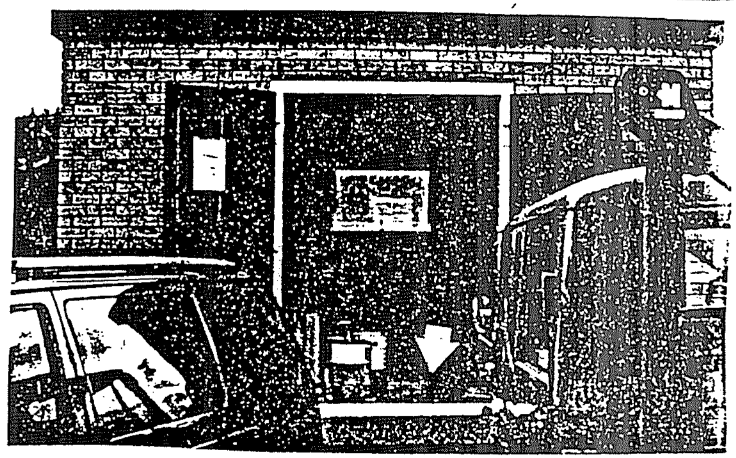
RESTRICTIONS PRE-ARRANGE ENTRY WITH DIRECTOR OF D.R.A.O.

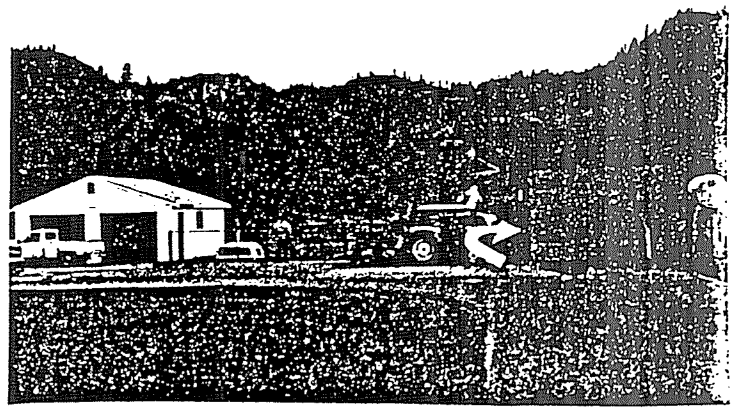
PLANIFIER L'ENTREE AVEC LE DIRECTEUR DE L'OBS-ERVATOIRE.

The station is located at the Dominion Radio Astronomical Observatory which is approx. 20km S of the town of Penticton. The station is situated in the oil products building, on a raised concrete floor and in the center of the building. The station is monumented with an aluminum disc.

La station est située à l'Observatoire fédéral de radioastronomie, qui est à environ 20km S de la ville de Penticton. Elle se trouve dans le bâtiment des produits pétroliers, sur un plancher de béton surélevé au centre du bâtiment. La borne-repère de la station est un disque d'aluminium.







EARTH PHYSICS BRANCH
DEPARTMENT OF ENERGY, MINES AND RESOURCES

DIRECTION DE LA PHYSIQUE DU GLOBE
MINISTERE DE L'ENERGIE, DES MINES ET DES RESSOURCES

International Absolute Gravity Basestation Network (IAGBN)

Station Location: Yellowknife, NWT | Country: CANADA

φ = 62.4700°N | λ = 245.5600° | H = 205 m | g = 982.0027567 Gal

Overview / Access / Outside View / Topo Map

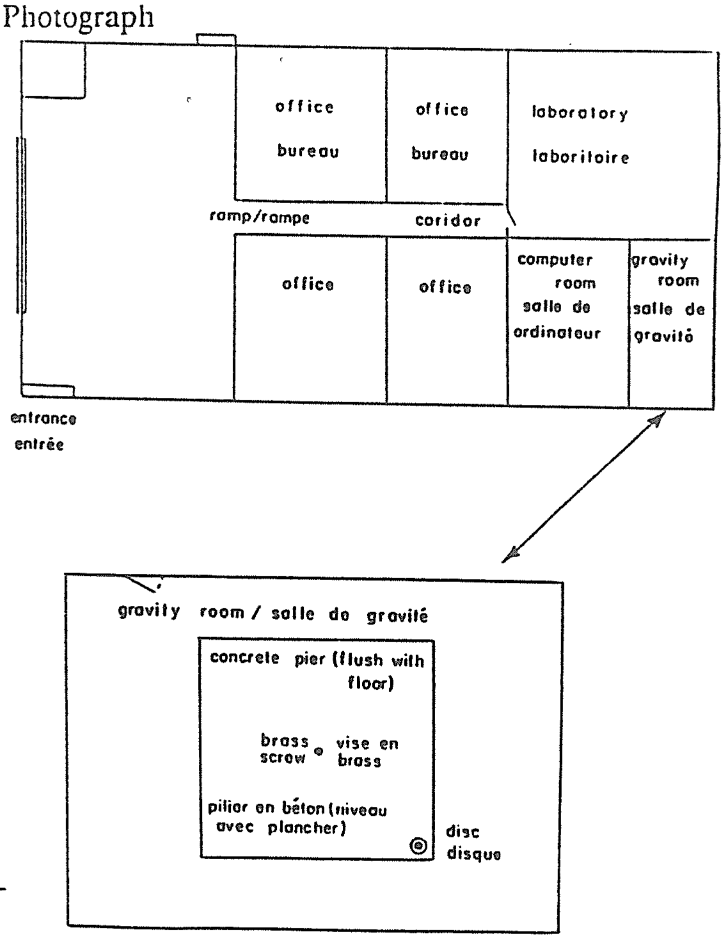
The station is located in the seismic building South East of the airport off the main highway. Telephone number for access during the week : 403 873 4573.

Remarks / Station Identity / Contact

Station number 991487

Detailed Sketch (North? Station Marker?) / Photograph

Laser beam of JILA type instr. must fall on "brass screw" at the center of the pier.



Date / Author

International Absolute Gravity Basestation Network (IAGBN)

Station Location: Schefferville, Q		Country: CANADA	
φ = 54.8047°N	λ = 293.1900°	H = 506 m	g = 981.3171077 Gal

Overview / Access / Outside View / Topo Map

The station is located in a small cabin on the McGill Subarctic Research Center land. It is close to the airport. Access is best to use the train from Sept-Iles, Q, or a chartered aircraft. No commercial flight for cargo.

Remarks / Station Identity / Contact

Station number 990288

Detailed Sketch (North? Station Marker?) / Photograph

Not available yet.

Date / Author

International Absolute Gravity Basestation Network (IAGBN)

Station Location: Tucson, (AZ) Country: United States of America

φ= 32° 26' 30" N λ= 110° 47' 30" W H= 2776 m g=9,788,104 x10^{-6}ms^{-2}

Overview / Access / Outside View / Topo Map

The station is located on the top of Mt. Lemmon at the Steward Observatory in Building 1412. It is about 16 mi NE of Pima County Courthouse in Tucson, AZ. To access from Exit 270 of Interstate 10 proceed 10.1 mi north on Kold Road. Turn east (right) on Tanque Verde Road and proceed 3.3 mi to Catalina Highway. Turn north (left) and proceed 5.2 mi to the entrance to Coronado National Forest. Continue for 24.7 mi trough the Santa Catalina Mountains to the ski valley access road and turn right. Proceed 1.4 mi to the base of the ski area, through the gate, and up the observatory access road for 1.9 mi to the entrance gate of the Steward Observatory. Proceed .2 mi on the most westerly road to Building 1412, owned by the University of Minnesota.

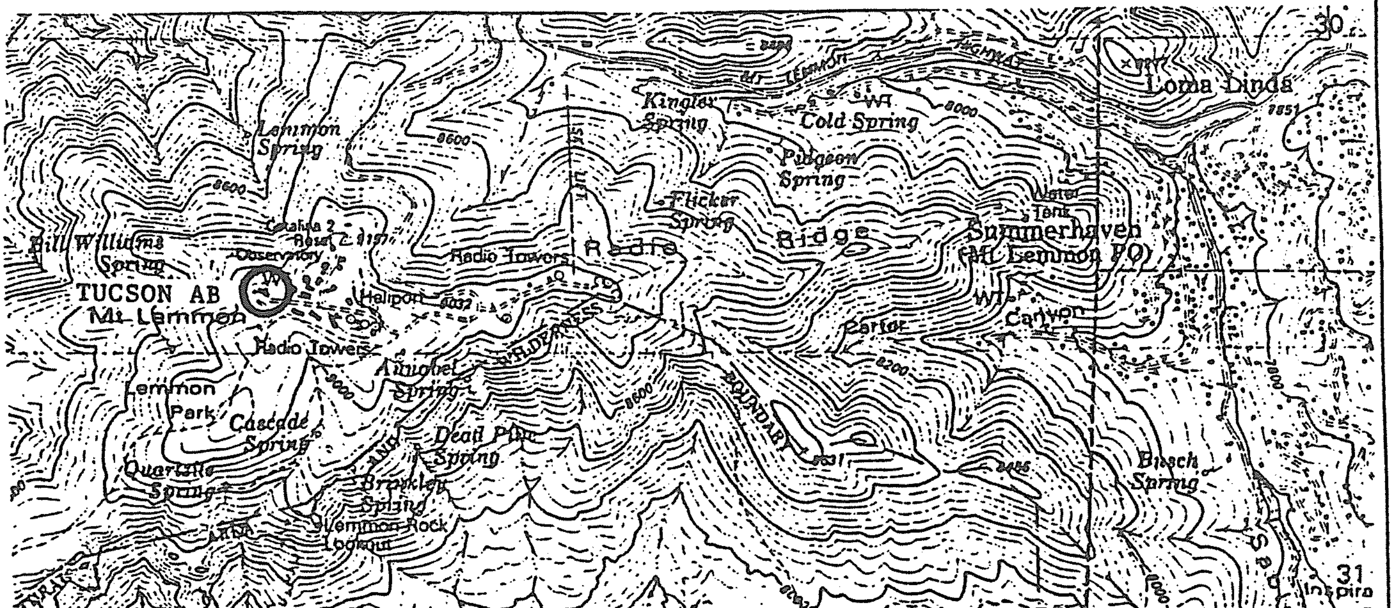
Remarks / Station Identity / Contact

Station designation is TUCSON AB. The station mark is a standard 3/4" NGS absolute gravity brass disk, mounted flush with the floor, set by NOAA/NGS. Inscription is US AGS 1989.

Station contact: Mr. Robert Petersen Tel:(602) 621-7931

Detailed Sketch (North? Station Marker?) / Photograph

The station is located in the SW corner of the building in the library. The station mark is 1.73 m.northwest of the SE wall and 2.19 m southwest of the NE wall.



Date / Author 2/15/1989; LTJG B. Bernard, NOAA/NGS

International Absolute Gravity Basestation Network (IAGBN)

Station Location: Fort Davis, (TX) Country: United States of America

φ = 30° 40' 18" N λ = 104° 01' 18" W H = 2056.6 m g = 9,788,200 x10^{-6} ms^{-2}

Overview / Access / Outside View / Topo Map

The station is 17 mi northwest of Fort Davis, TX, on Mt. Locke at the McDonald Observatory. To reach from the Court House in Fort Davis, go 15 mi NW along State Highway 118, then turn right and go southeast 2 mi along county road 78 to the Observatory. The station is east of the top of the mountain, at the end of the road in the 107" Telescope Building, ground level.

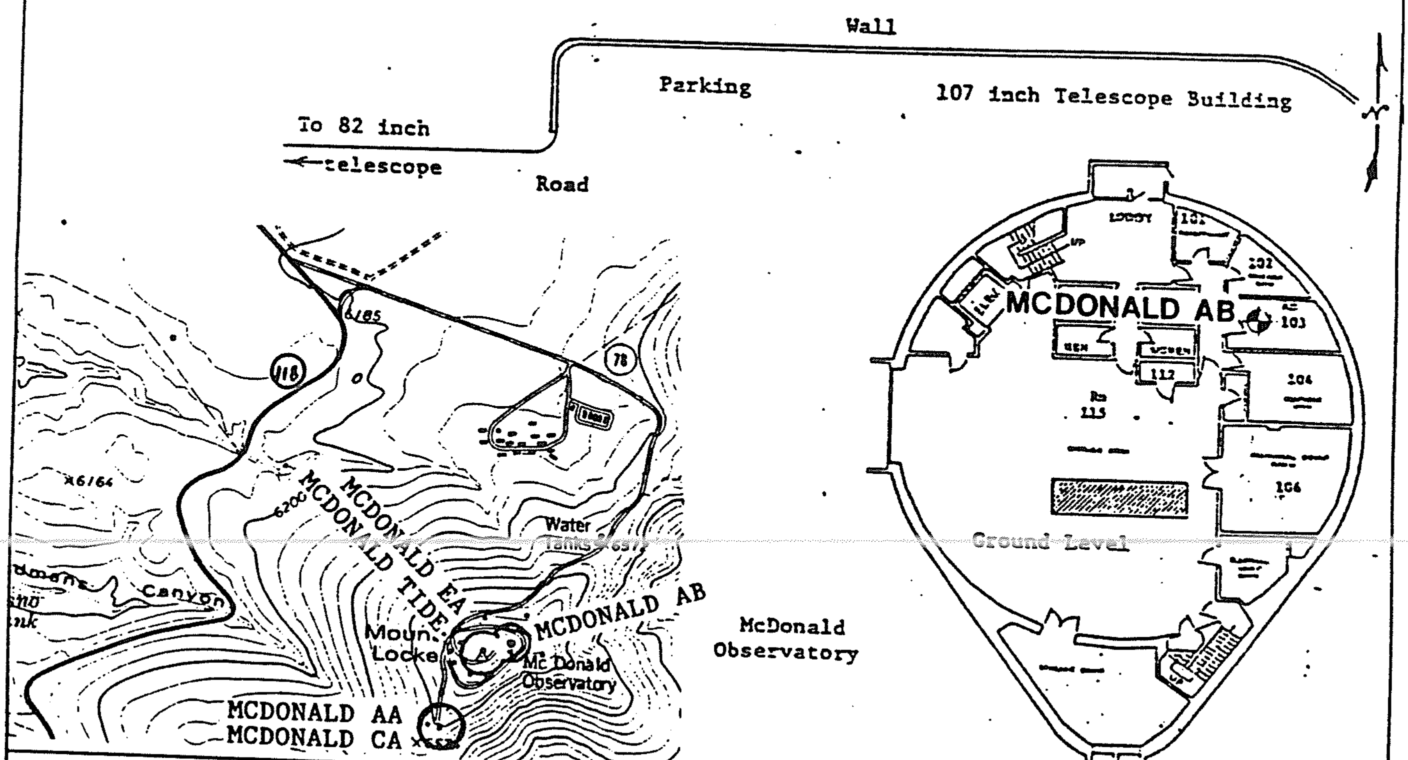
Remarks / Station Identity / Contact

Station designation is MCDONALD AB. The station mark is an approximately 2" diameter brass disc, set by DMAHTC/GSS. GSS Code: 119SO4.

Station contact: Mr. Ed Barker Tel:(915) 426-3263

Detailed Sketch (North? Station Marker?) / Photograph

The station is in room 103, 1.8 m east of the west wall and 1.1 m south of the north wall.



Date / Author 6/1980; W. G. Spita, DMAHTC/GSS

International Absolute Gravity Basestation Network (IAGBN)

Station Location: International Falls, (MN) Country: United States of America

φ= 48° 35' 05" N λ= 93° 09' 44" W H= 339.8 m g= 9,808,252 x10^{-6} ms^{-2}

Overview / Access / Outside View / Topo Map

Station is located at the Rainy Lake Visitor Center of Voyageurs National Park, on the south side of Island View, MN and east of International Falls, MN. To access from the intersection of routes US 53 (Third Ave) and MN 11 (Fourth St), go east on MN 11 about 10 mi and turn southeast (right) on the entrance road to the Visitor Center. Go 1.75 mi and turn east onto service road to back entrance of Visitor Center.

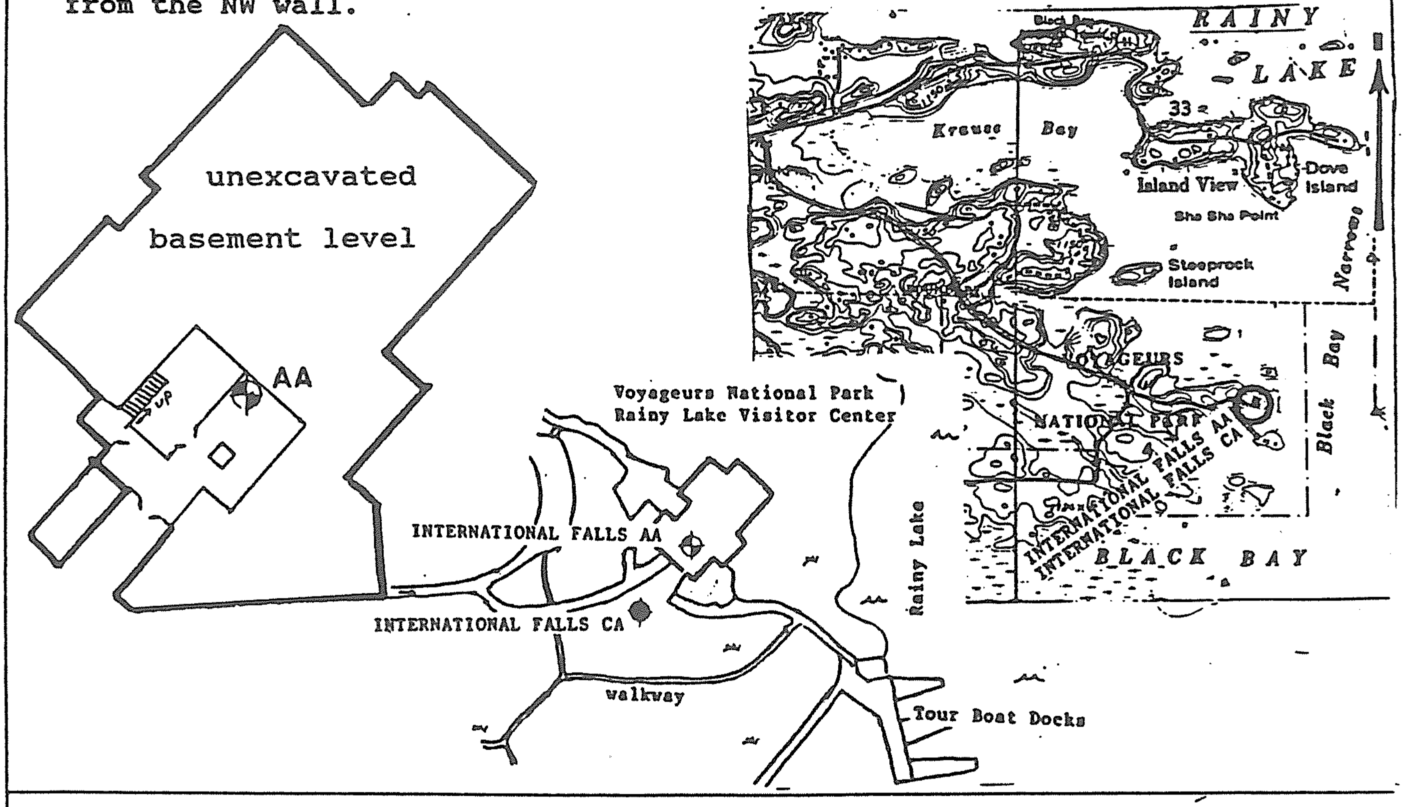
Remarks / Station Identity / Contact

Station designation is INTERNATIONAL FALLS AA. The station mark is a standard 3/4" NGS absolute gravity brass disk, set by NOAA/NGS. Inscription is US AGS 1988.

Station contact: Mr. Raoul Lufberry Tel:(218) 283-9821
Facility Manager
Voyageurs National Park
P.O. Box 50
International Falls, MN 56649

Detailed Sketch (North? Station Marker?) / Photograph

The station is in the maintenance room on the basement level of the Rainy Lake Visitor Center. The station mark is 1.1 m from the NE wall and 0.75 m from the NW wall.



Date / Author 10/27/1988; D. Winester, NOAA/NGS

International Absolute Gravity Basestation Network (IAGBN)

Station Location: Rolla, (MO) Country: United States of America

φ= 37° 55' 04.8" N λ= 91° 52' 21.3" W H= 274 m g= 9,798,975 x10^{-6} ms^{-2}

Overview / Access / Outside View / Topo Map

Station is located at McCormick Cave of the Univ. of Missouri at Rolla, MO. It is 1.6 mi east of Newburg, MO and 5.8 mi W-SW of the Phelps County Court House in Rolla, MO. To access from exit 179 of Interstate 44 go south on county road "T" for 1.8 mi and turn east (left) onto gravel road 281. Go 1.3 miles and turn right into the driveway of McCormick Cave.

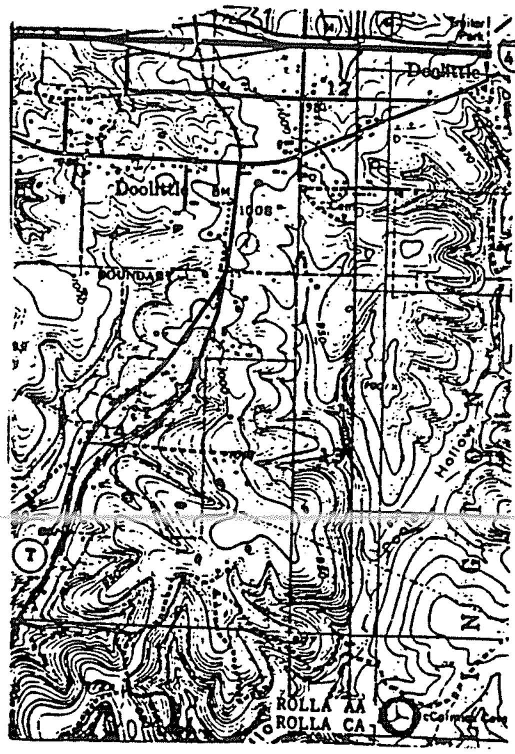
Remarks / Station Identity / Contact

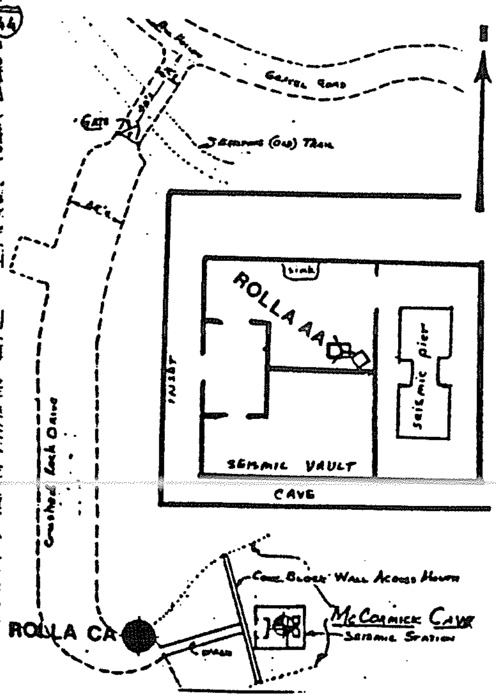
Station designation is ROLLA AA. The station mark is a standard 3/4" NGS absolute gravity brass disk, mounted flush with the floor, set by NOAA/NGS. Inscription is US AGS 1988.

Station contact: Dr. Charles E. Corry Tel:(314) 341-4852
Dept. of Geology and Geophysics
University of Missouri at Rolla
Rolla, MO 65401

Detailed Sketch (North? Station Marker?) / Photograph

The station is in the north room of the seismic vault. The station mark is 1.27 m from the north wall and 1.62 m from the east wall.





Date / Author 5/12/1987; D. Winester, NOAA/NGS

International Absolute Gravity Basestation Network (IAGBN)

Station Location: Great Falls, (VA) Country: United States of America

φ= 38° 59' 48" N λ= 77° 15' 18" W H=45.9 m g= 9,801,138 x10^{-6} ms^{-2}

Overview / Access / Outside View / Topo Map

The station is at the Visitor Center of Great Falls National Park. Station is about 2.2 mi east of the post office at Great Falls, VA, and about 13.6 mi west-northwest of the 0 milepost in Washington, D.C. To access from the Interstate 495 interchange no.13 in Virginia (second exit south of the American Legion Bridge), go west on VA route 193 (Georgetown Pike). Go 4.4 miles and turn north (right) to County road 738 (Old Dominion Road). Go 1.8 miles to Visitor Center on right.

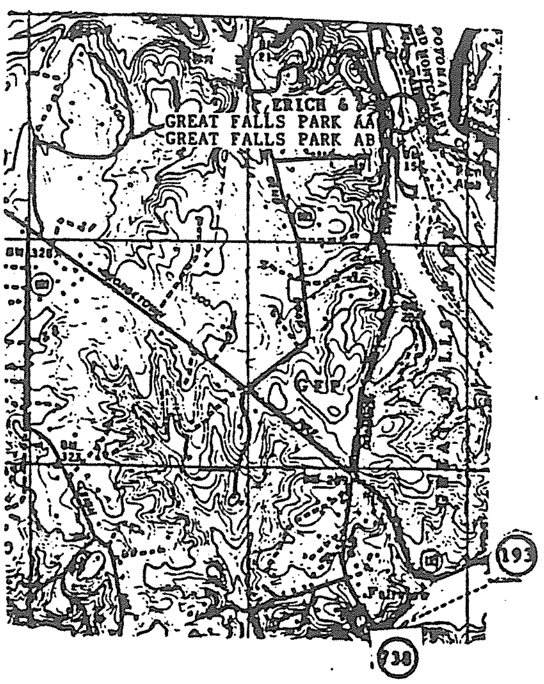
Remarks / Station Identity / Contact

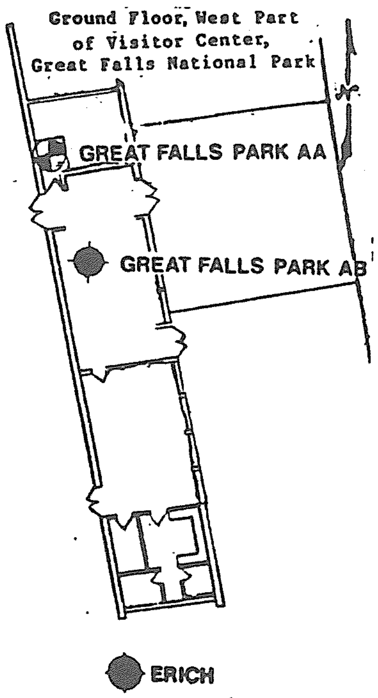
Station designation is GREAT FALLS PARK AA. The station mark is 3/4" brass disk set by NOAA/NGS. Inscription is US AGS 1987.

Station contact: Mr. Bruce McKeeman Tel: (703) 759-2168
Site Manager, Great Falls Park
National Park Service
P.O. Box 66
Great Falls, VA, 12066

Detailed Sketch (North? Station Marker?) / Photograph

The station is on the ground floor of the west wing of the Visitor Center in the specimen preservation room. The station is 1.778 m south of the north wall, 1.047 m east of the west wall, and 1.48 m west of the east wall of the room. Specimen preservation room is in the NW corner of the Library.





Date / Author 2/25/87; D. Winester, NOAA/NGS

International Absolute Gravity Basestation Network

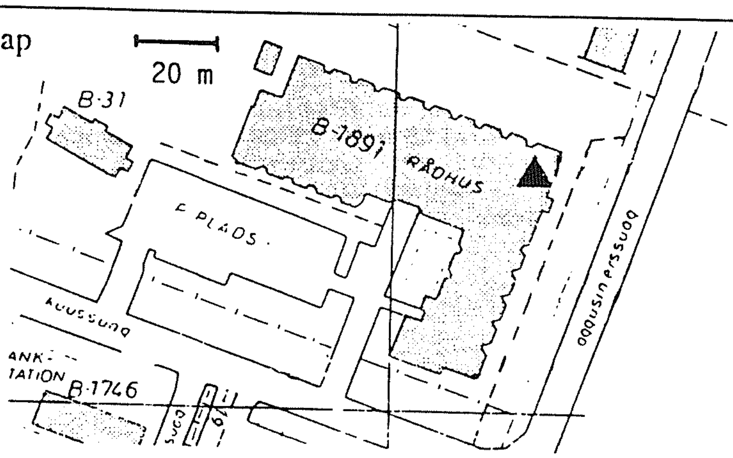
Station Location: Nuuk (Godthåb) Country: Greenland

$\varphi =$ 64°10'36"N $\lambda =$ 51°44'09"W H= 19 m

Overview / Access / Outside View / Topo Map

Station located in Nuuk city hall basement. Monumented by Geodætisk Institut bronce plate.

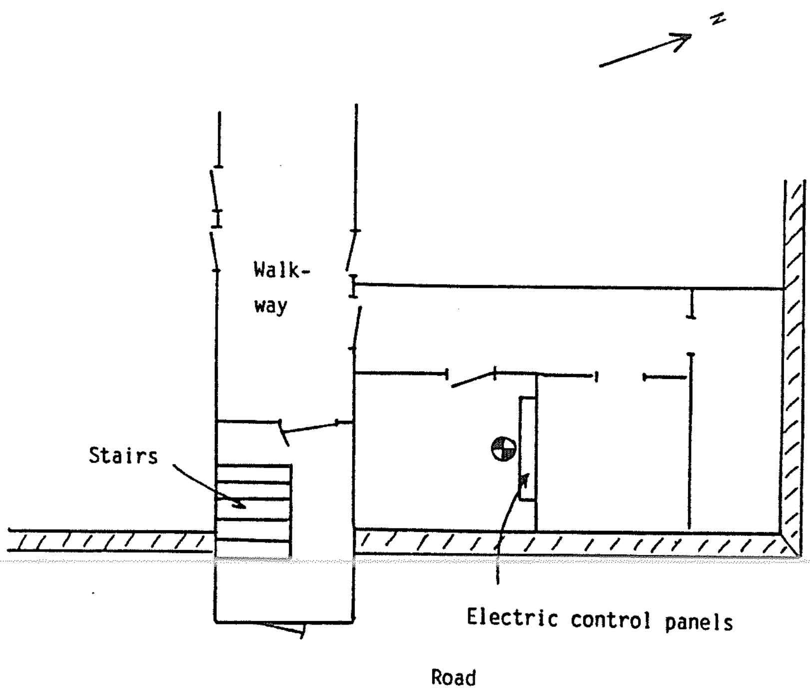
Geodetic Institute (Denmark) station no. 78801.
IfE no. 1072.



Remarks / Station Identity / Contact

Measurements performed in electrical panel control room in the basement near the rear entrance to the city hall, see sketch. Absolute measurements were made 1988 in center of room, with a short horizontal shift to bronce plate. Concrete floor directly on baserock. For access contact Nuuk Kommune technical dept., kommuneingeniør Leif Nørby Andersen, tel. 2 33 77.

Detailed Sketch (North? Station Marker?) / Photograph

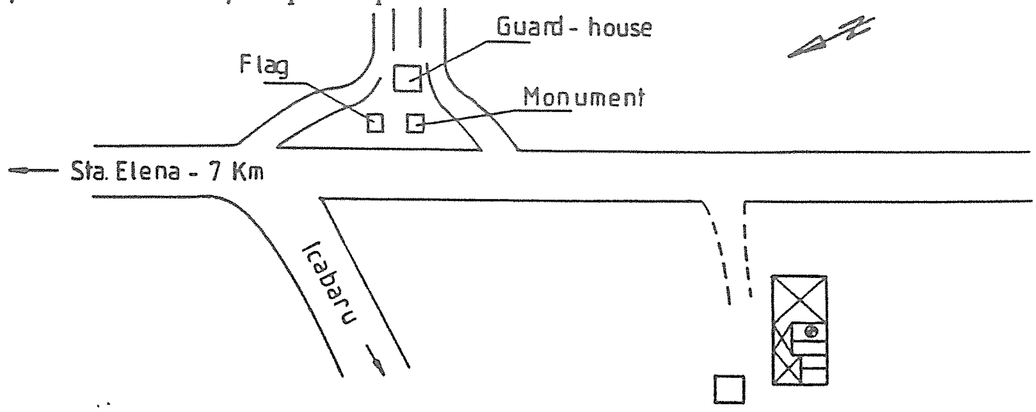


Date / Author Rene Forsberg, May 1988

International Absolute Gravity Basestation Network (IAGBN)

Station Location:	Sta. Elena Uairen			Country:	Venezuela		
φ=	4.67°N	λ=	61.07°W	H=	870 m	g=	977 822 085 µgal

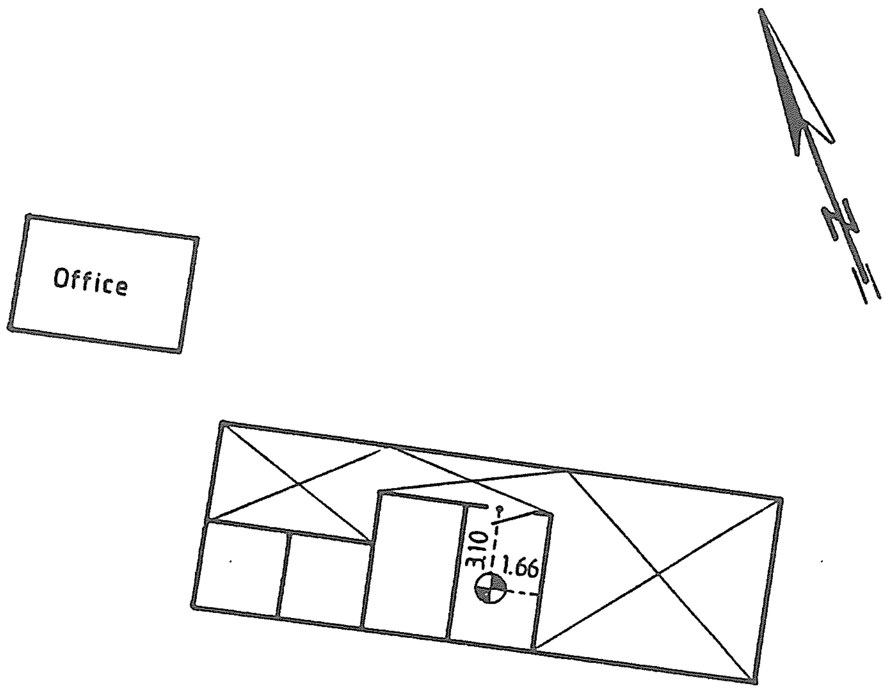
Overview / Access / Outside View / Topo Map



Remarks / Station Identity / Contact

Mearuments performed in a building of Ministerio del Ambiente y de los Recources Naturales Renovables (M.A.R.N.R.) near Sta. Elena Uairen on a pillar (same level as floor). Contact: Direccion de Cartografia Nacional
Edificio Camejo / Esq. Camejo
Centro Simon Bolivar
Caracas

Detailed Sketch (North? Station Marker?) / Photograph



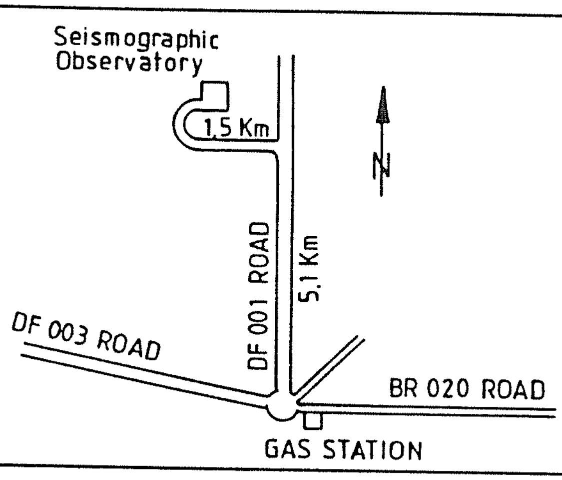
Date / Author July 1989 Rüdiger Röder

International Absolute Gravity Basestation Network (IAGBN)

Station Location:	Brasilia	Country:	Brazil

φ=	15.66°S	λ=	48.00°W	H=	1100 m	g=	978 048 790 μgal

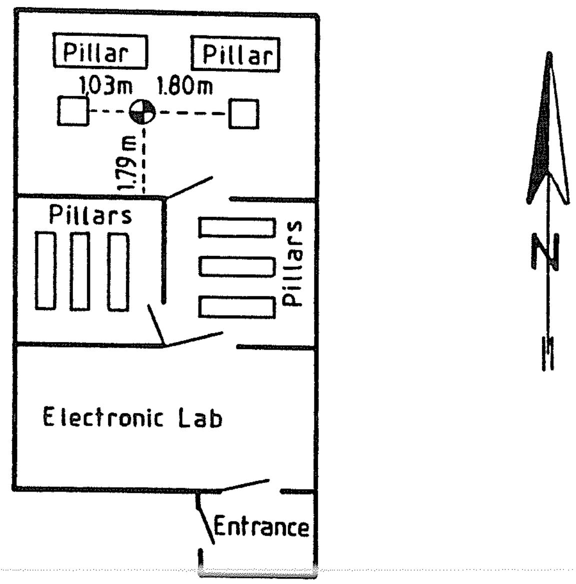
Overview / Access / Outside View / Topo Map



Remarks / Station Identity / Contact

Station is located in the observatory of Universidade Nacional de Brasilia, Departamento de Geociencias, Brasilia
The observatory is in a natural park 15 km north of the city.
Floor is concrete (35 cm thickness).

Detailed Sketch (North? Station Marker?) / Photograph

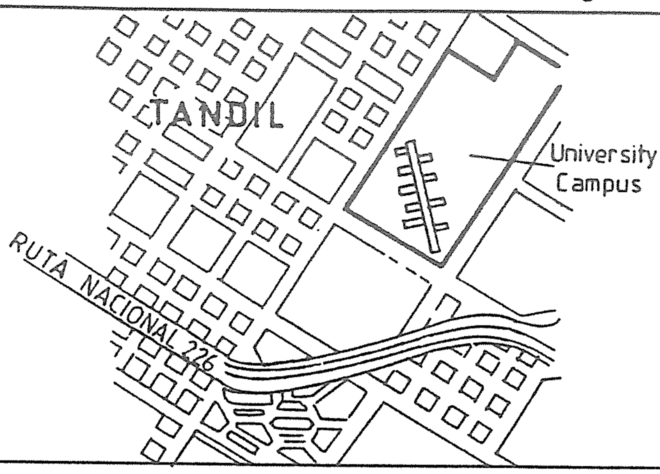


Date / Author	July 1989	Rüdiger Röder

International Absolute Gravity Basestation Network (IAGBN)

Station Location:	Tandil	Country:	Argentina
φ= 37.40°S	λ= 59.23°W	H= 180 m	g= 979 904 345 μgal

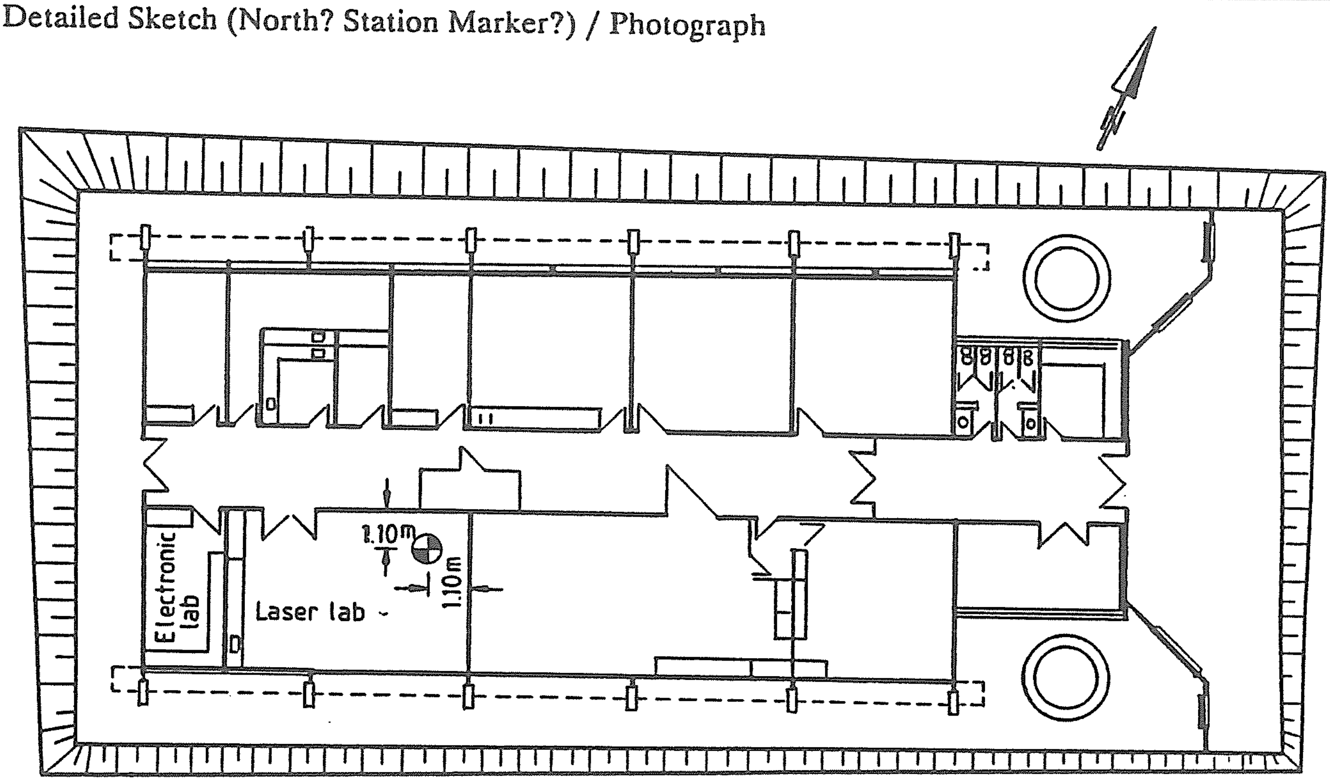
Overview / Access / Outside View / Topo Map



Remarks / Station Identity / Contact

Station is in the laser laboratory of Universidad Nacional del Centro de la Provincia de Buenos Aires, Fisica Experimental, Tandil (building No. 13).

Detailed Sketch (North? Station Marker?) / Photograph



Date / Author	July 1989	Rüdiger Röder

International Absolute Gravity Basestation Network (IAGBN)

Station Location: Sodankylä Country: Finland

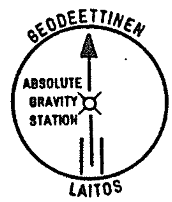
φ = 67°420 N λ = 26°395 E H = 276.635 m g = 9.823622 ms^{-2}

Overview / Access / Outside View / Topo Map

The auxiliary laboratory Pittiövaara of Sodankylä Geophysical Observatory of the Finnish Academy of Sciences. From Sodankylä 8.6 km W, direction to Kittilä, along the road No 953. Then left 0.8 km.

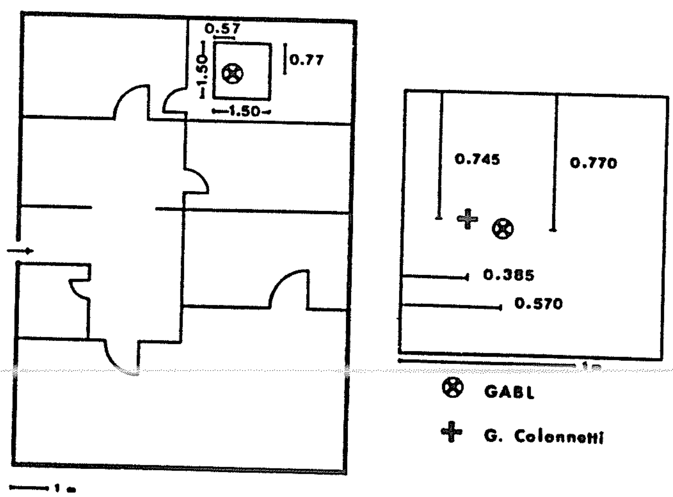
Remarks / Station Identity / Contact

The marker of aluminium on the observation point "G. Colonetti", see the next block. R = 49 mm.



Detailed Sketch (North? Station Marker?) / Photograph

The location of the observation pillar in the laboratory and the observation points on the pillar.



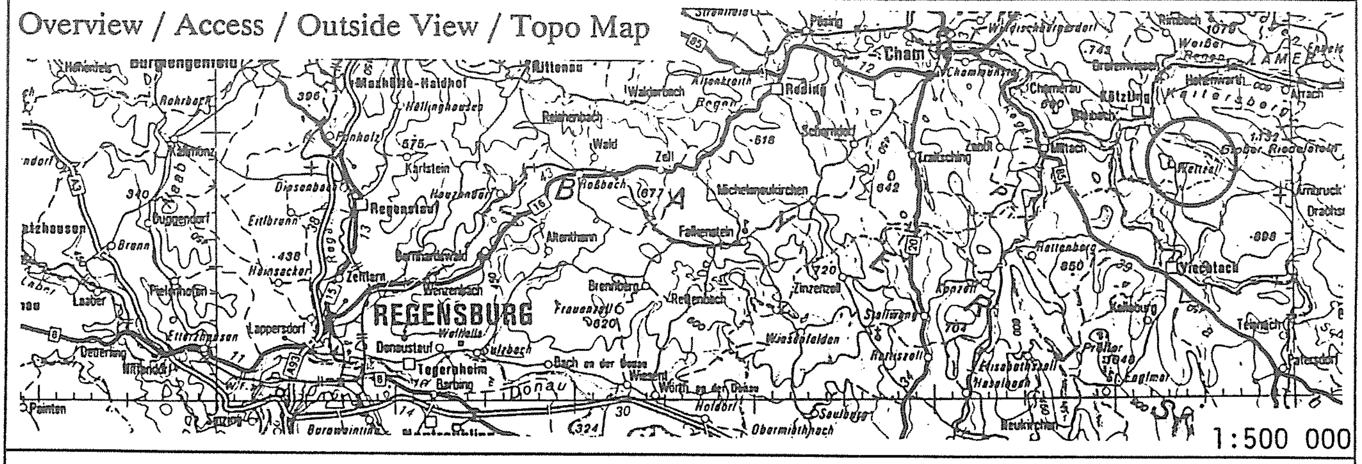
Date / Author October 18, 1988 Aimo Kiviniemi

International Absolute Gravity Basestation Network (IAGBN)

Station Location: Wettzell   Country: Federal Republic of Germany

φ= 49°08'37" λ= 12°52'42"   H= 613,780 m   g= 980 835,67 $10^{-5}ms^{-2}$

Overview / Access / Outside View / Topo Map

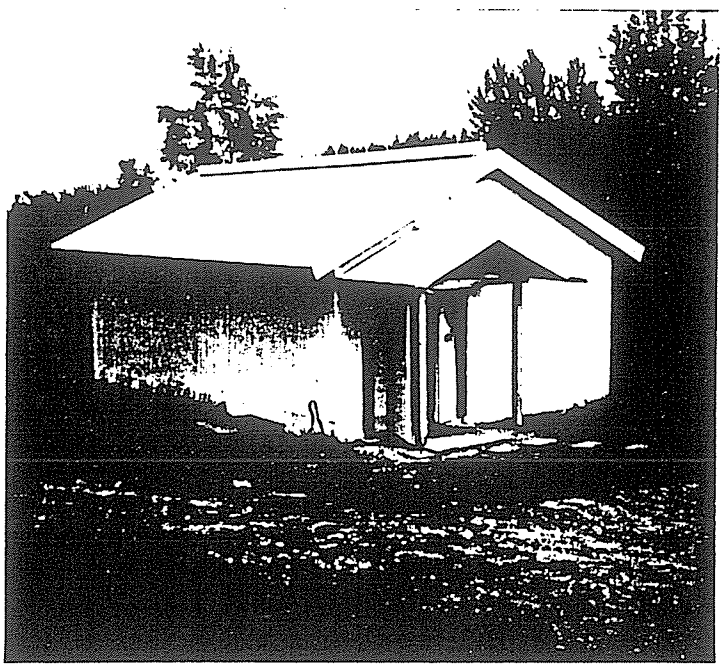


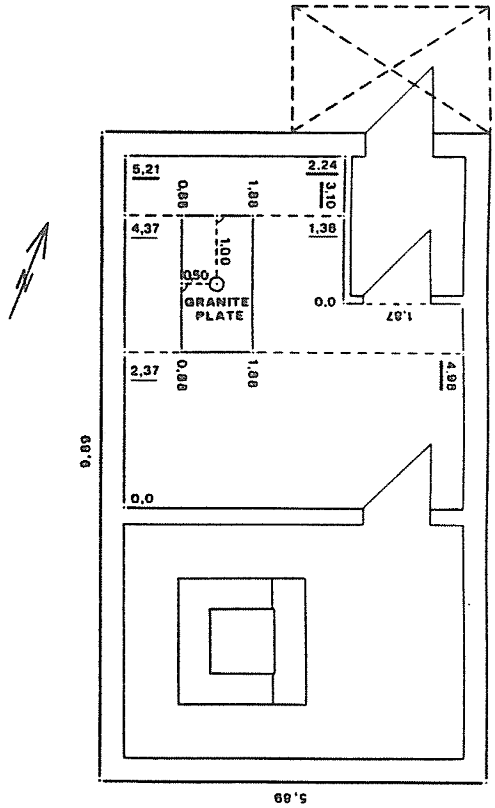
Remarks / Station Identity / Contact

Station Address:
Institut fuer Angewandte Geodaesie
Satellitenbeobachtungsstation Wettzell
D - 8493 Koetzting
Phone: 49-9941-8643
Telex: 69937 WESAT-D
Telemail: [WETTZELL.VLBI/OMNET] MAIL/USA

Contact Address:
Institut fuer Angewandte Geodaesie
Richard-Strauss-Allee 11
D - 6000 Frankfurt 70
Phone: 49-69-63331
Telex: 413592 IFAG-D
BITnet: IFAGSI 24@DDAGMD11

Detailed Sketch (North? Station Marker?) / Photograph





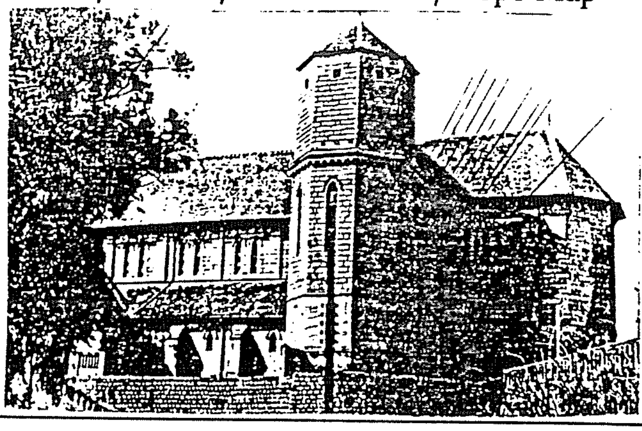
Date / Author   July 1989   Dr. B. Richter

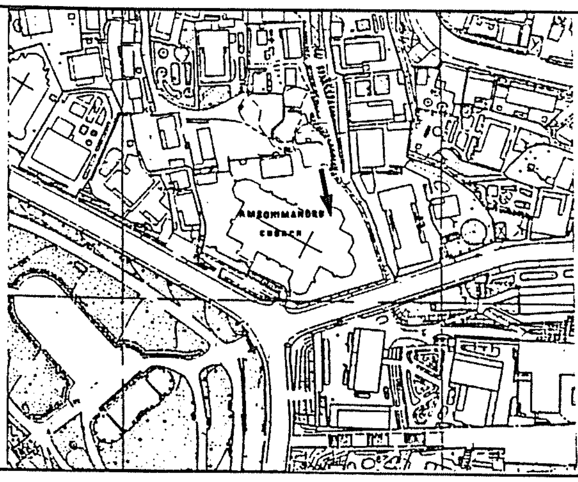
International Absolute Gravity Basestation Network (IAGBN)

Station Location: Antananarivo	Country: Madagascar

φ= 18° 54' 59" S	λ= 47° 30' 59" E	H= 1382,445 m	g= 9.78207626 ms^{-2}

Overview / Access / Outside View / Topo Map





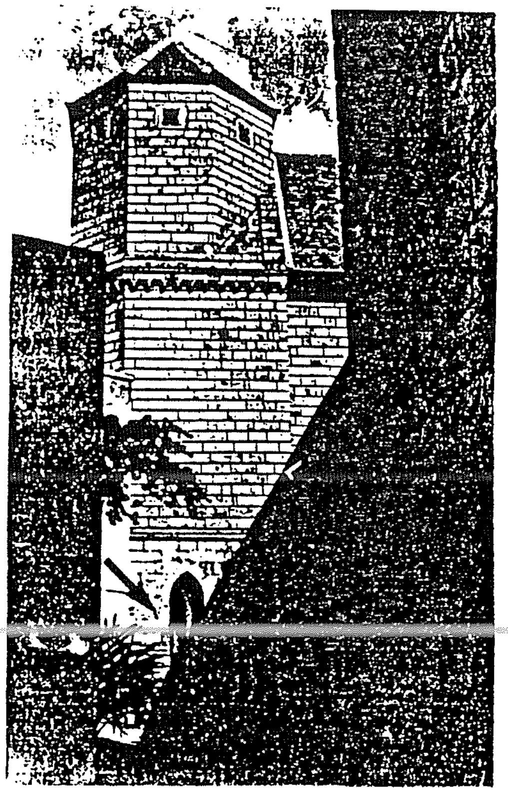
Remarks / Station Identity / Contact

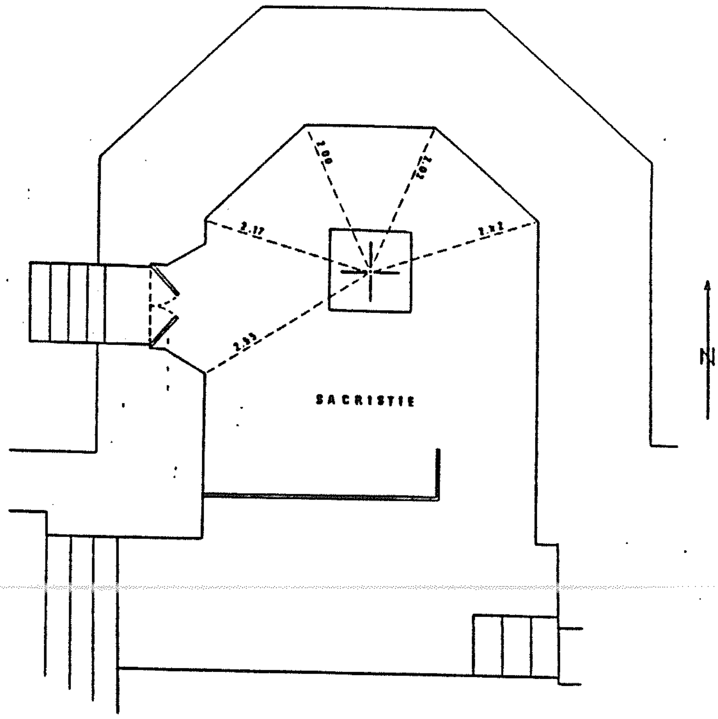
Sacristy of the Anglican Cathedral St. Laurent at Ambohimanoro, Antananarivo

River at the centre of a slab of marble (1 m · 1 m)

Contact: Prof. S. Andriamihaja, Comité National de Géodesie
et Géophysique, Secrétariat, B.P. 323, Antananarivo. Tel. 2 29-35

Detailed Sketch (North? Station Marker?) / Photograph





Date / Author: November 1988

International Absolute Gravity Basestation Network (IAGBN)

Station Location: Nanning		Country: China	
φ= 22°57′51″N	λ= 108°19′28″E	H= 188.1m	g=

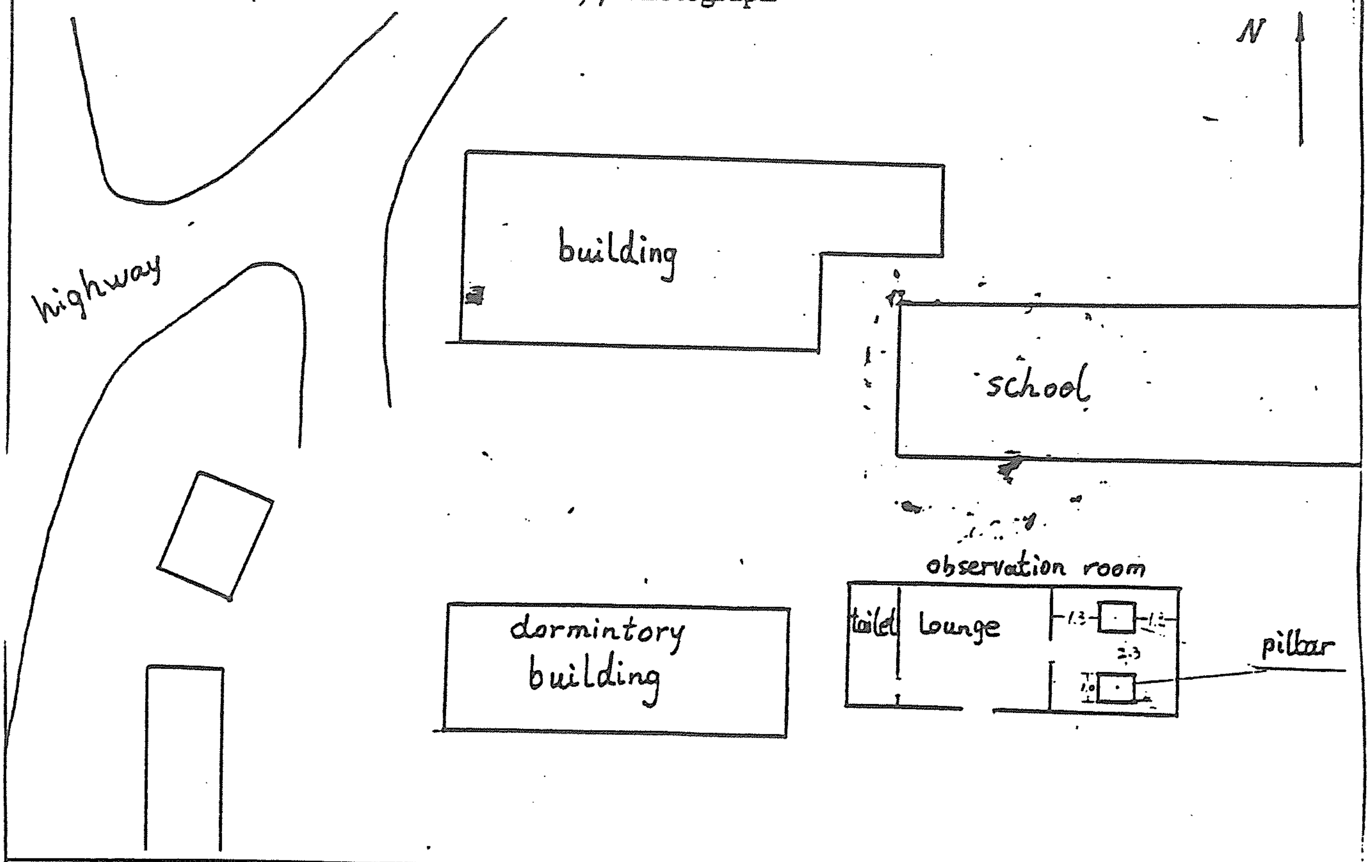
Overview / Access / Outside View / Topo Map

The station is located in a courtyard of Liuli branch, Gaofeng forestry, It is nearly 14Km from the centre of Nanning and it is accessible by highway.

Remarks / Station Identity / Contact

The observation room was specially built. It is located in east of a dorminitory building, two pillars for observation ,2.3m apart with each other, were constructed on the bedrock. there is air-conditioned in this room.

Detailed Sketch (North? Station Marker?) / Photograph



Date / Author

International Absolute Gravity Basestation Network (IAGBN)

Station Location: Beijing   Country: China

φ = 40°01′06″N λ = 116°10′17″E   H = 197.6m   g = 980110.6*10^{-5} ms^{-2}

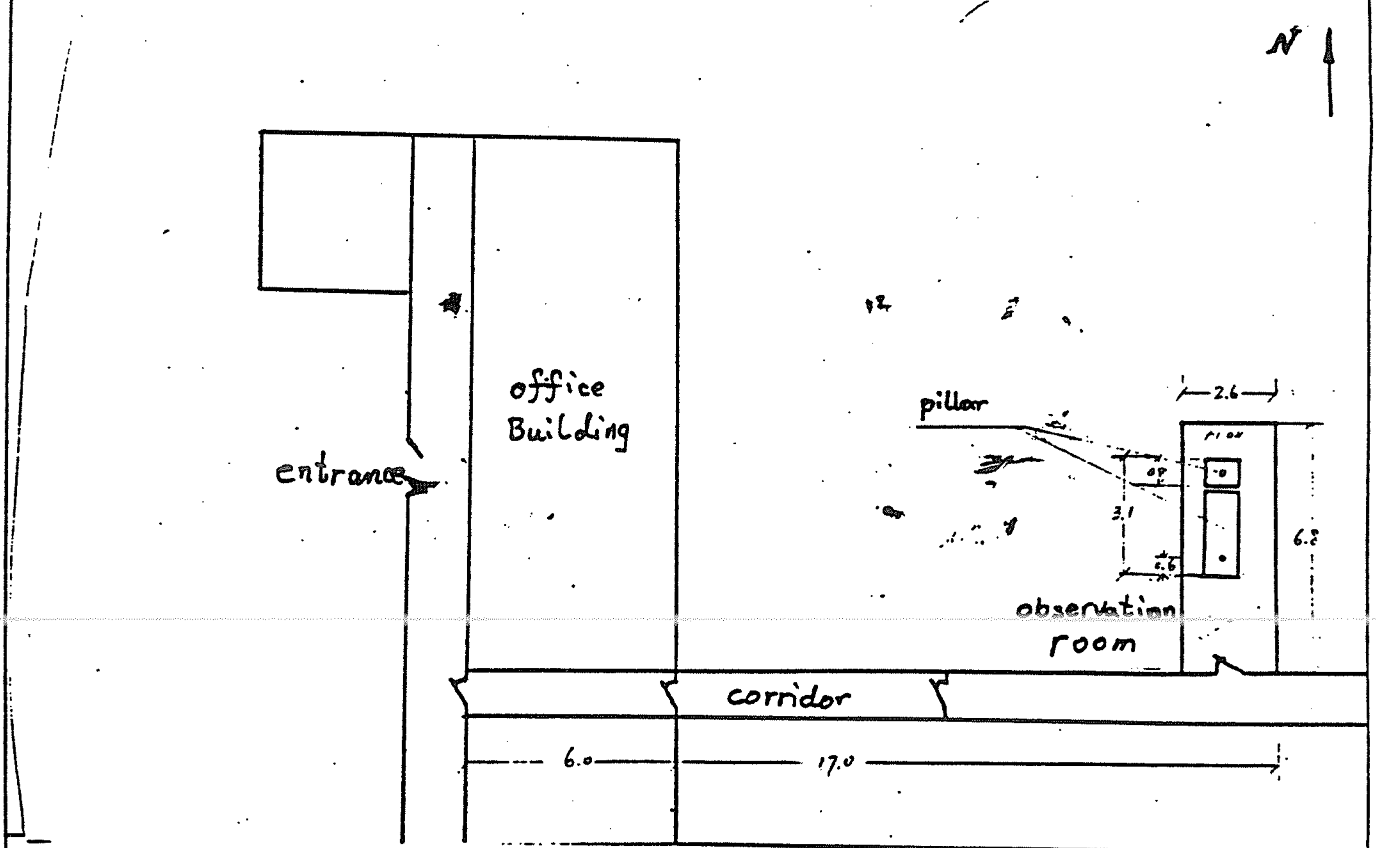
Overview / Access / Outside View / Topo Map

The station is located on a absolute gravity observation room in a observation cave for the Beijiatan Seismic Observation of Geophysical Institute, National bureau of Seism . It is 30km from the centre of Beijing . It is accessible by car.

Remarks / Station Identity / Contact

The observation paints in a artificial cave, are 50m from entrance of the cave . The temperating change in the room do not exceed ± 1°c . It is the room with dry condition , two pillars built on bedrock and leveled with the floor. The two pillars are apart from each other 2m.

Detailed Sketch (North? Station Marker?) / Photograph



Date / Author

GENERAL MEETING OF THE INTERNATIONAL ASSOCIATION OF GEODESY

Special Meeting of the International Gravity Commission
Saturday August 5, 1989
Edinburgh, U.K.

Report of Working Group 5 : Monitoring of Non-tidal Gravity Variations.

During the XIXth IUGG General Assembly in Vancouver, the International Gravity Commission approved on August 20th, 1987 the creation of the IGC-Working Group V: "Monitoring of Non-tidal Gravity Variations".

A resolution, first discussed by the present WG-members during a preliminary meeting, has been adopted by the IAG as Resolution n° 4 (Bul. Geod. Vol. 62, n° 3, p. 278). It supports the work of IGC-W5. According to the IAG rules, the resolution has been sent officially to all the concerned institutions.

The Terms of Reference of IGC-WG5 are :
"to link together the existing and future superconducting gravimeters in a network monitored by the absolute gravimeters in order to study residuals, after removal of the tides, for geophysical interpretation; leading to the monitoring of non-tidal gravity variations at a global scale".

A list of possible actions was suggested. It is :

A) coordination of regular intercomparisons between absolute and superconducting gravimeters in order to modelize instrumental effects (drift monitoring, calibration, ... ; evaluation of instrumental capabilities ...).

B) exchange of "know how" between participants at different levels : technical, data processing, standardization ...

C) multidisciplinary approach of environmental effects such as :
- removal of the "complete" tide;
- loading effects such as oceanic, atmospheric ... loadings;
- geohydrological effects, etc. ...

D) stimulation of instrumental developments
such as :
- improvement of absolute gravimeters
- development of a nitrogenic superconducting gravimeter ...

The basic ideas underlying the creation of IGC-WG 5 are based on the fact that there exist now two kinds of high precision gravimeters :

- the absolute gravimeters which now reach a precision of 10^{-9} and are transportable.
- the superconducting relative gravimeter which are site fixed, reaching a long term precision of 10^{-9} and measuring continuously. The main advantage of the superconducting instruments compared to spring gravimeters is a very low and quite regular drift rate allowing namely to detect the induced effect of polar motion (≈ 8 microgals/year).

After removal of the tide and environmental effects, it is expected that these instruments produce residue drift curves which can be representative of long term gravity variations at the microgal level.

A correlation of such curves coming from instruments located at different sites should allow to detect gravity variations on a large scale.

Regular absolute measurements, once or twice a year, are needed to refer the residues curves to an absolute value and to separate instrumental effects from the signal.

Measuring at the maximum and minimum of the biggest tide, absolute gravimeters can contribute to the calibration of superconducting gravimeters too.

At the level of precision of 10^{-9} , environmental effects are very critical. It is hoped that IGC-W5 will be the adequate platform for the exchange of informations and experiences between absolute and superconductive gravimetrists in view of a better modelization of these effects.

As it can be seen, the activity program of WG 5 is a long term program depending essentially on the willingness of the members to participate in the activities of the group.

The membership to IGC-WG5 is widely accessible to owners / responsibles of absolute and superconducting gravimeters and also to persons on the way to purchase such equipment to participate in the network. Some scientists deeply involved with research in the field of interest of the WG are welcome too.

Besides the members, some IAG officials and a number of geodesists, and geophysicists receive informations about the activities of the WG5. Their advices are very appreciated as they can contribute with "other eyes" to the activities of the WG. An updated list of members and informed persons is joined in annex to this report.

The principal communication way of WG5 is by means of circular letters. These are generally coupled with a questionnaire for maximum efficiency. The answers are then synthesized and serve as a starting point for another circular letter.

It results from this exchange of informations that a workshop will be highly appreciated by nearly all the members of the WG. The dates are not yet decided as all the answers to the last circular letter are not yet available. Nevertheless, the first answers seem in favour of the proposal to held a 3 days - workshop the week before the International Gravity Commissions in 1990. The meeting place would be Walferdange - Grand Duchy of Luxemburg. The European Centre for Geodynamics and Seismology (ECGS) could then support a part of the travel expenses in Europe and the cost of the proceedings.

An informal meeting (17 participants) of WG5 already took place in Walferdange in December 1987. The report of this meeting was attached to the circular letter n°2. Copies of it are available on request to the chairman of the WG.

Circular letters also carry other informations as paper abstracts, reports of other working groups (when available), etc...

One of the most important activity of WG5 is to encourage and coordinate absolute measurements at the sites of superconducting gravimeters. Until now, such experiences have been performed in :

- Brussels	1976	g = 981 116 662	microgals ± 18	IMGC
- Brussels	1987	g = " " 661	microgals ± 5	JILAG-3
- Brussels	1989	g = " " 663	microgals ± 3	JILAG-5
- Stasbourg	1989	g = ?		JILAG-5

the two last measurements being performed during a campaign (Finland, F.R. Germany, Belgium, France, Spain) organized by B. Ducarme thanks to the participation of the Finish Geodetic Institute.

It is hoped that the JILAG-5 measures again at the end of this year in Brussels and Strasbourg when the amplitude of the tide is the largest.

Similar joint measurements are planned for the year coming with the JILAG-4 in the U.S.A.

The agreement between the above three absolute values for Brussels have to be taken with caution as the measurements have not been processed in the same way. The formating, processing and archiving of absolute gravity measurements are very important questions to debate with the BGI and the IGC-WG2 and WG5. A clear and precise definition of all the corrections to apply to gravity observations should be defined and published. The original data sets should be stored in a convenient way to allow a fast reprocessing if necessary. Indeed , the behaviour of the residue curve of the superconducting gravimeters is not yet completely elucidated. However, they already focused attention on two points of importance :

- the need to measure the water-table variations with a precision of about 10 cm;
- the existence of an annual term with an amplitude of a few microgals. The instrumental origin of this periodic term is not yet demonstrated at all.

To prepare future exchanges of superconducting data, a list of existing instruments and available time series is under preparation. Provisionnal time-tables have been kindly asked to the absolute gravimetrists in order to be able to organize measurements in the right time at the superconducting sites. Both these kind of information will be included in the next circular letter as only a few answers to the previous one were received until now.

C. POITEVIN
Chairman

ANNEX I

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REPORT OF THE MEETING OF IAG-WG6
Edinburgh, August 9, 1989

Participants in Edinburgh : M. Becker, B. Carter, E. Groten, A. Kiviniemi, J. Liard, I. Marson, P. Medvedev, I. Nakagawa, Ch. Poitevin, B. Richter, R. Röder, A. Sakuma, J. Tanner, W. Torge, H.G. Wenzel and guests.

Pr. Groten chaired the meeting on behalf of Pr. Boulanger who could not participate. Main topic was the final organization of the Third International Comparison in Paris, Nov. 15-Dec. 4th.

The schedule was fixed like follows :

15.11 to 21.11	Group 1 : BIPM, Italy, Finland, Austria, China
22.11	Relative Measurements
23.11 and 24.11	Workshop
25.11 to 27.11	Relative Measurements (including Saturday and Sunday)
28.11 to 4.12	Group 2 : USA, Canada, USSR, Japan, F.R.G.

(Rem. : Nov. 22nd was scheduled to be used for relative measurements to assure 4 working days for relative instruments, 7 days for both groups of absolute instruments).

Fig. 1 and 2 show the stations prepared by Pr. Sakuma and the distribution of instruments, as agreed upon after discussions.

Pr. Sakuma agreed to measure on all stations with his apparatus prior to the campaign.

With the help of Ch. Poitevin of ICET, Groten was going to distribute the tidal corrections to be used prior to the measurements.

Two days were reserved for the Workshop of SSG 3.110 and the IGC Working Groups 2 and 6 covering topics like the tidal corrections, pressure corrections, polar motion correction, data formats, data exchange with BGI and computation and publication of results.

Relative Measurements

The following institutes agreed to participate in the relative measurements (grouping made by M. Becker, subject to changes).

Group 1 : Pr. Marson (R1), Pr. Wenzel (R2, G156F)
Dr. Peter (R3, D?F)
Dr. Ruess (R4, D9F), Dr. Becker (R5, D38F)

Group 2 : Pr. Marson (R1, Pr. Wenzel (R2, G249F)
Dr. Peter (R3, D?2F), Dr. Ruess (R4, G625F)
Dr. Hananda (R5, G , not confirmed yet)

Group 3 : Dr. Richter (D21), agreed upon special observation dates because of different reading procedure.

It was requested in the circular letter of Pr. Boulanger to observe at three positions at every station, 10 cm, 80 cm and 120 cm above the pilars. However, due to practical considerations the following scheme was proposed :

1. Observation of a 10 station network consisting of the ground point and the point at 80 cm of every station. The ground point lies about 4-5 cm above the ground with standard LCR meters. A special small tripod to obtain the desired height of 10 cm would cause additional uncertainties and complications. The upper point at 80 cm is to be situated on a tripod. Heights will be accurately measured to reference points to be marked at every site. Participants were asked to bring their own tripods, however, three tripods built from geodetic tripods with an 20 x 20 x 1.5 aluminium plate in an Zeiss-foot, were said to be provided.
2. Observation of the gradients between the ground level and the station at 120 cm height.

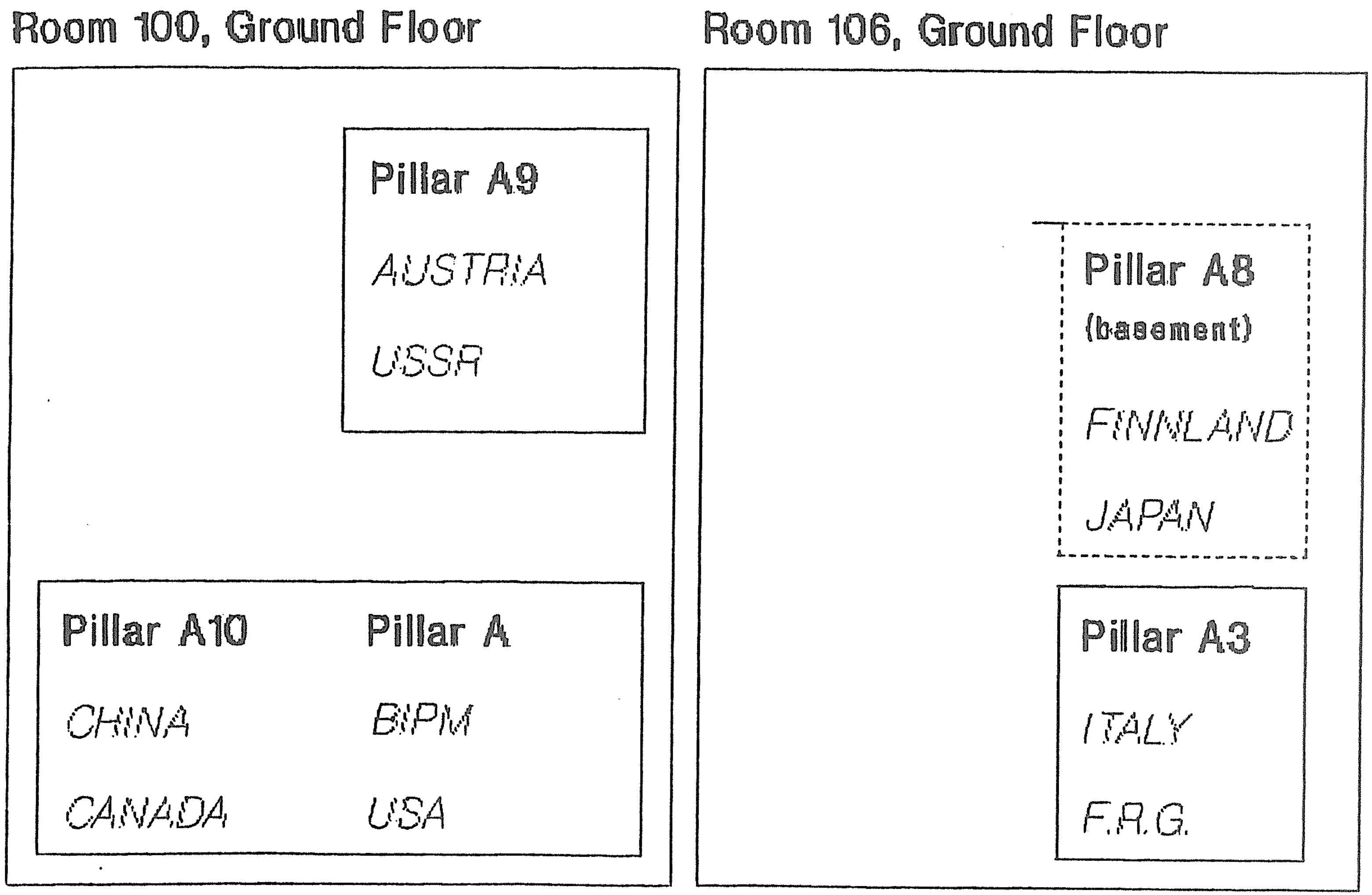
In this way the network and the gradients are observed twice, so that all in all every station is observed 6 times. A detailed scheme for the observations was presented and is given in the appendix. The network structure was intended to avoid systematic errors at certain stations and to provide strong connections for the stations at 80 cm which are supposed to be close to the reference points of the absolute instruments. Nonlinearities in the gradients may be studied by comparing the gradients between 0 to 80 and 0 to 120 cm.

The time schedule for relative ties was set as follows :

Thu., Nov. 22nd	8.00-13.00 Group 1 (Net) 13.00-18.00 Group 2 (Net)
Sat., Nov. 25th	8.00-13.00 Group 1 (Gradients) 13.00-18.00 Group 2 (Gradients
Sun., Nov. 26th	8.00-13.00 Group 2 (Net) 13.00-18.00 Group 1 (Net)
Mon., Nov. 27th	8.00-13.00 Group 2 (Gradients) 13.00-18.00 Group 1 (Gradients

Pr. J. Groten
(Chairman)

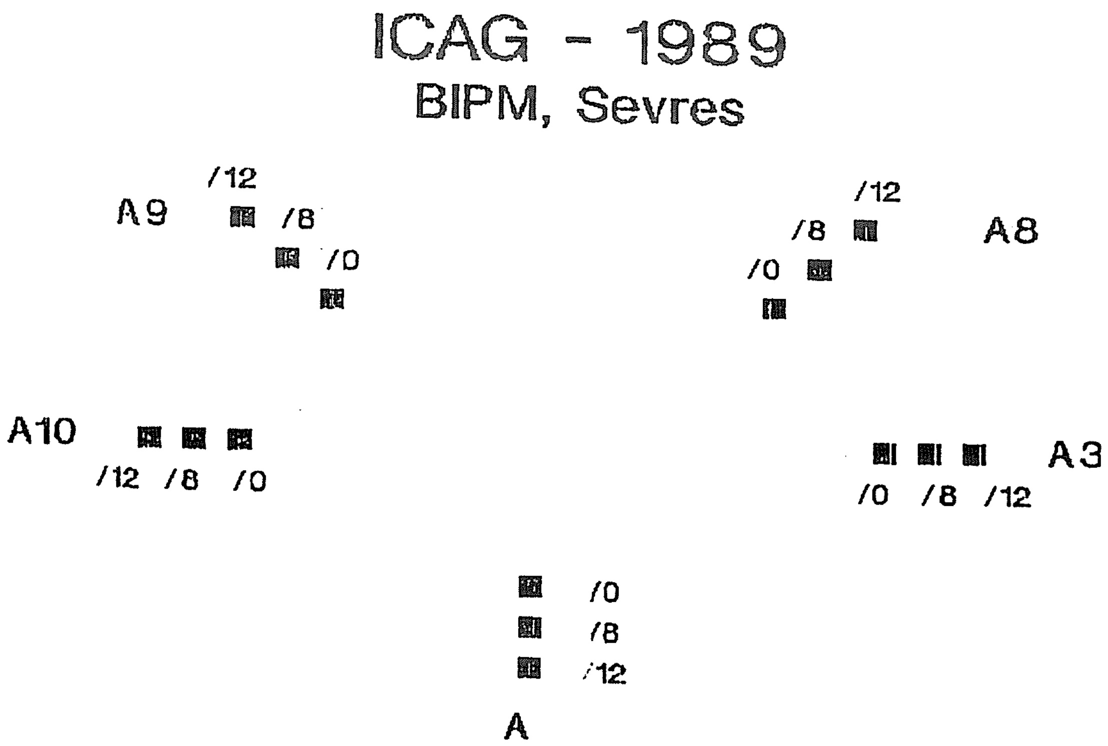
ICAG - 1989
BIPM, Sevres



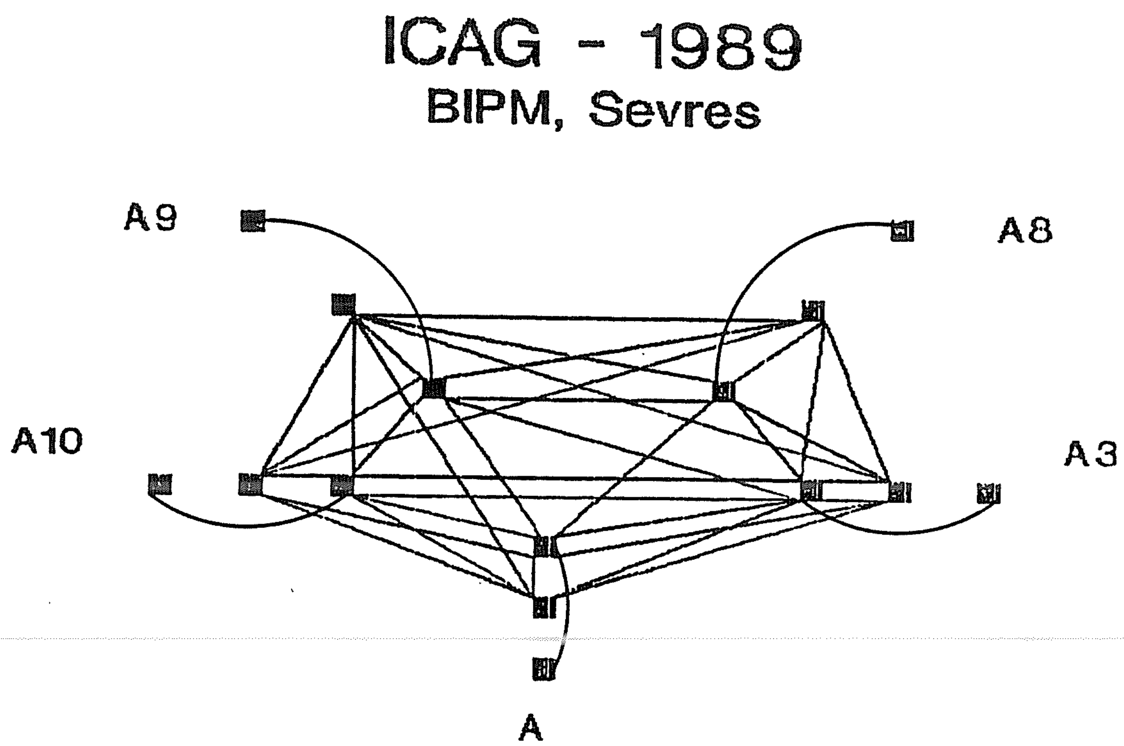
Sketch of Stations

Fig. 1

3rd International Comparison of Absolute Gravimeters



Sketch of Network



Sketch of Network and Ties between Stations

TABLE 1

Parameters of the station of SEVRES (BIPM)

Station : Paris-Sèvres M1 (0315)

Latitude : 48 49 45 N

Longitude : 2 13 20 E

Height : 62 m.

Distance from the coast : 150 km.

MAIN GRAVIMETRIC TIDAL FACTORS (δ, α)

group	wave	δ	$\alpha°$
1-110	O1	1.1618	0.14
111-197	K1	1.1522	0.53
198-260	N2	1.1760	4.28
261-300	M2	1.2022	3.39
301-347	S2	1.2143	1.75
348-363	M3	1.0450	-.45
364-483	MF	1.1600	0.00

obtained from :

- measurements performed by Dr. SAKUMA on a time interval of 1177 days
- analysis performed by the International Centre for Earth Tides (ICET-IFAG) (a more detailled model is available).

Rem. : The synthetized gravimetric tide computed at this station by the complete development of the tidal potential of Cartwright-Edden-Taylor

- do not include the permanent tide M_0 S_0 (21.1 μgl)
- is corrected of the inertial correction (proportionnal to the square of the angular velocity).

Table 2

Schedule of Relative Measurements

Measurement Nr.	Instrument Nr. R1	R2	R3	R4	R5
1	A0/0	A10/0	A9/0	A8/0	A3/0
2	A0/8	A10/8	A9/8	A8/8	A3/8
3	A10/0	A9/0	A8/0	A3/0	A0/0
4	A10/8	A9/8	A8/8	A3/8	A0/8
5	A9/0	A8/0	A3/0	A0/0	A10/0
6	A9/8	A8/8	A3/8	A0/8	A10/8
7	A8/0	A3/0	A0/0	A10/0	A9/0
8	A8/8	A3/8	A0/8	A10/8	A9/8
9	A3/0	A0/0	A10/0	A9/0	A8/0
10	A3/8	A0/8	A10/8	A9/8	A8/8
11	A0/8	A10/8	A9/8	A8/8	A3/8
12	A0/0	A10/0	A9/0	A8/0	A3/0
13	A3/8	A0/8	A10/8	A9/8	A8/8
14	A3/0	A0/0	A10/0	A9/0	A8/0
15	A8/8	A3/8	A0/8	A10/8	A9/8
16	A8/0	A3/0	A0/0	A10/0	A9/0
17	A9/8	A8/8	A3/8	A0/8	A10/8
18	A9/0	A8/0	A3/0	A0/0	A10/0
19	A10/8	A9/8	A8/8	A3/8	A0/8
20	A10/0	A9/0	A8/0	A3/0	A0/0
21	A0/8	A10/8	A9/8	A8/8	A3/8
22	A9/8	A8/8	A3/8	A0/8	A10/8
23	A3/8	A0/8	A10/8	A9/8	A8/8
24	A10/8	A9/8	A8/8	A3/8	A0/8
25	A8/8	A3/8	A0/8	A10/8	A9/8
26	A10/0	A9/0	A8/0	A3/0	A0/0
27	A3/0	A0/0	A10/0	A9/0	A8/0
28	A9/0	A8/0	A3/0	A0/0	A10/0
29	A0/0	A10/0	A9/0	A8/0	A3/0
30	A8/0	A3/0	A0/0	A10/0	A9/0

Remarks :

1. total 30 readings à 10 minutes ≙ 5 h

2. Repetition at day 2

3. Gradients from site AN/0 to AN/12, clockwise change of the 5 relative gravimeters on the 5 stations.

INTERNATIONAL GRAVITY COMMISSION

WORKING GROUP NO. 7

COMPUTATION OF MEAN GRAVITY ANOMALIES

Chairman : Hans-Georg Wenzel, Geodätisches Institut, Universität Karlsruhe, Englerstr. 7, D-7500 KARLSRUHE 1, Federal Republic of Germany.

Report for the Period June 1988 to July 1989

Presented to Special Meeting of the International Gravity Commission, August 5, 1989, Edinburgh U.K.

1. Origin of the Working Group

During the meeting of BGI directing board in June 1988, the relations between the BGI and the planned International Geoid Service of the International Geoid Commission have been discussed. It has been strongly recommendet, that any duplication of work between the BGI and the International Geoid Service should be avoided. Thus, BGI will remain responsible for terrestrial point gravity data,and should be able to compute and distribute small size (e.g. 5'x 5') gridded point or mean free air gravity anomalies to the scientific community, especially to the International Geoid Commission. In order to assist BGI with this task, the establishment of a new IGC working group No. 7 "Computation of Mean Gravity Anomalies" has been proposed.

2. Preliminary Terms of Reference

The preliminary terms of reference of WG 7, as defined by the BGI directing board at June 24, 1988, are :

- the aim is the computation of a world wide set of mean free air gravity anomalies and standard deviations of block size 5' x 5' (or as agreed with the International Geoid Commission), using current BGI data holdings,

- to test existing software for the prediction of mean gravity anomalies from point data with respect to accuracy and computation time,

- to supply BGI with appropriate software for production computation of mean gravity anomalies,

- to assist BGI in collection and compilation of 5' x 5' mean gravity anomalies from other terrestrial gravity sources (maps, already existing mean values of equivalent block size),

- to establish and supply BGI with procedures for the merging and validation of mean gravity anomalies.

These terms of reference should be modified during the current IGC meeting.

3. Opinion of the Executive Committee of the International Geoid Commission

Because the computation of small size gridded or mean free air gravity anomalies is closely related to the requirements of the International Geoid Commission, I have asked its Executive Committee (Blitzkow/Merry/Rapp/Sanso/Sünkel/Vaniček/Wenzel) on the general idea of WG7 and some specific details.

The majority of the Executive Committee of the International Geoid Commission is of the opinion, that

- it is the task of BGI to provide small size gridded or mean free air gravity anomalies to the scientific community,

- 5' x 5' is an appropriate size for a high resolution world wide gravity anomaly data set, having in mind that there exist a complete world wide 5' x 5' gridded elevation data set,

- mean free air gravity anomalies have a wider application for the geoid determination than gridded point free air gravity anomalies.

For the last item, the majority was not very distinct and some additional comments have been given. It seems that there is a need for both mean and gridded point free air gravity anomalies, but mean values are prefered because of e.g. easier data exchange and smaller representation errors.

4. Current and Future Activities

- I have recently noticed, that the BGI offers in its Bulletin d'Information already as a usual service the computation of mean free air gravity anomalies from its data holdings for selected areas. I am currently trying to get a description of the procedure implemented at BGI for the mean anomaly computation. If this procedure would meet the todays scientific and operational requirements, the main task of WG7 would be finished.

- Dick Rapp, Hans Sünkel and Peter Vaniček have software for the production computation of small size mean free air gravity anomalies from point data, which can be released to BGI. I will ask them to provide a short description of the software and the method applied.

- Up to now, WG7 has a chairman but no members, because I have not looked for members before the consultation of the Executive Committee of the International Geoid Commission was finished. Thus, the major current activity for me is to find a few, but active members for WG7.

Karlsruhe, July 1989

Hans-Georg Wenzel

Part III

WORKSHOP

ON

GRAVITY DATA VALIDATION

(Review)

Toulouse, October 17-19, 1989

WORKSHOP ON GRAVITY DATA VALIDATION

This workshop was decided last year at the BGI Directing Board meeting held in Paris, in the framework of the Working Group 1 activities.

It was held from Tuesday, October 17 to Thursday, October 19, 1989 in the BGI premises, at the Observatory of Midi-Pyrénées, and was attended by eleven participants, representing about 50 % of the maximum participation which had been anticipated. Nevertheless, we think it was a success, from our appreciation of the level of the presentations, of the discussions and of the software demonstrations performed.

The program, as it appears on the next page, was organized around :

I - formal presentations of validation techniques by representatives of agencies ; time devoted to each one was fairly comfortable (especially due to the lack of representation of two groups...).

II - software demonstrations and processing of a data set in real time ; the BGI softwares PFATES (batch) and VERSET (interactive with lots of graphics), plus the Danish software GEOGRID, were successfully operated in a number of cases... avoiding traps due to visitor's effects and Murphy's laws !

III - four technical panels on subjects related to the data base and software interfaces, acceleration techniques, type and accuracy of prediction methods, graphic tools.

Participants were not asked to produce a written paper, due to the technical and informal characteristics of the workshop. Therefore we give instead the copy of the presented viewgraphs with additional comments issued from the discussions.

WORKSHOP ON GRAVITY DATA VALIDATION

Tuesday, Oct. 17

9.30	Opening	G. Balmino
Contributed Papers - Session I		
9.45	Data Validation Techniques at K.M.S.	C.C. Tscherning
10.15	Batch Procedure Developed at I.F.E.	*Canceled*
10.45	Break	
11.15	BGI Validation Techniques - Part I : Prediction and Triangulation Methods	M. Sarrailh
11.45	BGI Validation Techniques - Part II : Interactive Graphic Software : VERSET	D. Toustou
14.00	Demonstration of Software Capabilities at BGI	M. Sarrailh, D. Toustou
15.00	Processing of a Data Set in Real Time	M. Sarrailh, D. Toustou, Ch. Poitevin

Wednesday, Oct. 18

Contributed Papers - Session II		
9.00	Methods Developed at GSC	J.D. Rupert
9.30	Data Validation Procedures at ULIS	I. Windle
10.00	Presentation by the Group at Univ. of Edinburgh	*Canceled*
10.30	Break	
11.00	Technical Discussions A. Data Base -Software Interfaces	G. Balmino
14.00	Technical Discussions (continued) B. Acceleration Techniques for Measurement Selection	M. Sarrailh
15.00	C. Accuracy of Prediction Methods - Identification of Erroneous Data	C.C. Tscherning
16.00	D. Graphic Tools as a Help to Data Validation	G. Balmino

Thursday 19, 1989

9.30	Results of the Data Set Processing Performed Tuesday p.m.	Ch. Poitevin, M. Sarrailh, D. Toustou
10.30	Future Activities in the Field	(J.D. Rupert, on behalf of K. McConnell, IGC WG.1 Chairman)
11.00	Break	
11.30	Conclusions of the Workshop	
12.00	Adjourn	

CONTENT

DATA VALIDATION TECHNIQUES AT K.M.S.

(C.C. Tscherning)

Introduction : KMS is the National Mapping and Cadastral Agency of Denmark.

APPROACHES

(1) Comparison with values already stored in Data Base

(2) Plotting : location, value, source

(3) Contouring using :
- least-squares collocation
- weighted interpolation.

t > 1987 : NEW DEVELOPMENTS

(4) Prediction/interpolation from points closeby

(5) Prediction from independent data-types (altimetry)

(6) New adjustments of sea-gravity (SKV-Norway)

BASIS FOR VALIDATION

(A) Gravity Data Base

(B) Digital terrain model (1 km x 1 km - not good enough for Norway)
Digital depth model (5' x 5', ETOPO5), for marine data

(C) Interpolation software (GEOGRID - R. Forsberg)

(D) Plotting - contouring software package (GEOPLOT - R. Forsberg)

(E) General prediction package (GEOCOL - CCT)

(F) Terrain correction software (GEOFOUR, TCFOUR, TC - R. Forsberg)

(G) Grid interpolation software (GEOIP, (TCIP) R. Forsberg)
(Interpolates terrain effects + spherical harmonic reference field values) - contains good subroutines for UTM ↔ (ϕ, λ) conversions.

DATA BASE

Index-sequential access :
Geographical key (here 0.1° x 0.1° resolution).
$\phi = 036.5131, \lambda = 137.2321 \rightarrow 01336752$

⇒ search for data in specific area very fast (sequential search only necessary in part of physical data base file)

Record structure*:

- Access code
- Latitude + suffix
- Longitude + suffix
- Height type code (= DMA)
- Height + suffix
- Suppl. height + suffix
- Gravity - 976000 Mgal + suffix <u>as published</u>
- Free Air anomaly
- Source code (KMS defined) ←
- Base station ref. n° (DMA)
- Sequence n°
- Error estimate for Δg
- Correction to published value (- 1)

....(80 char.)

- Terrain correction
- Spherical harmonic expansion ref. value
- Source file
- Address file
- Litterature file

(Source file, Address file, Litterature file) } - - - - - - ASCII-sequential ←

PHYSICALLY : 3 FILES

$\lambda > 3°$	(SCAN GRAVREG) 200 000
$\lambda \leq 3°$, except	Greenland (FOGRAVREG) 100 000
Greenland	10 000

Not all data loaded :

Sea gravity : 1 point/km
Old values deleted or given high st. dev.

+ file of reference spherical harmonics grid values, at 6' x 12' interval and between h = 0 and 2000 m (OSU 86 F + I.F.E. models).

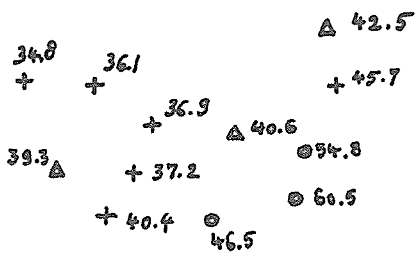
VALIDATION PROCEDURE

(A) At entry : compare to old data → gives duplicates, but also errors !

check $\Delta g = g - \gamma$

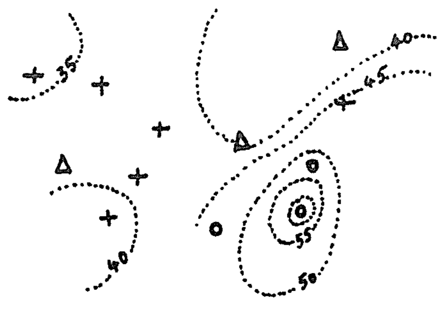
(B) Subtract Δg_{REF}, Δg_{TC}

Plot location + Value



*Time is not stored

Make contour map



(C) Remove suspected errors
- try to get feed-back from original data supplyers
- re-load values, if verified.

TYPES OF ERRORS FOUND

(A) Wrong or no conversion from Potsdam system

(B) Mis-punched values - location, height, gravity
Easy : 1° error
100 m error
100 mgal

(C) Misprints in published values

(D) Values deleted by originator not deleted by DMA, which sometimes get preliminary data set.

Procedure very time consuming

NEW DEVELOPMENTS

Automatic procedures

Use of other data types (terrain used now)

Adjustment of sea-gravity : requires track I.D. stored + time - not kept in DMA data !

(a software has been developed at SKV -Solheim is the contact; also DMAAC and H.G. Wenzel have sea gravity adjustment softwares...).

BGI VALIDATION TECHNIQUES**

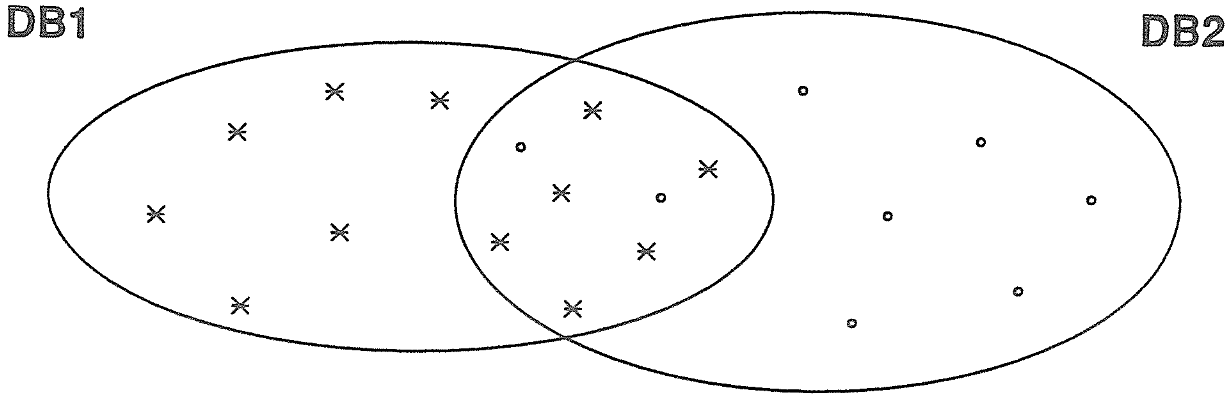
Part 1 : Prediction and Triangulation Methods

(M. Sarrailh)

First approach

- histograms for anomalies, height
- determination of extrema
- control (new determination) of anomalies, detection of errors on ϕ, h, g, Δg.
  Disadvantage : we need ϕ, h, g <u>and</u> anomalies.
- coverage examination
  Comparison with geographical maps
  Detection of errors on ϕ, λ.

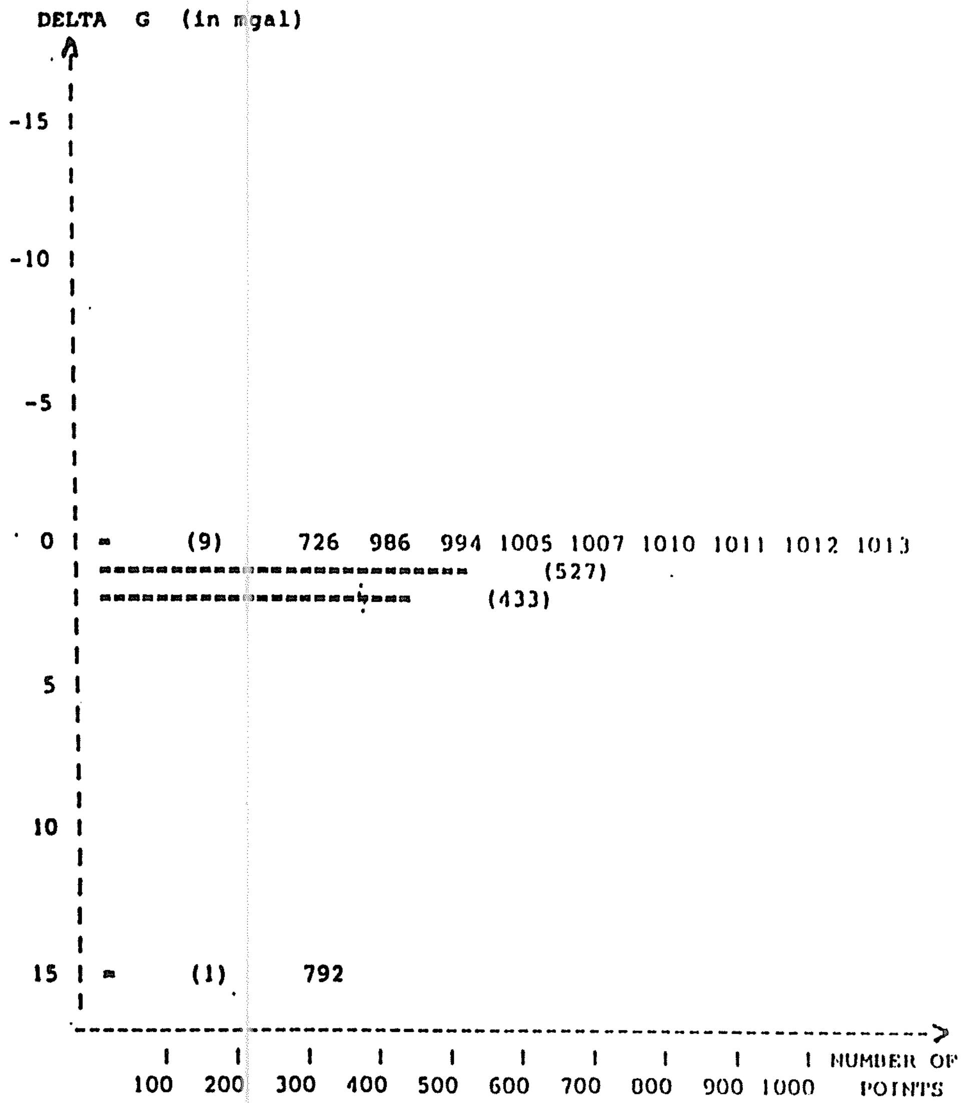
Merging Two Gravity Data Base : 1981 (with duplicate points/sources).

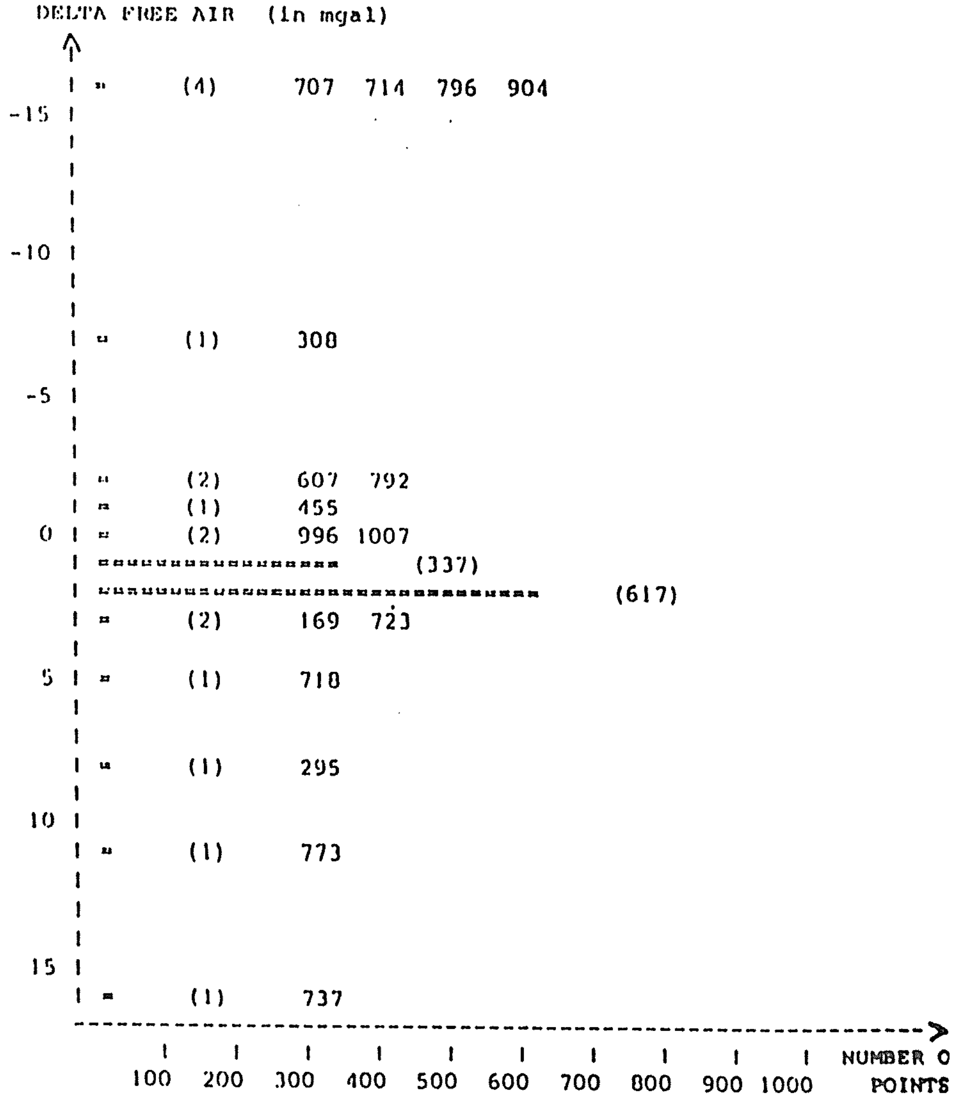


- detect bias between sources
- suppress duplicate points.

**Refer to BGI Technical Note n° 10

SOURCE 2B 007



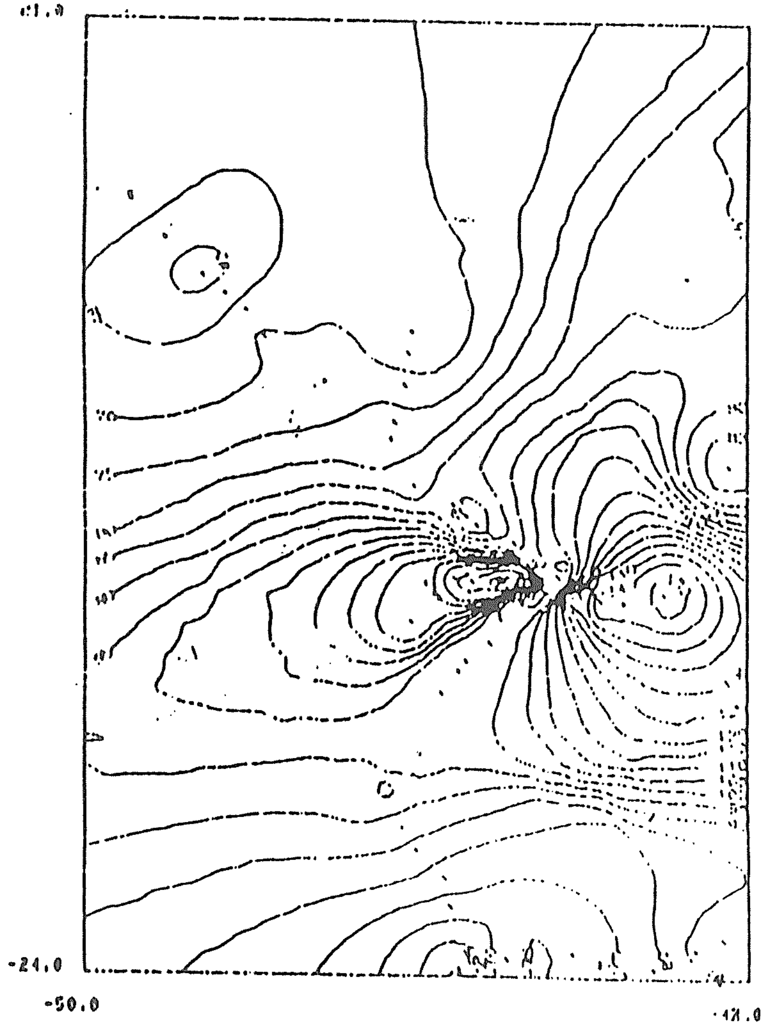


978 IDENTIFIED STATIONS

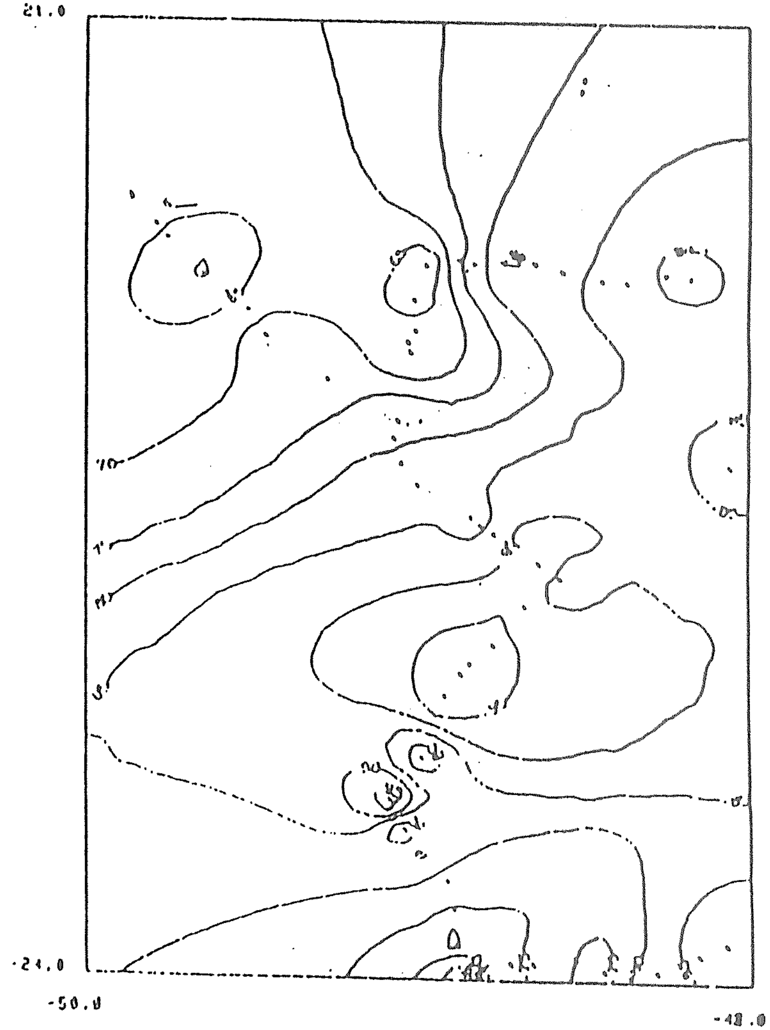
DATA EVALUATION

CONTOURING

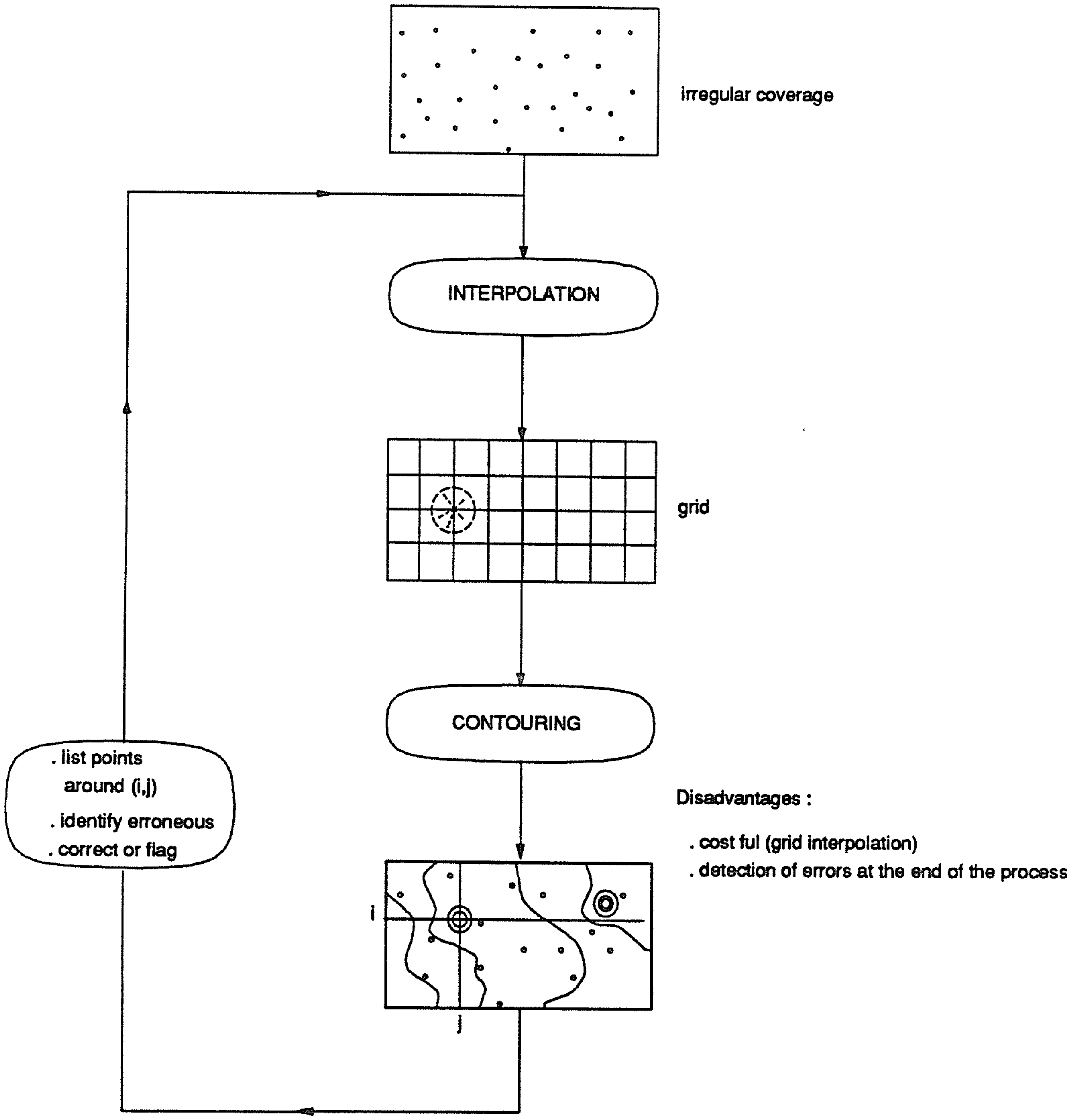
BGI



DMA



VALIDATION THROUGH MAPPING



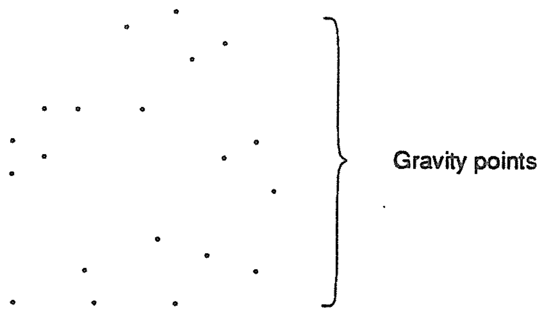
A NEW APPROACH FOR DATA VALIDATION

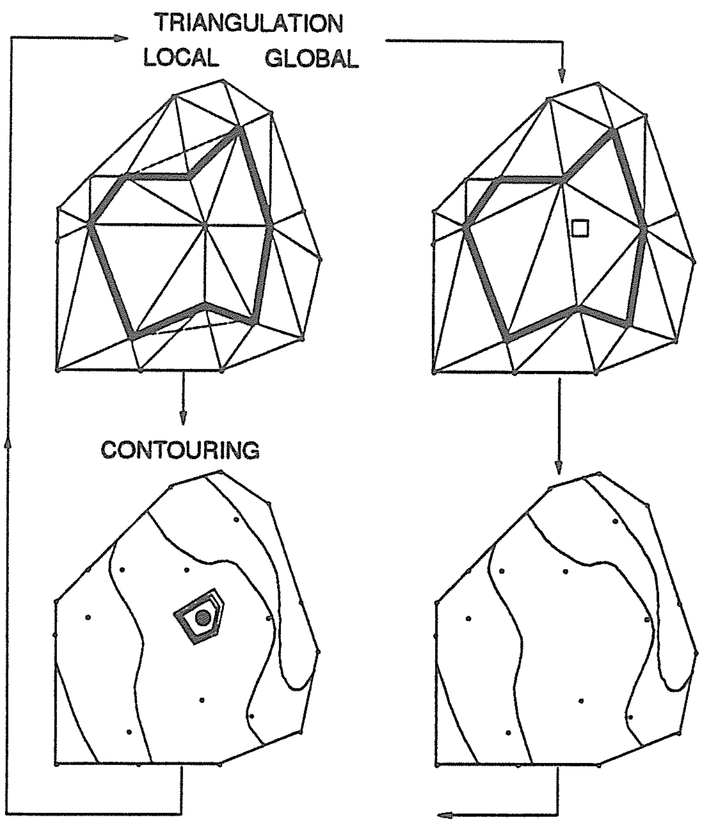
. THE NEEDS

- to control gravity points using the neighbouring ones, we need to identify quickly points at a given distance.
- we need an efficient method to predict the anomaly to be compared to the measured one.
- we need a mapping method, for control, which respects measurement points.

. THE SOLUTIONS

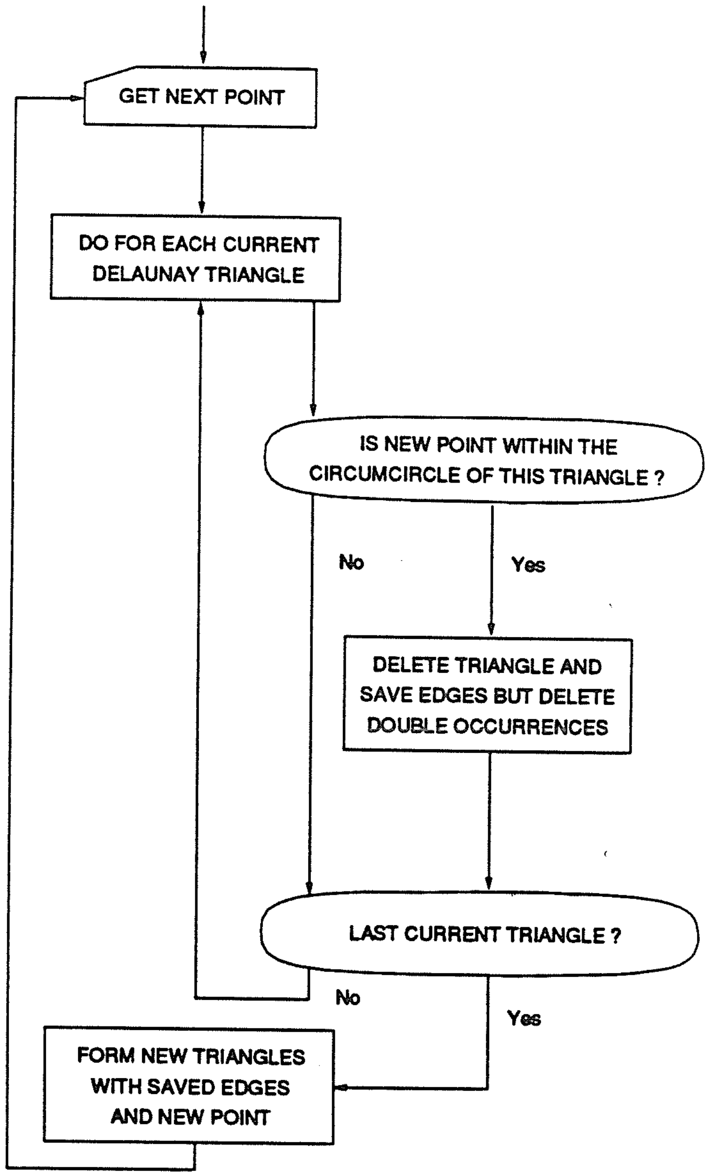
- collocation/kriging methods for prediction
- triangulation method
  * for cartography,
  * to find the nearest points
  * for local modifications (suppressing, adding a point).





TRIANGULATION

. "equal angles" triangulation (Delaunay)
ACORD



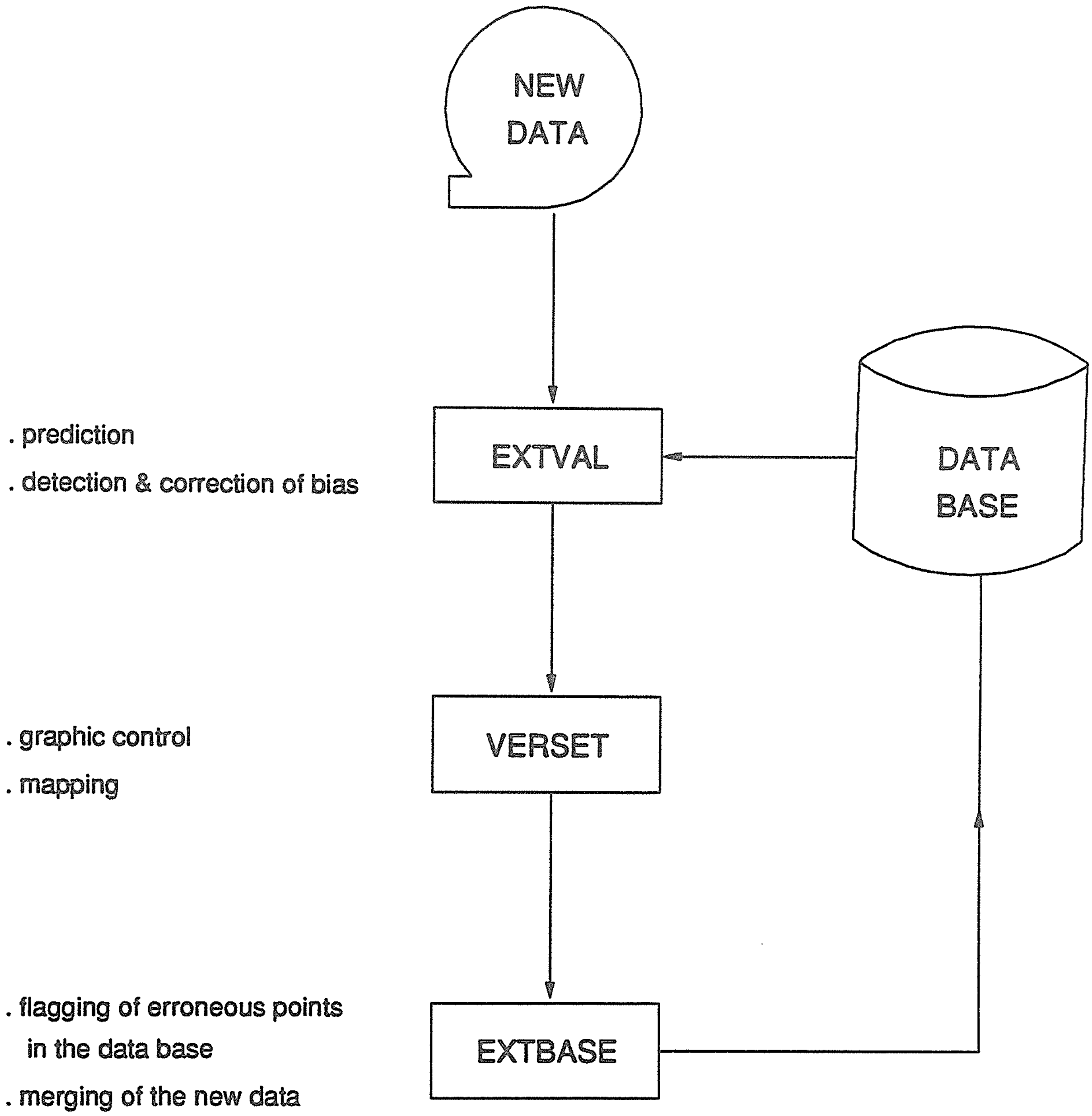
. "minimum perimeter" triangulation (Gerstl)
NETGEN

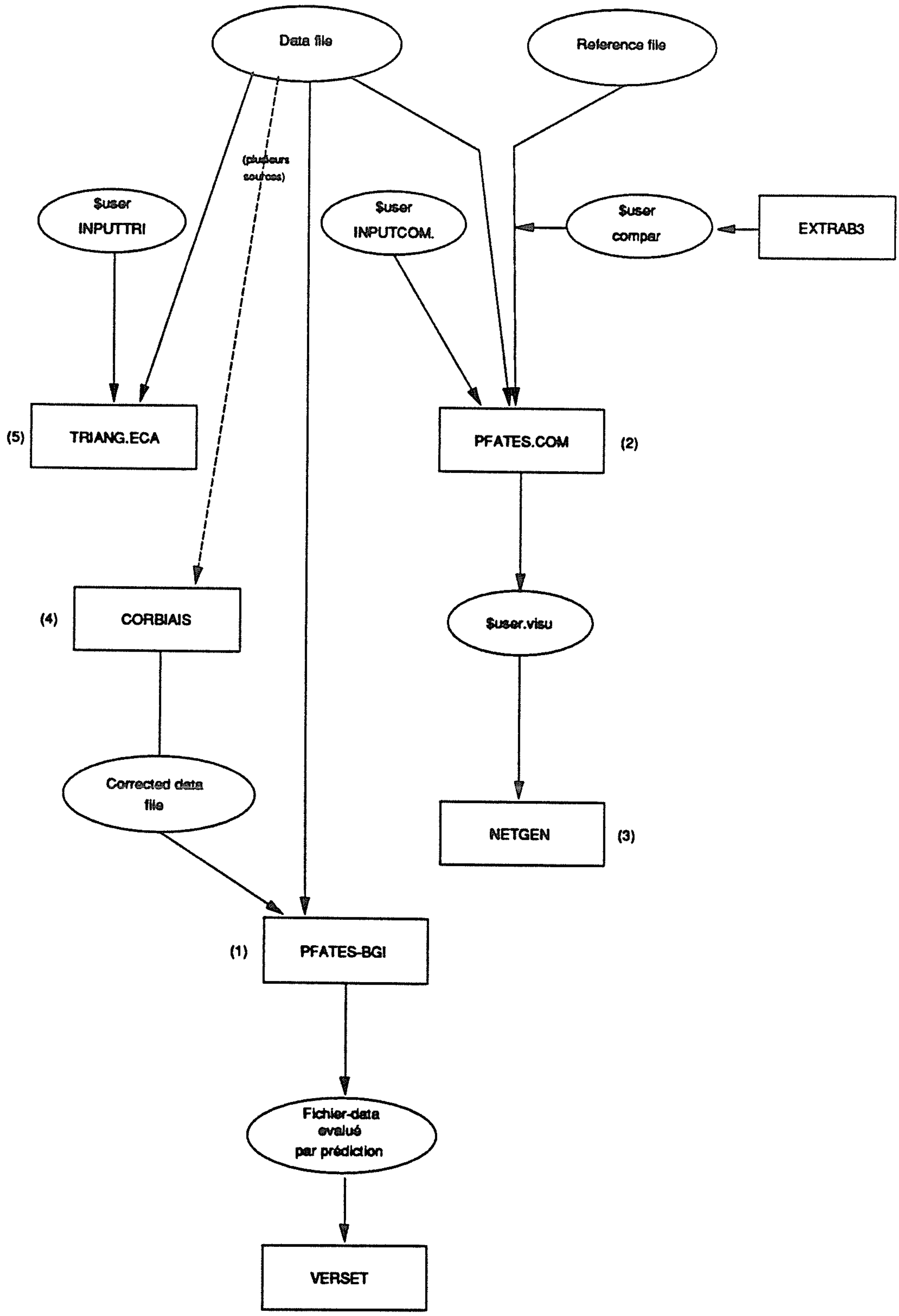
THE TRIANGULATION ALTERNATIVE

WHY USE TRIANGLES ?

The objections to the grid base methods :

1) considerable computer time to interpolate a large regular grid to represent relatively few data points,
2) lack of flexibility in responding to variable data densities in different parts of a map,
3) non-honouring of data points caused by insufficiently fine a grid in order to keep computer time down to reasonable levels, and
4) difficulty in representing fault information adequately on a continuous surface has led to the intensive development in recent years of alternative methods of generating contour maps.



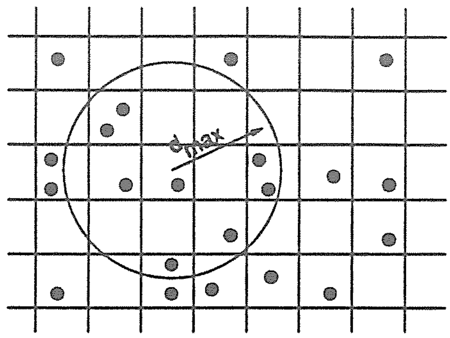


GENERAL SCHEME OF THE EXTVAL S/W

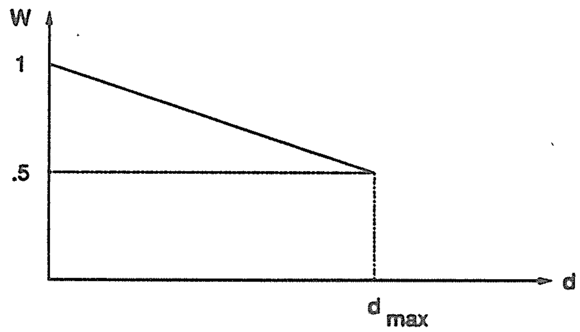
PREDICTION TECHNIQUE (one source)

. Collocation (Wenzel, Institut für Erdmessung, Hannover Universität)

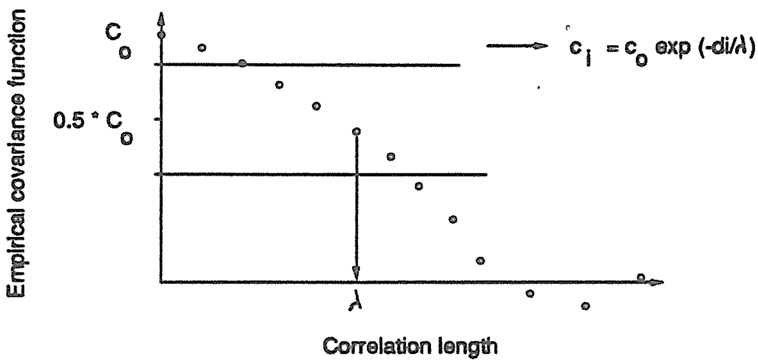
- point research



- regional field :



- prediction :



- Rejection threshold :

1) $| \Delta g_{obs} - \Delta g_{pred} | > 2.*\sigma_{\Delta g_{pred}}$

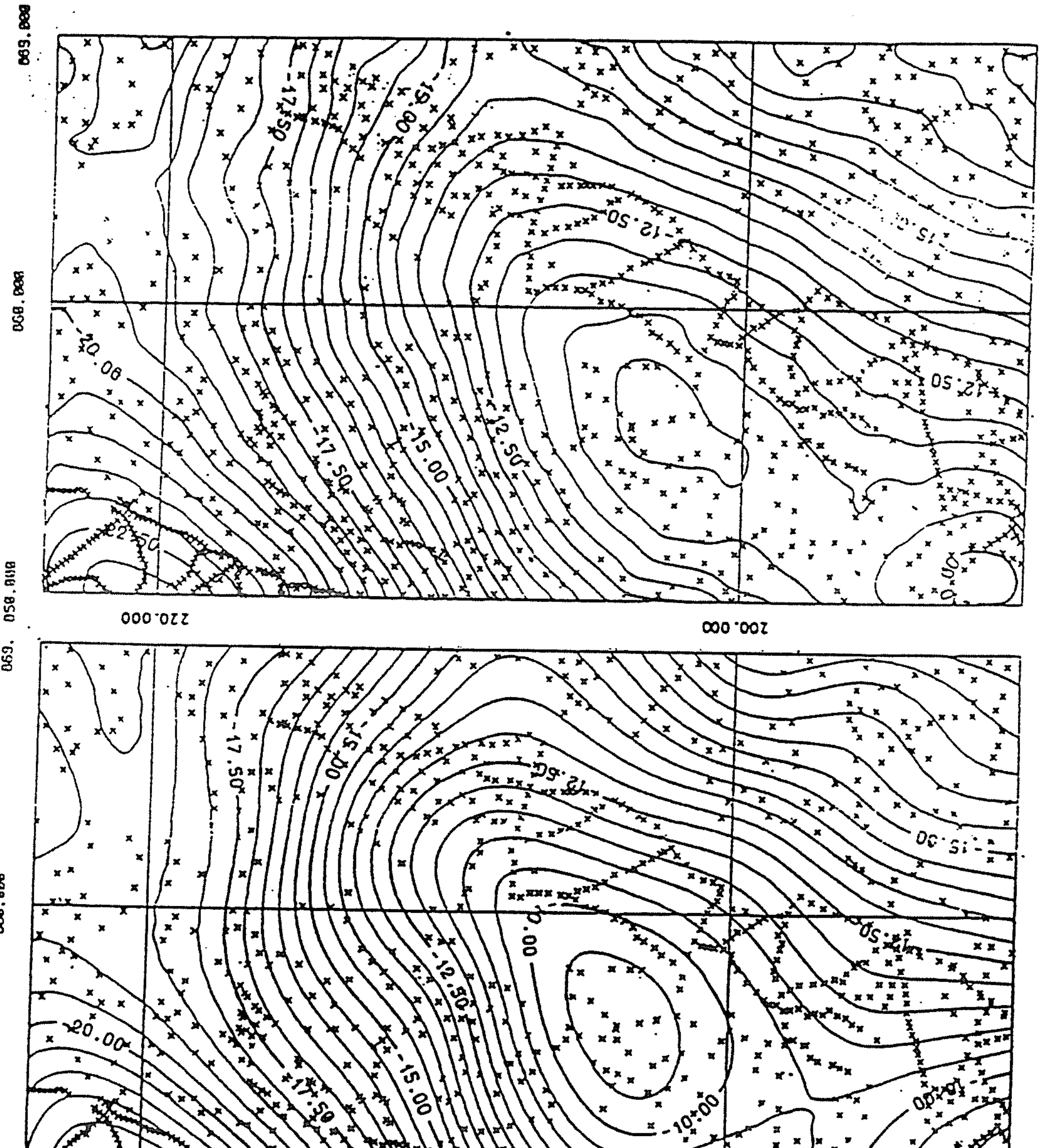
2) $| \Delta g_{obs} - \Delta g_{pred} |$ > limit error (fixed, input).

EXAMPLE 1

A : Geostatistical regional field
B : Spectral regional field

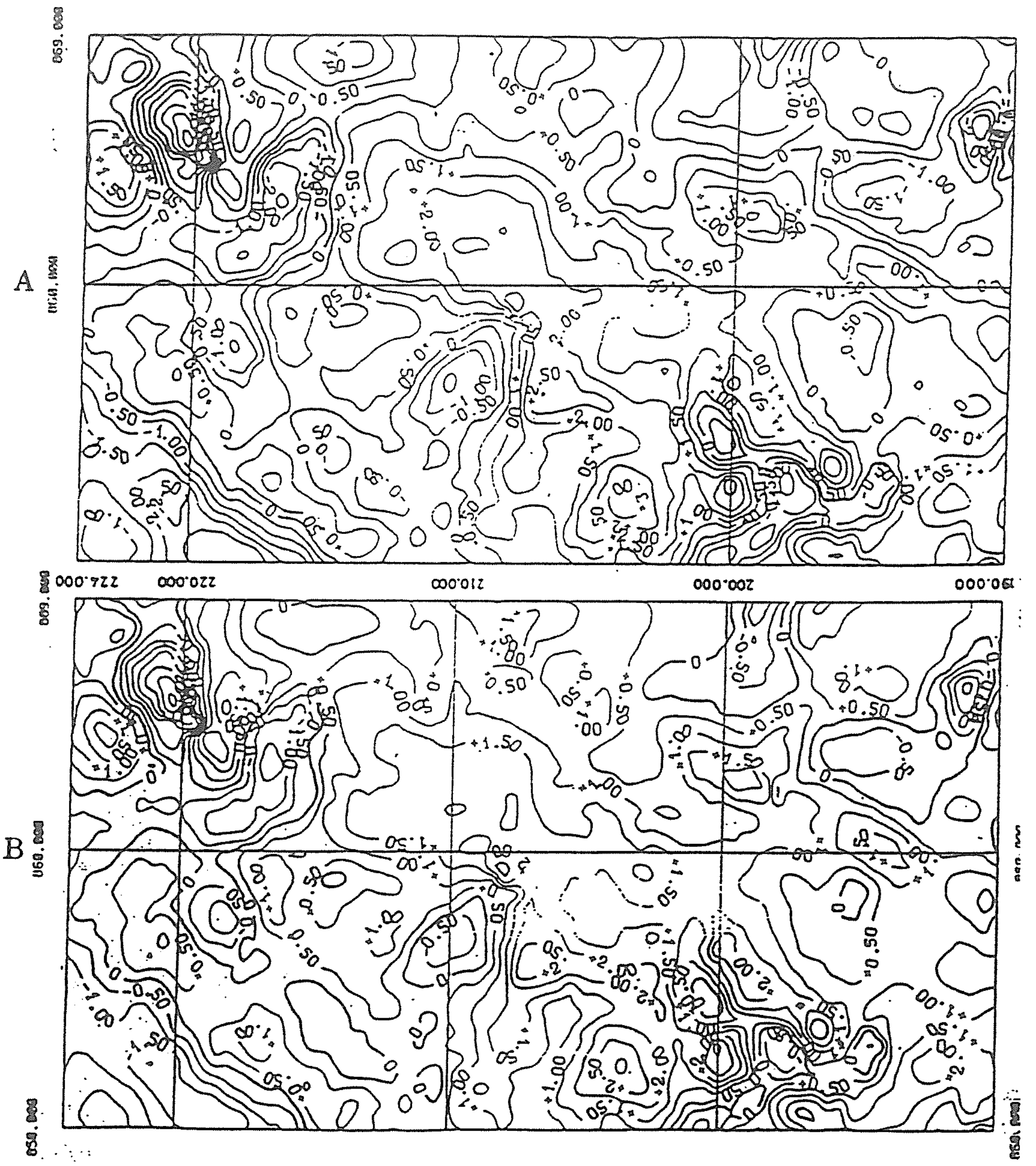
A

B



EXAMPLE 2

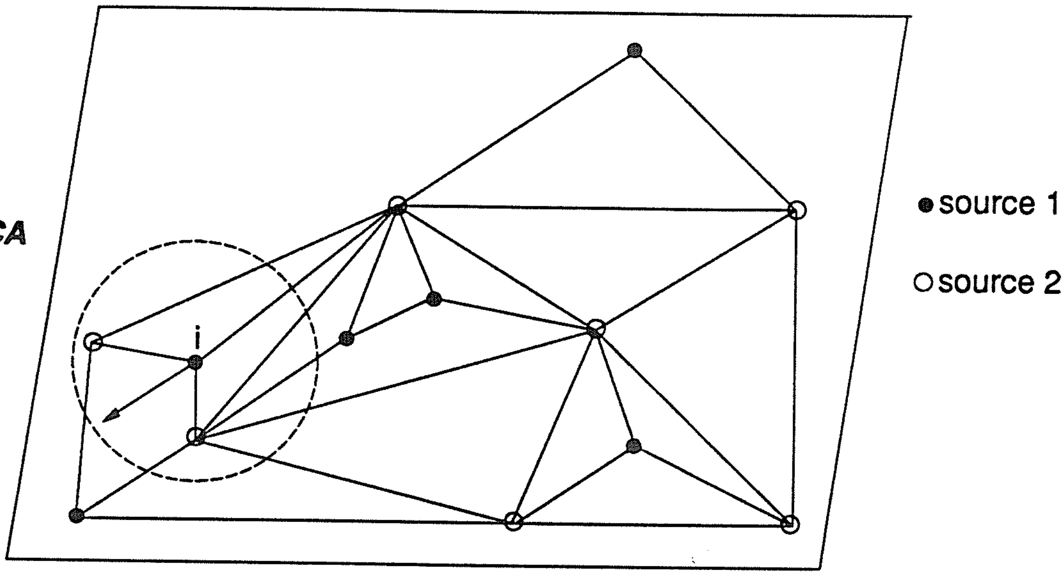
A : Geostatistical residual field
B : Spectral residual field



COMPARISON BETWEEN N SOURCES

- identify double points (reference stations) : accurate determination of bias
- identify neighbouring points from different sources : (via triangulation)

TRIANG-ECA



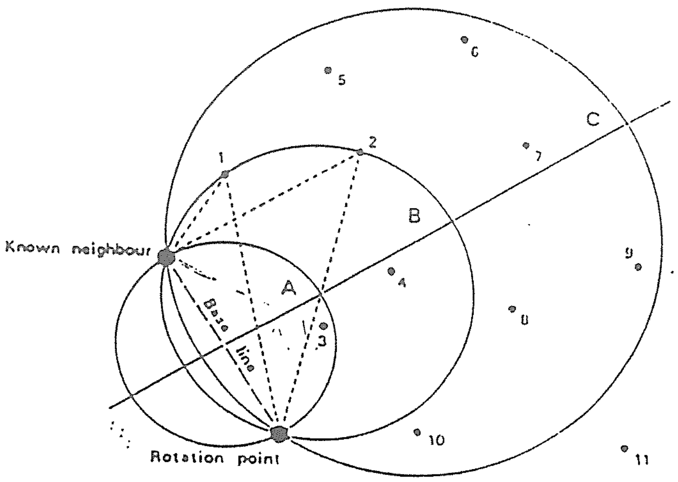
→ . list of double points
. histograms of Δg for each source

→ . mapping of Δg between two sources (new source v/s data base)
NETGEN

COMPARISON BETWEEN TWO SOURCES

. Collocation

Prediction at the points of the new source, using reference points.



Comments on M. Sarrailh Presentation

- C.C. Tscherning : when merging new data, biases are determined with existing data, new data are corrected <u>before</u> going to the archive file.

  ⇒ . the original information is lost.
  ⇒ . the bias may be determined better in the future with new data.

- Discussion between C.C. Tscherning and G. Balmino :

  The regional field may be contaminated by sets of erroneous points

  ⇒ use a spherical harmonic reference grid.

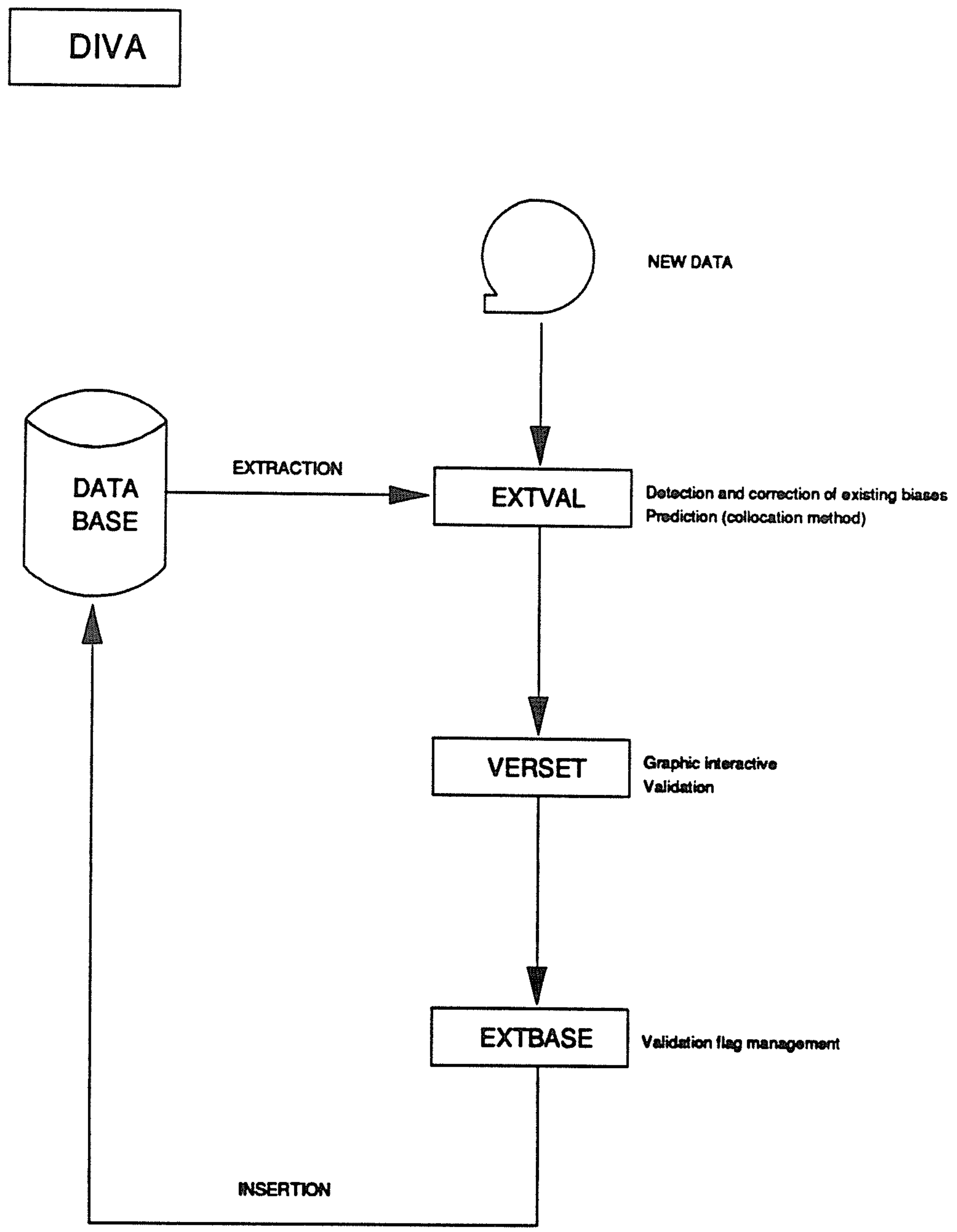
  (the best would be to compare it with a moving average which window is compatible with the resolution of the spherical harmonic expansion).

- M. Sarrailh : in the future, we could use the map of <u>h</u> together with the map of g as a criteria of rejection.

BGI VALIDATION TECHNIQUES***

Part 2 : Interactive Graphic software : VERSET

(D. Toustou)



GENERAL SCHEME

***Refer to BGI Technical Note n° 10

VERSET	(VERification SET)

THE GRAPHIC INTERACTIVE VALIDATION MODULE OF DIVA

- Multiple point management
- Colored histogram and shadded coverage display
- Searching correlations between gravity anomalies and geographical parameters
- Interactive mapping of anomalies as a visual control

SOFTWARE

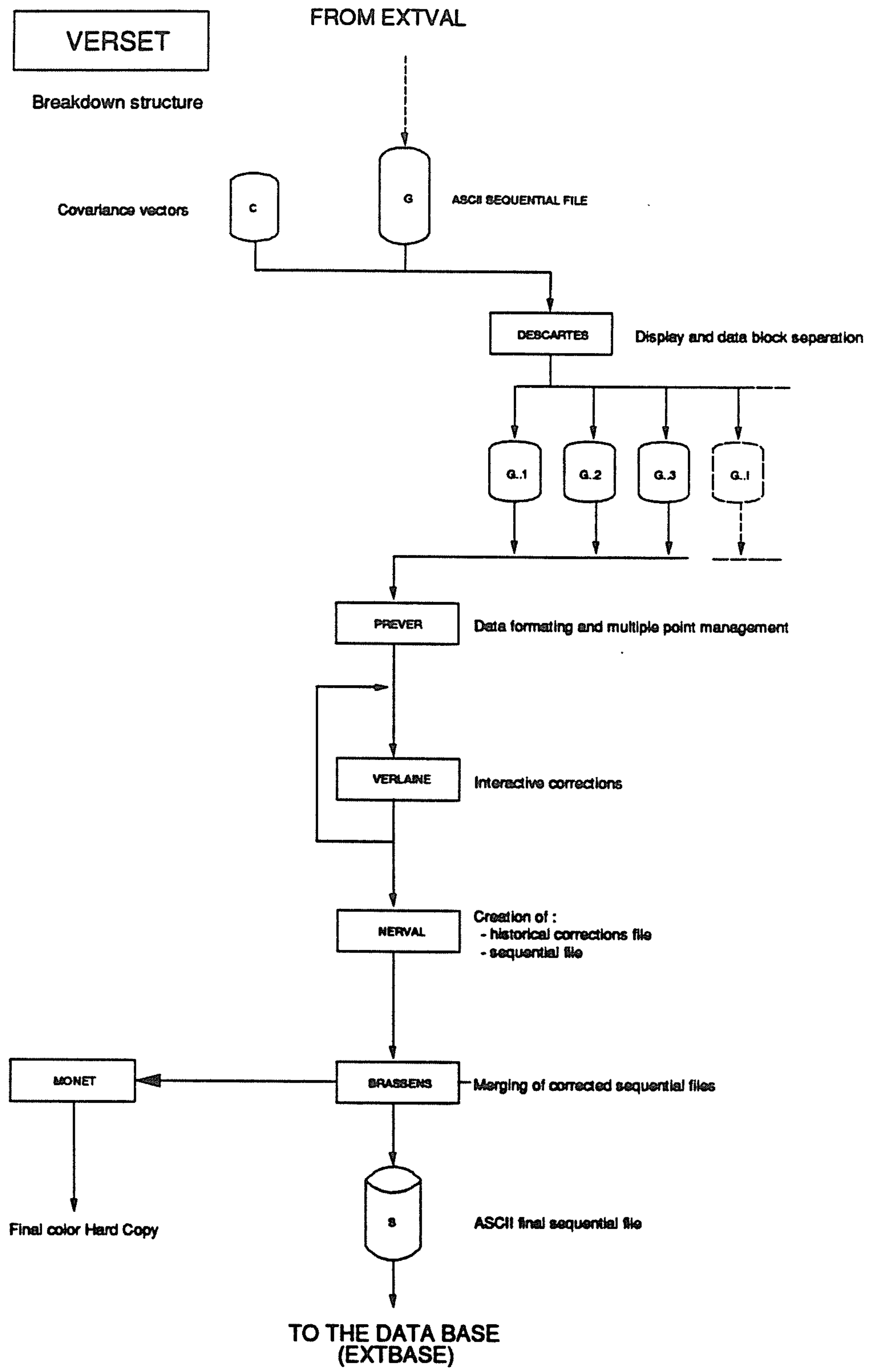
- Designed by BGI
- Written in Fortran V (77) with CDC extensions
- Graphic library used : IGL/PLOT 10 of Tektronix
- About 10000 lines of code.

HARDWARE

- Running on Cyber 992 (CDC) under NOS/VE operating system
- Graphic intelligent terminals used :
  Tektronix 4125 or 4225 with 64 colors minimum.

USUAL PERFORMANCES

- Better performances : processing of 1000 to 1500 points at a time.
- An experienced operator can validate about 5000 or 7000 points per day when everything works well.


VERSET
Breakdown structure
FROM EXTVAL
Covariance vectors
C
G
ASCII SEQUENTIAL FILE
DESCARTES
Display and data block separation
G.1
G.2
G.3
G.I
PREVER
Data formating and multiple point management
VERLAINE
Interactive corrections
NERVAL
Creation of :
- historical corrections file
- sequential file
MONET
BRASSENS
Merging of corrected sequential files
Final color Hard Copy
S
ASCII final sequential file
TO THE DATA BASE
(EXTBASE)

VALIDATION FLAG MANAGEMENT

<table>
<tr><th colspan="2">Input File</th><th>PREVER</th><th>VERLAINE</th><th colspan="2">Output File</th></tr>
<tr><td rowspan="4">New Data
Extended Archive format
175 char.</td><td rowspan="2">0</td><td>1</td><td>1
2
3
4</td><td>1
2
3
4</td><td rowspan="4">Archive
format

160 char.</td></tr>
<tr><td>9</td><td>9</td><td>9</td></tr>
<tr><td rowspan="2">5</td><td>5</td><td>1
2
3
4</td><td>1
2
3
4</td></tr>
<tr><td>9</td><td>9</td><td>9</td></tr>
<tr><td rowspan="7">Data from BGI
data base

Extended CGDF fromat

85 char.</td><td rowspan="2">1</td><td>1</td><td>1
2
3
4</td><td>1
2
3
4</td><td rowspan="7">CGDF
Format

70 char.</td></tr>
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4</td><td>1
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<tr><td>9</td><td>9</td><td>9</td></tr>
<tr><td>3</td><td>9</td><td>9</td><td>9</td></tr>
<tr><td rowspan="2">5</td><td>5</td><td>1
2
3
4</td><td>1
2
3
4</td></tr>
<tr><td>9</td><td>9</td><td>9</td></tr>
</table>

0 not yet valided
1 good
2 doubtful
3 outdated
4 modified (good)
5 predicted false
9 previously outdated

DATA STRUCTURE

INPUT FILE

Sequential formatted Ascii : new data : 175 char. (ext. Archiv. F)
from BGI data base : 85 char. (ext. CGDF F)

INTERNAL STRUCTURE : IP 3

All the data fields are converted to integer

2 BINARY DIRECT ACCESS FILES :

.. Parameters file — record length : 18

- The 2 first records are the header of the file with general statistics.
- Current record : 1 record = 1 block of points : 18 parameters like :
  - starting point number
  - number of points
  - min, max in X, Y, Z, G...

.. Data file — record length : 4096

- 1 record = 256 points or stations
- for each station 16 parameters :
  - longitude
  - latitude
  - elevation
  - G observed value
  - Free air anomaly
  - Bouguer anomaly
  - sequence number in the source
  - duplicate point flag
  - validity flag
  - modification flag
  - estimate offset
  - source number
  - trend value
  - standard deviation
  - 2 unused

OUTPUT FILE

Sequential formatted Ascii : new data : 160 char. (Archiv. F)
from BGI data base : 70 char. (CGDF F)

DESCARTES

. Display of gravity observation coverage

. Interactive block decomposition of the data set

- definition of the extraction polygons (maximum : 50 vertices)
- management to avoid overlaps.

PREVER

. Data reformating : sequential file → IP3 structure (2 direct access files)

. Data block separation : 100 geographical and identical boxes ⇒ fictitious decomposition to optimize :

  - the update of the several views,
  - the number of graphic segments.

. Multiple point management using SORT-MERGE CDC software for each multiple point : all stations are sorted in descending order according to the absolute value of prediction offset
⇒ only the least false station is not declared outdated.

NDUO		Observation point		IVAL
0		Single point		1, 2, 5, 9
1		First station		1, 2, 5, 9
2		2nd station		9
2		3th station	multiple point	9
3		last station		9
4		Complete double point		9
1		1st station	multiple	1, 2, 5, 9
3		last station	point	9
0		Single point		1, 2, 5, 9

NERVAL

Creation of :

- an historical corrections file
- Ascii sequential file (corrected data)

BRASSENS

Merging of all the corrected sequential files to build up again the corrected original data set.

MONET

Production of a final color Hard Copy

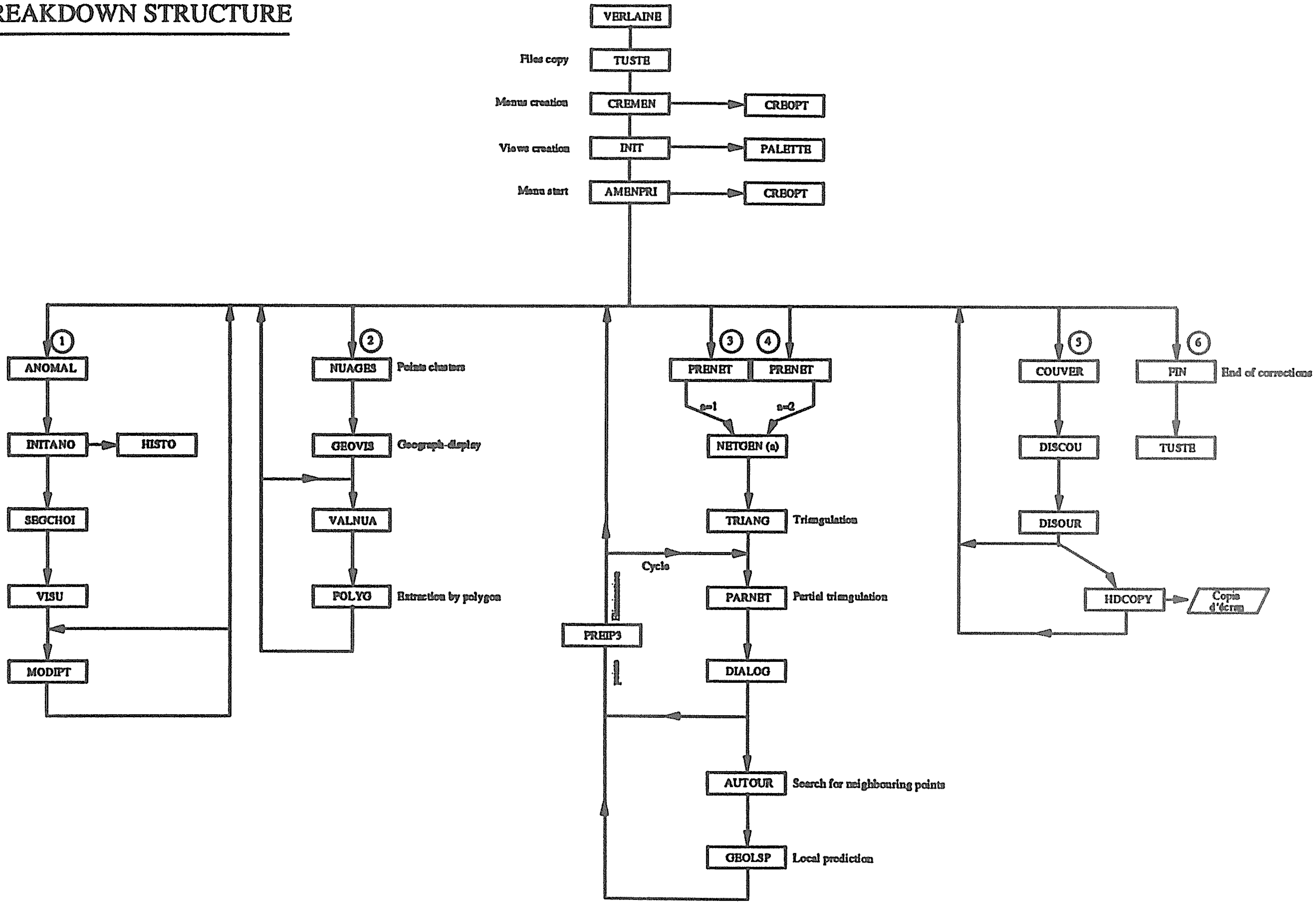
VERLAINE

All the Verset modules are built arount VERLAINE. By means of a menu, VERLAINE puts at the user's disposal, four interaction tools for finer data validation.

MAIN MENU		
SHADED COVERAGES	(1)	Geographical display upon selection of various functions of the data (e.g. anomaly) with colored histogram. Apart from longitude and latitude, all the station parameters can be corrected.
POINT CLUSTER	(2)	Simultaneous displays of the point cluster of which base parameters have been chosen by the user, and geographical representation, so as to study correlations (by interactive definiton of polygons). Only validation flags can be changed.
LEVEL AND TRIANG.	(3)	After triangulation, display of colored maps with contour lines and stations. Possibility to change the validation flag of points with new display and new partial prediction around the modified points****.
GRADIENT & TRIANG.	(4)	Same as above, but colors are assigned depending on the gradient.
DATA COVERAGE	(5)	Display of the data coverage with different symbols for each source and list of source references.
END OF CORRECTIONS	(6)	

****Question was raised on the necessity of recomputing the trend (see technical discussion C)

BREAKDOWN STRUCTURE



MENU OF STATION PARAMETERS

STATION NUMBER : 15 873

SOURCE NUMBER : 3528020

LONGITUDE : 3.1687

LATITUDE : 39.3308

ALTITUDE : 10.3 m

G. VALUES : 0.00 MGAL

FREE-AIR : 66.6 MGAL

BOUGUER : 64.3 MGAL

VALIDATION : OK
1-OK
2-Doubtful
3-Lapsed

PREDIC. OFFSET : 8.4MGAL

STAND. DEVI. : 3.7MGAL

Change can be done on these parameters only.

GRAPHIC SYMBOLS MANAGEMENT

Validation Flag	Marker			Multiplicity Flag NDUO (4)	Modification Parameter ICHANG (5)
1	+	O.K.		0 or 1	0 or 1
2	□	doubtful		0 or 1	0
3	◇	outdated		0 or 1	0 or 1
4	*	good after modification		0 or 1	1
5	O	predicted false		0 or 1	0
9	◇	"completely" false (unmodifiable)	complete double point	> 1	0
			previously lapsed in the data base	∀	0
			outdated extremum	0 or 1	0 or 1
	⊠	(1)			

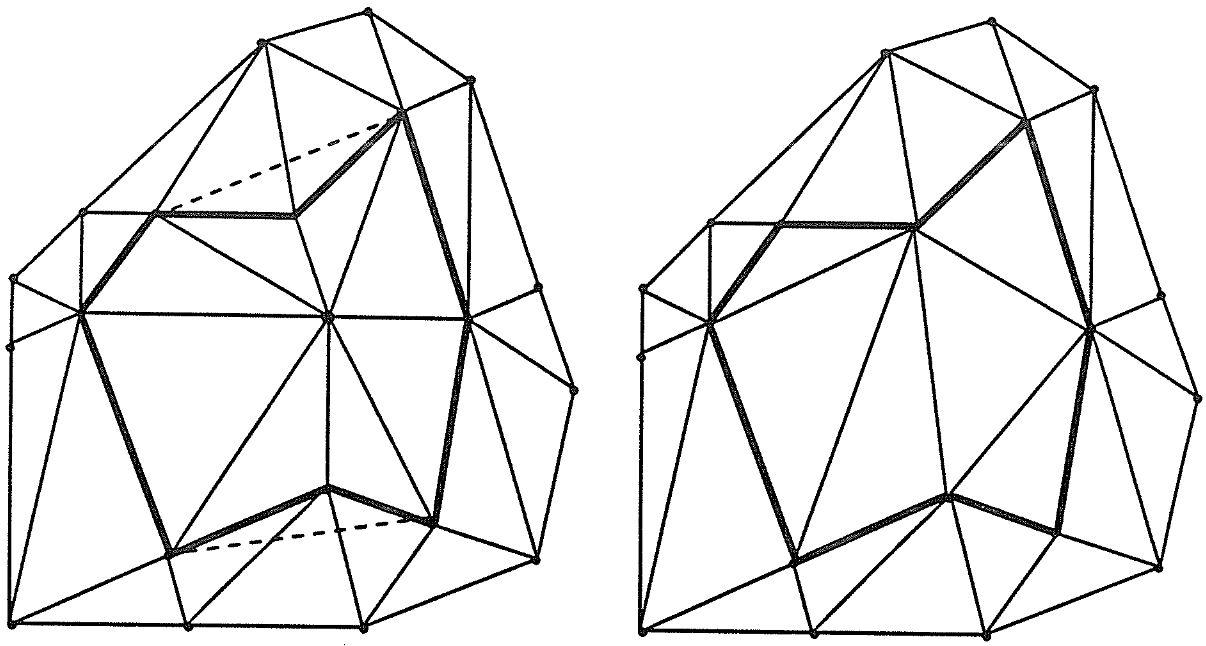
(1) rounded coordinates point

TRIANGULATION

. Used algorithm : from M. Gerstl, G. Heindl, E. Reinhart (Canberra, 1979)

. Concept :
  - minimum perimeter criteria

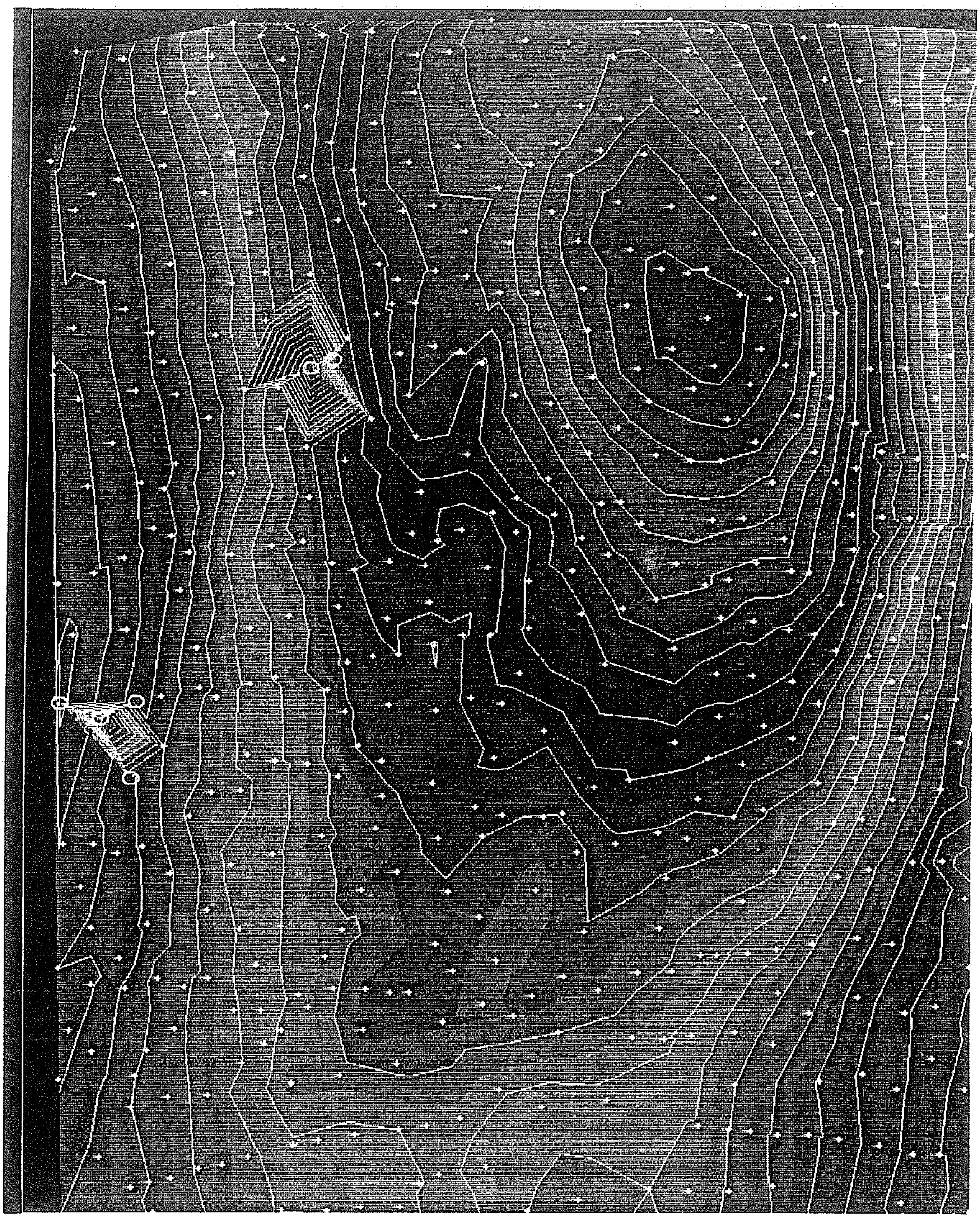
LOCAL TRIANGULATION



SEARCH FOR NEIGHBOURING POINTS

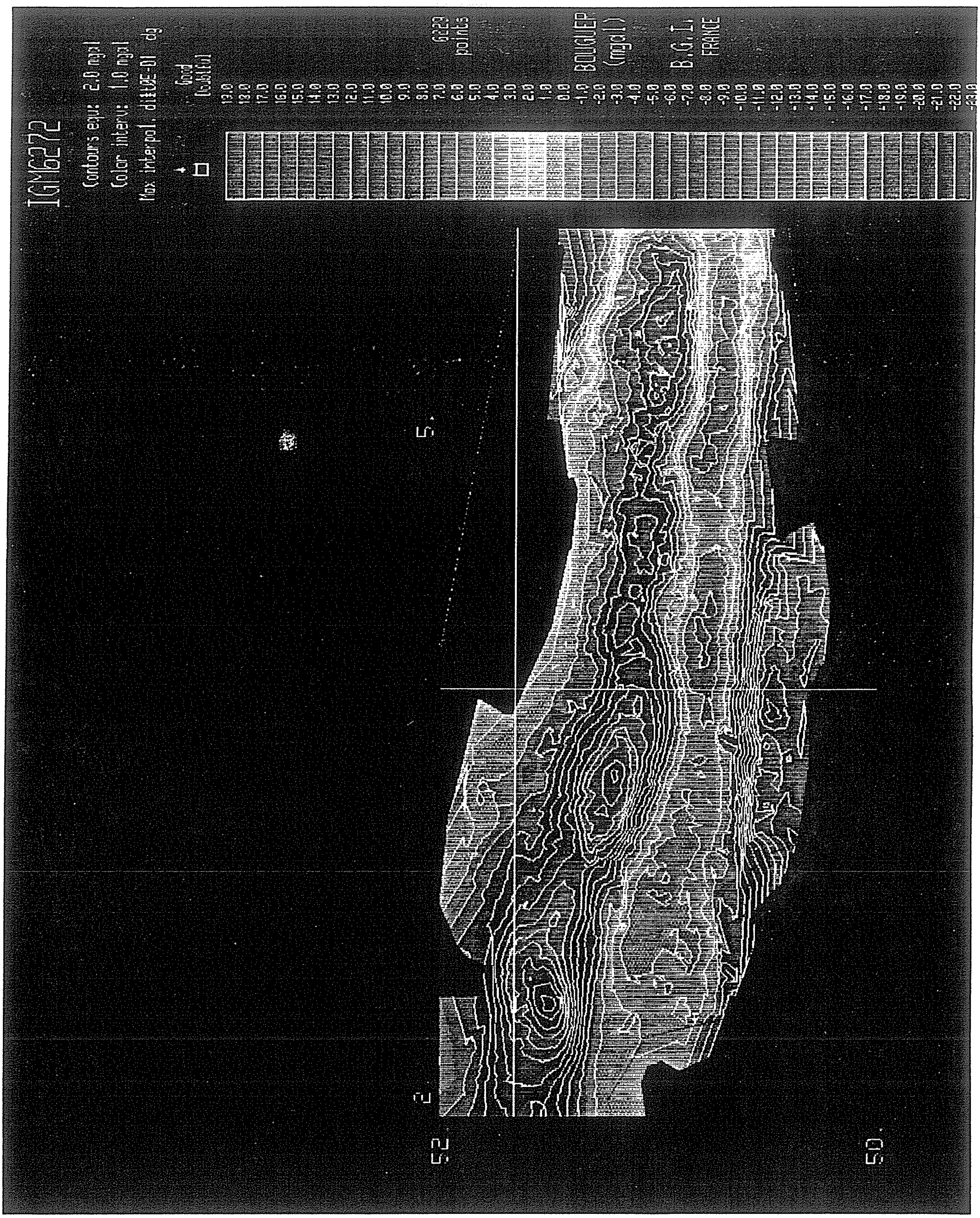
. Recursive calls to two identical subroutines with pile management

Bouguer anomaly map with six measurements predicted "doubtful"



Bouguer anomaly map. Same as 1, but after correlation of two erroneous data

Example of final product : Bouguer anomaly map for an extended area



METHODS DEVELOPED AT G.S.C.

(J.D. Rupert)

J. Rupert's presentation concentrated on the validation of marine gravity data.

After pointing out the crucial difficulties illustrated by a few examples, the emphasis was on the various softwares developed, their characteristics and performances.

1. EDPLOT Software

- Interactive editing of dynamic sea surface gravity data (1984)
- INPUT : Index sequential file (indexed on time)
- DISPLAY :
  . free air
  . observed gravity
  . Eötvös
  . depth
  . G accuracy
  . time (day, hour, minute) - US data
- OUTPUT : listing of deleted points
- HARDWARE : VAX, TEKTRONICS 40XX
- SOFTWARE : FORTRAN, Data plotting DPICT, UNIRAS Version ?
- EDITING :
  . delete one point
  . delete an interval of points
  . restore points
  . rescale plot.

2. ASSOB Software

- Adjustment of sea surface observations
- Time sequential data ⇒ line segments.
- Line segments sorted by longitude.
- Crossovers found.
- Observation records created between crossovers.
- Gauss-Seidel interactive method or matrix inversion.
- Data discarded when observation rejected.
- Test for disconnected network :
  . add 1 milligal to grial g-values,
  . adjust if trial g's do not return to previous value-network disconnected.
- Used to adjust 600.000 points off the East coast of Canada.

3. EDGRAV Software

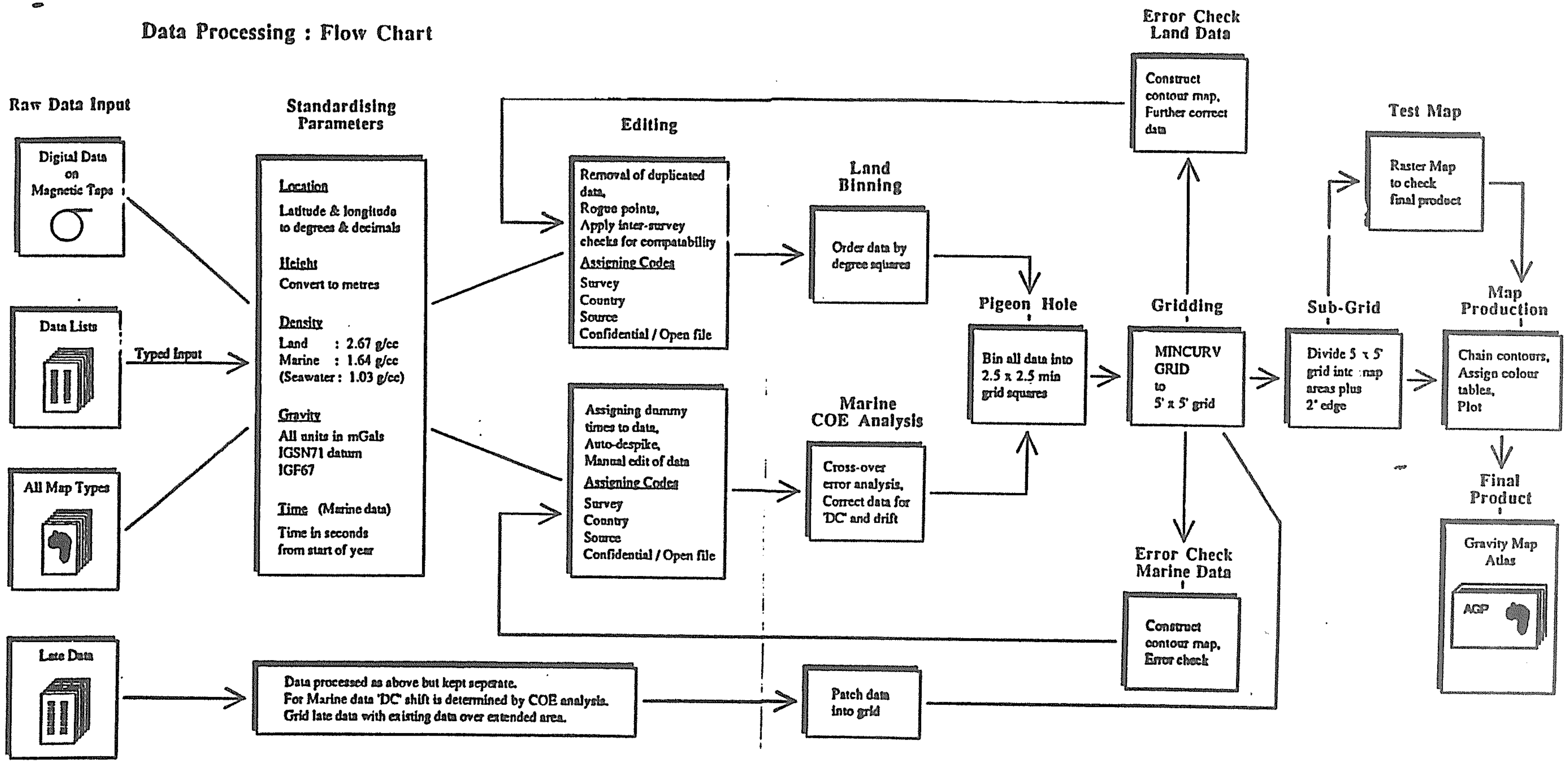
Interactive editing of data using colour contours (1985).

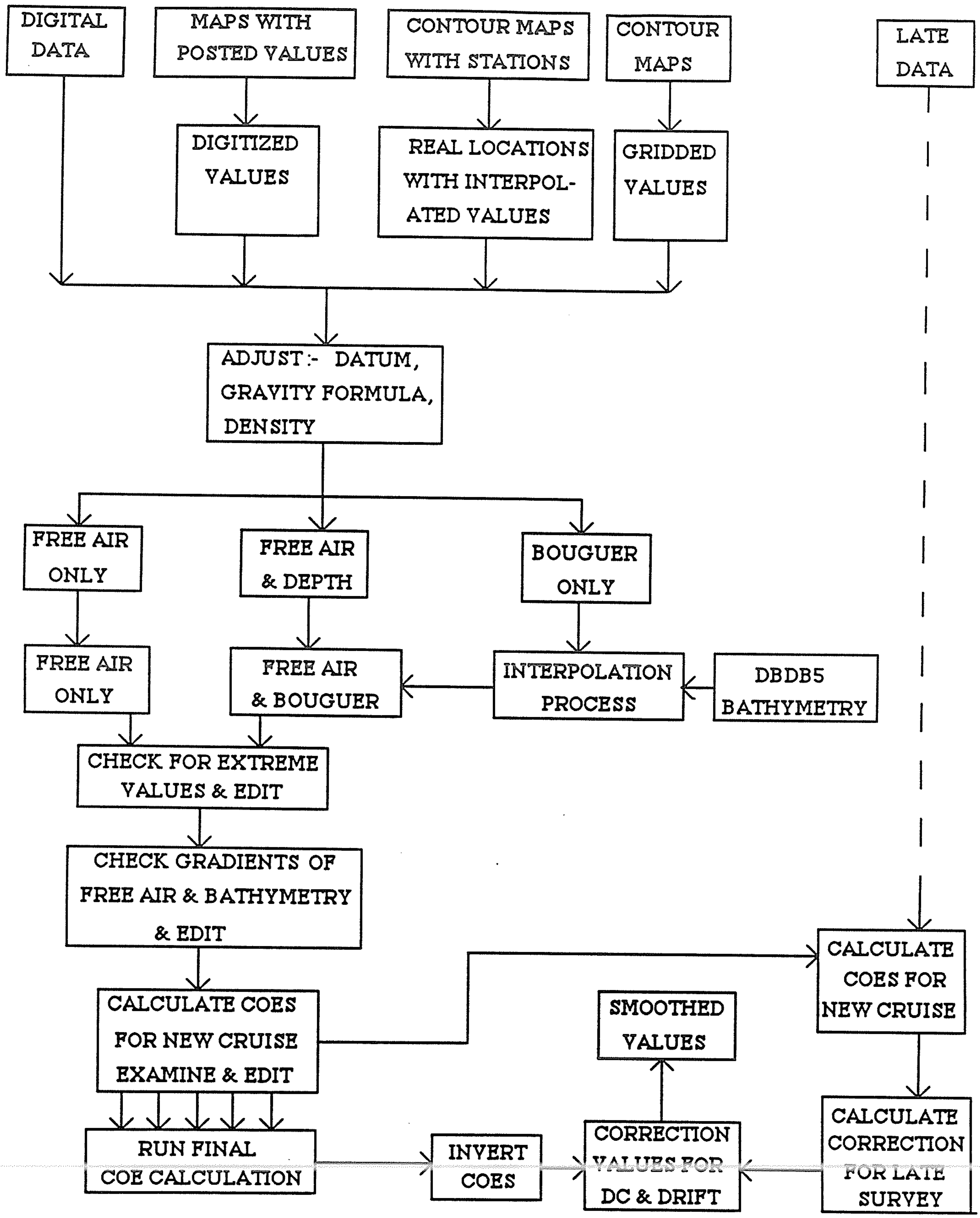
- triangulation and contouring (Watson algorithm).
- Input : national gravity data base standard retrieval record.
- Output : data file + listing of deleted points used to update the data base.

DATA VALIDATION PROCEDURES AT ULIS

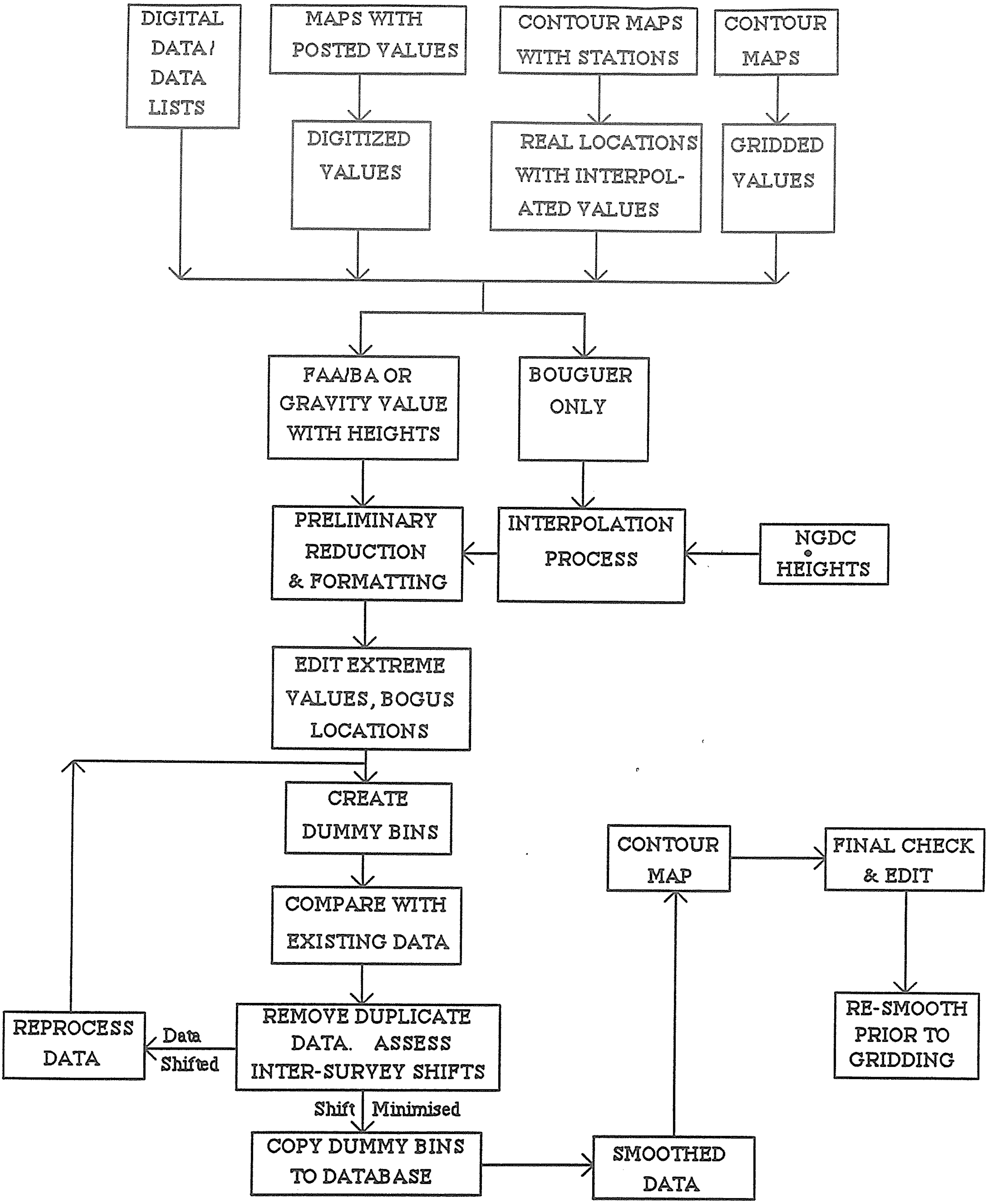
(I. Windle)

Data Processing : Flow Chart





Overview of Procedures (1)



Overview of Procedures (2)

Processing of Land Data

1 Introduction
2 Raw Gravity Data
3 Accuracy of Land Gravity Data
4 Adjustment to Common Datum
5 Binned Gravity Data
6 Data Verification

Adjustment to Common Datum

The original technical specification of the African Gravity Project stated that wherever possible all the land and marine gravity should be reduced using the following parameters:

'Observed Gravity will be adjusted to the IGSN71 datum. New international gravity ties currently being made for Africa and subsequent improvement of IGSN71 base station values will be incorporated into the project as and when they become available to ULIS.

Theoretical Gravity (γ) will be based on the International Gravity Formula IGF 1967 where:

$$\gamma = 978031.85\,(1 + 0.005278895 \sin^2\theta + 0.000023462 \sin^4\theta)\ \text{mGal}$$

where θ is the geodetic latitude of station.[1]

Locations of stations will be given in degrees (and decimals) latitude and longitude as well as UTM co-ordinates.

Free air Correction will assume the value of 0.3086 mGal m-1.

Bouguer Correction will use a reduction density of 2.67 g/cc on land and 1.64 g/cc at sea.

Terrain Corrections where already known and applied will be incorporated in the Bouguer anomaly maps.'

Sample Land Data

```
    1         2          3          4        5       6  78   9     10  11 12      13      14
5.3650   27.0317   977823.5      728.0 -28.9-110.3L0   0.0   ORSCARORS
5.3583   27.0750   977829.0      700.0 -31.9-110.2L0   0.0   ORSCARORS
5.3383   27.1100   977831.7      684.0 -33.8-110.3L0   0.0   ORSCARORS
```

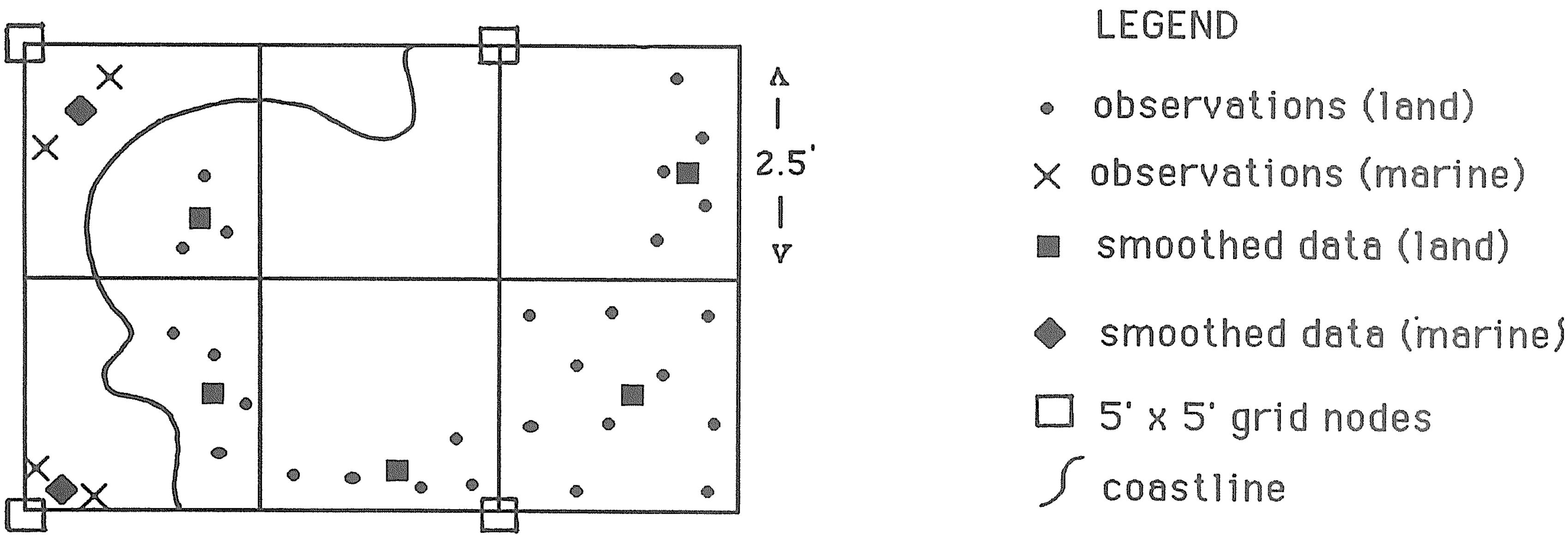
Sample Marine Data

```
5.7592   54.9859   978077.0   -4976.0  -6.9-335.1M0       V1910AFRLAM19731600
5.7575   54.9492   978068.3   -5021.0 -15.5-329.6M0       V1910AFRLAM19735200
5.7565   54.9430   978068.4   -5049.0 -15.4-331.7M0       V1910AFRLAM19738800
```

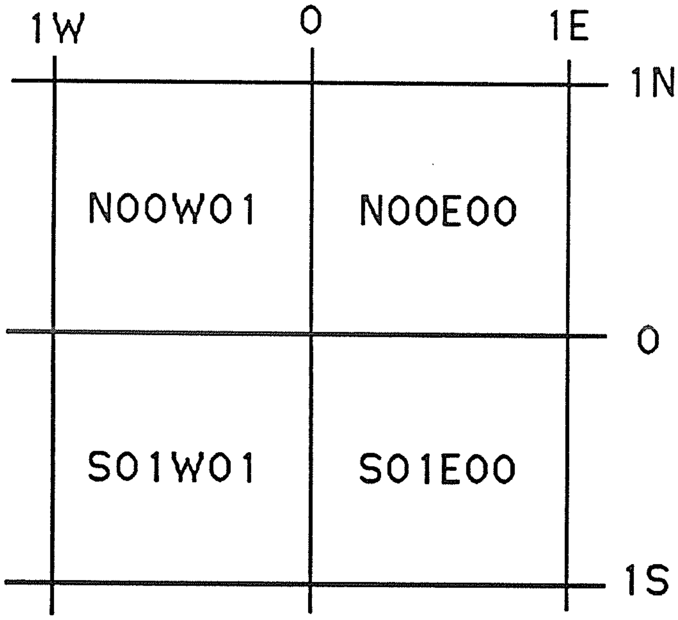
1	F10.4	LATITUDE (DEGREE)		
2	F10.4	LONGITUDE (DEGREE)		
3	F10.1	OBSERVED GRAVITY (mGal)		
4	F10.1	ELEVATION (m) -32000.0 = NO VALUE		
5	F6.1	FREE AIR ANOMALY (mGal) 9999.9 = NO VALUE		
6	F6.1	BOUGUER ANOMALY (mGal) 9999.9 = NO VALUE		
7	A1	TYPE OF DATA	'L' -->	ON-SHORE
			'M' -->	OFF-SHORE
8	I1	CONFIDENTIALITY	0 -->	NON CONFIDENTIAL
			1 -->	CONFIDENTIAL
9	F5.1	TERRAIN CORRECTION (mGal)		
10	A5	SURVEY CODE		
11	A3	COUNTRY CODE		
12	A3	SOURCE CODE		
13	I8	TIME IN SECONDS OF MEASUREMENT FROM START OF YEAR (MARINE ONLY)		
14	2X	BLANK - 2 EXTRA DATA FIELDS		

Table 1 Examples of non-confidential gravity data and format for land and marine areas

SMOOTHING


2.5'
LEGEND
observations (land)
observations (marine)
smoothed data (land)
smoothed data (marine)
5' x 5' grid nodes
coastline

BINNING



AGP - LAND DATA

No. of Bouguer Anomaly Data Points	777,552
No. of Free Air Anomaly Data Points	750,913
No. of Smoothed Bouguer Anomaly Points	245,374
No. of 5' x 5' Grid Squares Containing Data	124,266
% of 5' x 5' Grid Squares Containing Data	33%

TECHNICAL DISCUSSION A : DATA BASES - SOFTWARE INTERFACES

The discussion concentrated on the following items :

- APPROACH

Volume, utilization...

- TECHNIQUES

Computer, systems
In house vs. commercial DBMS

- FILES

Main working file (s)
Additional files : sources, countries
Archive
Formats, accuracy...

- UPDATING

New sources
Obsolete data
Flagged (erroneous data) ← validation

Participants expressed their opinion on some or all of these points.

J.D. Rupert

Data bases :

1. Canadian data

   600.000 data in base (canadian) : production uses S2K (SIS/CDC) →to go to ORACLE (Vax) in 1990 - tests already made.
   + 20 000 new points/year.

2. Additional data non distributed.

   Requests : ≈ 300 external requests/year.

Archive :

On magnetic tapes ⇒ optical disks in the near future (worm drive).

C.C. Tscherning

Data base :

≈ 10^6 points in the base.

Few requests from outside (≈ 5/year).

Large data sets are coming from oil/mining companies.

Data retrieval S/W :

Non integrated to graphics

Runs on Apollo 10 000

Uniformisation of D.B. systems is desirable

Most efficient systems : all based on geographical keys.

Archives :

No archive except original data on tapes (not duplicated, nor re-read).

If a big data set comes in, KMS has to re-create the data base...

Wishes :

BGI should publish in the Bulletin d'Information the new sources of data acquired and the list of the newly validated data.

M. Sarrailh

. Comments on adding data to the base : current DBMS updated for this purpose (efficient).

. ULIS philosophy : good for regional data base, not for worldwide.

. Cost : 1 000 points in 1 sec retrieved on the CYBER 992.

. Terrain correction is not stored in the CGDF... a mistake from the begining ! ⇒ could be interpolated in precomputed grids (where available) when needed.

I. Windle

In the near future :

- Bin philosophy kept but extraction by source added.
- Marine data might be stored by survey instead of bins.

M. Mennechet

Two systems are currently used at BRGM, one is ORACLE.
(present status as far as gravity is concerned is not known by the BRGM representant).

Ch. Poitevin

Change of computers soon to happen in Brussels (Apollo main stations + 8 Apollo mini-stations), with optical fiber links ; ORACLE will likely used.

Mme Legeley

Archaic system still in use at ORSTOM.

TECHNICAL DISCUSSION B :
ACCELERATION TECHNIQUES FOR MEASUREMENT SELECTION

M. Sarrailh, leader of this panel, gives an account of various techniques :

- Equal block decomposition.
- Triangulation : minimum parameter algorithm-Gerstl - see next page. Delaunay decomposition.
- Tree organisation.
- Tricks to be used when data cannot be all in core (overlapping blocks).
- Accelerated procedures for grid generation.

The discussion mostly runs on the interest of the triangulation approach and various applications.

From : Gerstl, M., G. Heindl, E. Reinhart: "Interpretation and Approximation by Piecewise Quadratic Smooth Functions of Two Variables", paper pres. 17th IUGG General Assembly, Canberra, 1979.

The Minimum Weight Triangulation

We give a brief description of the concept of a minimum weight triangulation.

Let be given a set, V, of N points in the plane, called vertices. In the set of the $\binom{N}{2}$ possible straight line segments, called edges, between vertices in V, we consider subsets such that no two edges intersect in a point which is not an endpoint of both of the edges. A triangulation T of V is defined to be maximal***** among such subsets.

This definition implies : Each mesh of a triangulation T is a triangle which contains no point of V but its three vertices. Each edge of the convex hull of V is in T. We take advantage of this property when constructing a triangulation of V. The edges on the boundary can be cancelled afterwards if not required.

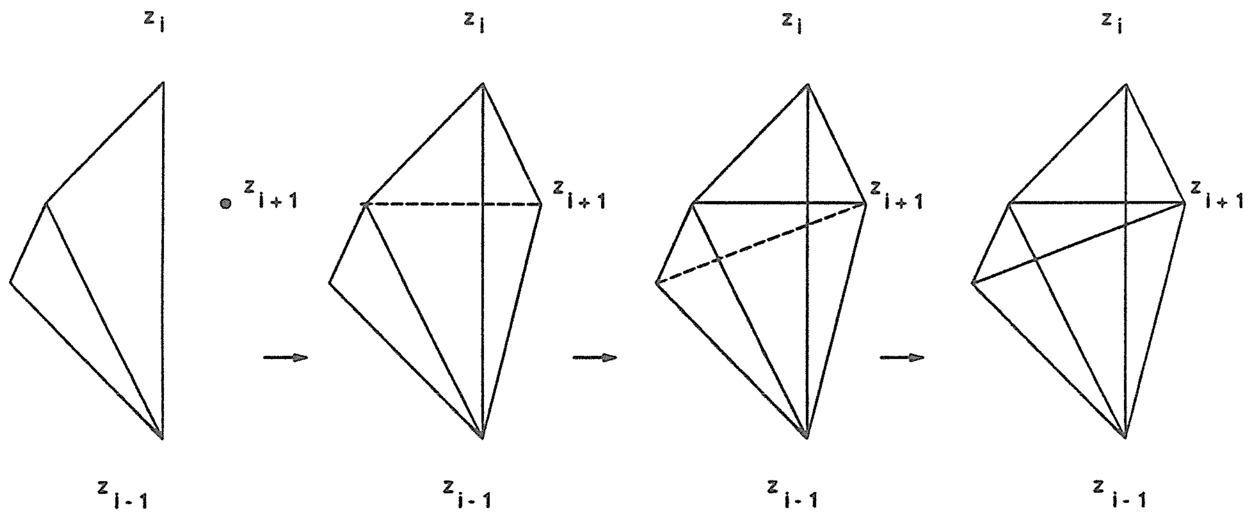
We are interested in a triangulation of which the sum of the edge lengths is minimal among all the triangulations of V, for it is known from the theory of finite elements that such a minimum weight triangulation has better numerical properties.

Our algorithm for constructing a minimum weight triangulation from a given set of vertices was inspired by the Voronoi diagram algorithm of M. Shamos and D. Hoey. For that purpose, the points $z_i = (x_i, y_i)$, i = 1,..., N, have to be ordered such that z_{i+1} is not contained in the convex hull of $\{z_1,..., z_i\}$ which is assured for instance if for every i z_i is lexicographically smaller than z_{i+1}, i.e.

$$x_i < x_{i+1} \vee x_i = x_{i+1} \wedge y_i < y_{i+1}.$$

If we have formed a minimum weight triangulation of $\{z_1,..., z_i\}$ for some i < N and marked its convex boundary H_i, then the point z_{i+1} must be connected with all the vertices of H_i which it sees. Any edge seen by z_{i+1} must be cancelled it it can be intersected with a shorter edge originating at z_{i+1} (see fig. 1). In this way the edges surrounding z_{i+1} are successively processed. This algorithm is dual to the construction of the Voronoi polygon of z_{i+1} and works also in those cases where the Voronoi diagram is not the dual of a triangulation.

Fig. 1.



The storage required by this procesure consists of an ordered list of the vertices on the boundary of the actual convex hull and, for each point z_i, of a clockwise ordered list of the vertices connected with z_i at the present time.

*****Denoting the system of all such subsets by S, a maximal subset is defined to be an element of S which is not a proper subset of any other subset in S.

TECHNICAL DISCUSSION C :
ACCURACY OF PREDICTION METHODS
IDENTIFICATION OF ERRONEOUS DATA

The panel leader makes an extensive presentation which covers most aspects of the subject. The main facts are related below :

1. GENERAL COMMENTS

- A comparison of a "geographicaly located" quantity to quantities in the vicinity is a general test for error identification.
- Interpolation program modified so that values closer than e.g. 1 m are not used for prediction/interpolation.

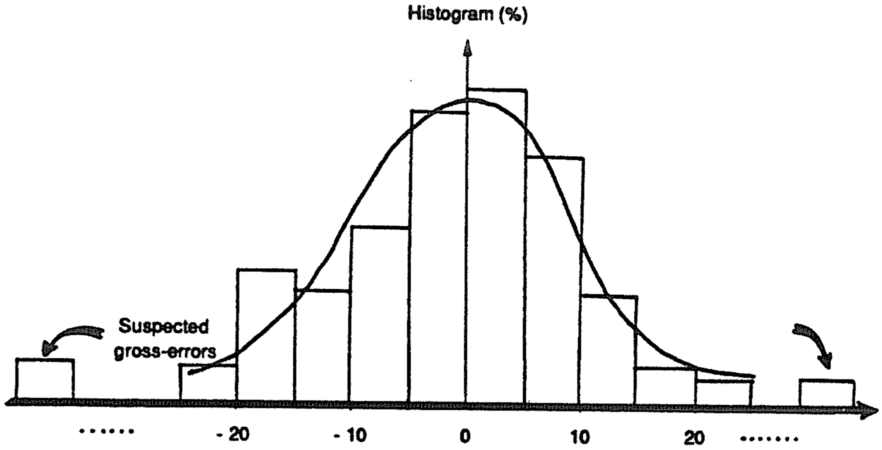
  Error detection procedure : | OBS. – PREDICTED |> LIMIT ?

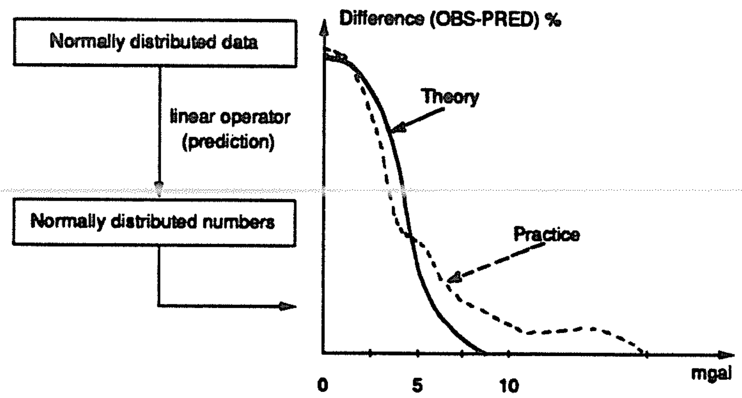
  ⇒ which limit ?
- Main tool : collocation (Wiener-type estimation technique, here related to integral equations with reproducing kernels in physical geodesy).

2. STATISTICAL PROPERTIES OF OBSERVATIONS

Gravity data without long wavelength information and without topographic influence are, in the absence of (too-many) gross errors :

- normally distributed.
- of mean value ≈ 0 mgal.
- of standard deviation ≈ 10-20 mgal.





3. LEAST SQUARES COLLOCATION

Pred =	{covariance obs_i with pred.}^{T}	∘	{covariance obs_i - obs_j}$^{-1}$	∘	{obs}
	C_{iP}		+ error. var $\overline{C}_{ij}$		Δg_j

. Error estimate :

$$\sigma^2(obs-pred) = C_{pp} - \{C_{ip}\}^T \{\overline{C}_{ij}\}^{-1} \{C_{jp}\}$$

⇒ Is this a good estimate ?

. Not for an individual quantity but O.K. for "many" quantities !

. Not "good" because covariance function changes from area to area :

→ Estimate covariance function for all small areas ??

Too complicated : ⇒

(I) Update C_{pp} everytime ?
(II) Update mean-value or local polynomial trend ?

. Local collocation used in software "GEOGRID" : (N closest points).

$$C(\psi) = C_o(1+\psi/\alpha)e^{-\psi/\alpha}$$

"Second order MARKOV covariance function"
C_o = local variance
ψ = spherical distance
α = correlation distance * 0.595 (typically 5-20 km).

. Suspected gross-error detected if :

$$|OBS - PRED| \geq 3 * \left(C_{pp} - C_{Pi}^T\{\overline{C}_{ij} + Err_{ij}^2\}^{-1} C_{pj}\right)^{1/2} \quad \text{and} \geq \text{given limit}$$

. This gives <u>many</u> suspected errors.

⇒ (A) update C_{pp} locally using

$$C_{pp} = \sum_{i=1}^{N} \Delta g_i^2$$

N closest points

⇒ (B) use very short correlation distance ⇒ pessimistic error estimate.

4. DISTANCE - WEIGHTED INTERPOLATION :

$$WSUM = \sum_{j=1}^{N} 1/D_j^n$$

$$WF = \sum_{j=1}^{N} OBS_j/D_j^n$$

n = power of interpolator (2 in general for harmonic functions - from Poisson kernel).
D_j = distance to j' th obs.
PRED = WF/WSUM

No error estimate available !

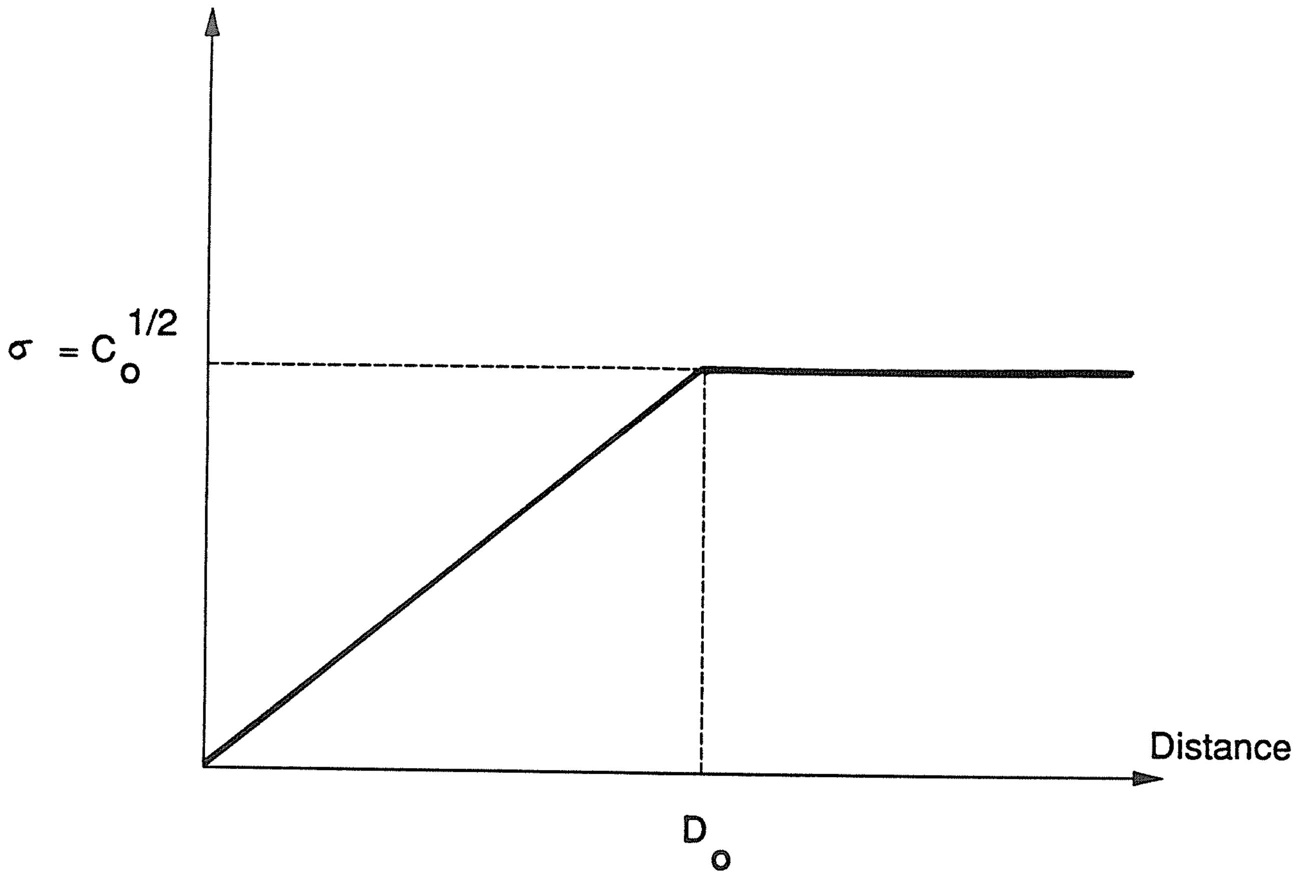
⇒ construct error estimate with :
D_o = distance to first zero point of covariance function
D_{min} = distance to the closest point.

Then, if $D_{min} < D_o$:

$$\sigma(OBS - PRED) = ((D_{min}/D_o)^2 C_{pp} + Err_{obs}^2)^{1/2}$$

(Err_{obs} : error-estimate of observed quantity to be evaluated).

Error estimate



(ex. if 360 x 360 reference field removed ⇔ 50 km resolution,
D_o should be ≈ 25 km).

5. FURTHER TEST

One should have :

$$\frac{|\,Obs - pred\,|}{error} \approx t - distribution$$

↑ estimated from collocation.

This can be used to check statistics ! (requires local mean value to be zero !)

The discussion mostly runs on the local properties of the covariance function, on the estimated error in distance - weighted interpolation (C.C. Tscherning outlines the proof), on the estimation of the measurement errors from the variogram in kriging (nugget effect) - can be effective.

It would be important to describe statistical characteristics of gross-errors ! and have the possibility to use position dependent covariance-functions.

Theory still not clear !

TECHNICAL DISCUSSION D : GRAPHIC TOOLS AS A HELP TO DATA VALIDATION

The discussions ran on the items listed below.

TOOLS :

- Histograms
- $f(g)$ $\left.\begin{matrix} f \\ g \end{matrix}\right\}$ $\Delta g_{FA}, \Delta g_B, h, \phi, \ldots$

$\Delta g_B(h)$ is the most indicative plot.
→ clusters, polygonal selection, interpretation

- cross-overs (marine, aerial data)
- contouring (without gridding)
- coloured maps : Δg ' s, errors
- 3-D's

LANGUAGES with respect to :

- Completeness
- User friendly characteristics
- Efficiency : machine dependent

⇒

GSC uses :	UNIRAS (needs losts of core, is slow, non efficient, full of bugs, has no good scaling routines...) DATAPLOT (developed by a private group in Toronto) PLOT10 (basic package) VERSAPLOT (some disadvantages).
KMS uses :	an old package written in Algol The Graz package (based on GKS)
ULIS uses :	VERSAPLOT GEOSOFT (UNIRAS will be installed).
BGI uses :	IGL (used in VERSET → future conversion to GKS ? - portability) UNIRAS.

Poitevin (Obs. Royal de Belgique) points out the SURFER software available on PC and PS2 computers, which performs very well on small data sets ; for example, 500 points processed all at a time (this a a maximum) need only 3 minutes on a PS2 ! The package is cheep (≈ 300 $ U.S.) and is recommended in developing countries agencies.

COMMENTS ON THE DEMONSTRATION OF SOFTWARE CAPABILITIES

1. BGI SOFTWARE : PFATES (batch), VERSET (interactive)

- Demonstrations were performed on tuesday 17, afternoon, with just one practical incident (interruption of the ethernet line : to be investigated by BGI later).
- The tests shown with a first file of the belgian data brought by Ch. Poitevin ran well.
- Scales need to be added in all graphics.
- The gradient map could be better utilized and as efficient as the collocation prediction.
- The local re-triangulation and re-prediction takes long → ways to optimize it ?
- A subset of data showed anomalous detection of erroneous points by PFATES : later investigated in the course of the workshop, this was shown as being due to wrong choice of the covariance function parameters ; after correction, results appeared very satisfactory.

2. KMS Software : GEOGRID (batch)

- Sent a few days in advance to BGI (Apollo 10 000 version).
- Was successfully compiled and ran on the CDC Cyber.
- C.C. Tscherning could quickly validate the CDC version with a test data set he had brought.
- GEOGRID was then used with some subsets of the belgian data : results almost agree exactly with those of PFATES. Future tests by BGI will assess whether it is better, in the operational mode, to use GEOGRID or PFATES...

RESULTS OF THE TEST DATA SET PROCESSING

The table below summarized the results which were presented on the last day of the workshop on the processing of five files (about 11 000 points).

File number	1	2	3	4	5	Remarks
Number of Points	593	480	6282	3003	568	
PFATES output = number of flagged points	6	16	63	5	0 ↓	
Number of corrections in VERSET	6	16	72	12	No	
Points outdated	3	2	46	4	graphic	
Points doubtful	0	4	9	5	control	

Comments

- PFATES does more things that GEOGRID for tuning the covariance function... but the point selection seems not to take account of the azimuth (distribution in quadrants).
- the correlation distance and the variance are very important ! locally, one can adjust the variance (with a few points) in keeping the correlation length.
- BGI should consider adding the t-distribution test (see Technical Discussion C)******.
- PFATES presently needs about 50 sec. for processing 1500 points simultaneously, and GEOGRID 15 s.

******Ref. Tscherning, "Current Problems in Gravity Field Approximation", Hotine-Marussi Symposium, Roma, June 3-6, 1985.

OTHER MATTERS

BGI PLANS

1. Software

- Further comparisons between PFATES and GEOGRID.
- Comparisons between the used triangulation algorithms and a new subroutine recently acquired, so as to optimize this phase.
- Final upgrading of the VERSET software.
- Investigate more about marine gravity validation : usage of GSC software of which M. Sarrailh got some training (problem of conversion of pre-processor) ; availability of SKV-software ; new developments in house ?...

2. Validation ; Operational Phase

A plan will be established soon. The strategy is first to run the PFATES (or GEOGRID) software in a systematic way on all land data, then to refine the error detection by running VERSET. The main problem is of course the feedback from the data suppliers...

Report on this major activity will be given next year at the 13th meeting of the I.G.C.

THE WORLD GRAVITY MAP COMPILED BY BGI AND GSC

J. Rupert presented the first version of the coloured map of gravity anomalies (Bouguer) compiled by the two organizations.

. 5' x 5' land average values were computed by BGI (only gross errors were detected).
. 5' x 5' marine data come from Haxby's global solution from satellite altimetry derived geoid, and from ETOPO5 (to compute the Bouguer anomaly).

The current version is at 1:50 million scale in the Van der Gruiten projection (a smaller scale could be used, and the Robertson projection might look better...). North of Norway, the 5' x 10' values computed by SKV could be included if available.

Additional regional 5' x 5' grids coming from AGP or SAGP being not yet in the public domain, the first publication of this map (a 1000 set) will not include these data.

BGI and GSC are going to finalize the text to appear on this map (twenty paragraphs - ten in English, ten in French, of about 10 lines each, will be written).

Part IV

CONTRIBUTING PAPERS

Absolute Gravity Observation Documentation Standards

- July 1989 version -

(G. Boedecker, Chairman)

1. Introduction

Working Group 2 (WG2) 'World Gravity Standards' of the International Gravity Commission (IGC) has published - after site selection criteria for stations of the International Absolute Gravity Basestation Network (IAGBN) - at last "Absolute Observations Data Processing Standards & Station Documentation" in the Bulletin d'Information (no. 63 as of December 1988) of the Bureau Gravimetrique International (BGI); that publication will be referenced as WG2/1988 here. In continuation of this standardization in the sequel some guidelines for absolute observations documentation are published as working standards to be applied for observations in the IAGBN. However, these are recommended for use for all absolute observations employing modern free-rise-and fall or free-fall instruments.

There have been a number of global absolute observations in the past few years and it appears necessary to make sure also by adequate observations documentation, e. g. for the BGI data holdings, that optimum use can be made of these observations also for later re-analysis and for correlation with any other type of relevant data.

2. Basic Viewpoints

- Absolute observations to be published should be made homogeneous in form and comparable.

- Data exchange should be facilitated.

- The procedures leading from the very original observations to the published g-value should be made more transparent and should be published more completely.

- If in future new standards are introduced it should be possible to re-evaluate the original processing at least in the more significant parts.

- Whereas the latter argument would favour a publication of every digit used in the whole proceure this would conflict with transparency. A compromise can be found utilizing the idea of normal observations (explained below).

- These standards will require the storage of slightly more numbers and the application of more complex rules as compared to conventional gravimetry. However this seems to be acceptable because:

  · the rules have to be implemented in the software only once
  · advanced possiblities always require more complex rules
  · compared to the absolute instrument itself, the additional complexity of data handling is totally negligible
  · the additional data are negligible considering the present capabilities of mass storage media

- The reading of an absolute gravity meter may depend on - besides the gravity acting - also on the current state of the instrument including the physical construction, adjustment, calibration and software, the current state of the environment as air pressure etc. and the current state of the station. Therefore the most significant parameters of these have to be referenced or recorded along with the gravity reading.

- As gravity at a location may change, also the instrument, the environment and the station may change with time. Therefore the history of these has to be recorded as far as it may be relevant for the observations.

- The costs of absolute observations are quite high. Thus there should be an adequate effort towards data documentation in order to guarantee the best possible future exploitation of the data.

3. The Data

Starting from the above considerations, each absolute gravity observation report prepared as the result of the work of one party at one station at one epoch (usually taking a few days) should consist of two parts:

- a header section that contains all the data that may change from year to year but remain unchanged in the days when an observation takes place.

- an observation section containing a series of (normalized) observations.

3.1 Header Section

- Station Subsection
  - Country
  - Station name: Number and/or name of town or habitat
  - Identity: Number or name for identical station used by others

- Description: Reference to station documentation or description included on present state; photograph and sketch are helpful
- History: Reference to relevant information on earlier states of the station
- Coordinates: Latitude and longitude to 0.0001 deg., altitude to 0.001 m incl. height reference system
- Gravity: The current final g-value observed for the station to $1*10^{-9}$ ms^{-2} for A (0.80 m height above ground marker), B (definition height of the instrument) and C (ground marker).
- Vertical gravity gradient: Reference to publication or own observed value
- Excentricities: Gravity differences to excentres
- General remarks

Remarks to the station subsection:

* Identity: Two stations can only be regarded as identical if they coincide to the millimetre
* History: As one could learn from the fate of many IGSN71 stations which made necessary various revisions and updates, it is important to keep track of the changes of the station, e. g. construction modifications in the near vicinity, changes of the floor covering, changes of seismic noise etc.
* Vertical gravity gradient: Reference to publication or details of the determination such as type of instruments etc.
* Excentricities: If the/an instrument could not observe in the plumbline through the station marker, details should be given as to the relative gravity ties etc.

- Instrument Subsection

    - Type/status
    - Reference to publication or details on type of frequency standard, type of light source, absorbtion line/wave length, material/weight of falling object, drift rates

      Remarks to instrument subsection:
      * Type/status: As e. g. in the case of software and also as is done in a similar way when a relative gravity meter is modified, one has to define different states in the ongoing development and modifications of an absolute meter, by a suffix to the name, e. g. JILAG-6.4 or JILAG 6.1988. The details for an instrument so defined should either be given by referencing another publication or in the observation report itself.

- Environment Subsection

    - General situation: Remarks on humidity, power supply etc.

3.2 Observation section

- Reference subsection

    - Reference for the standards used for the corrections applied

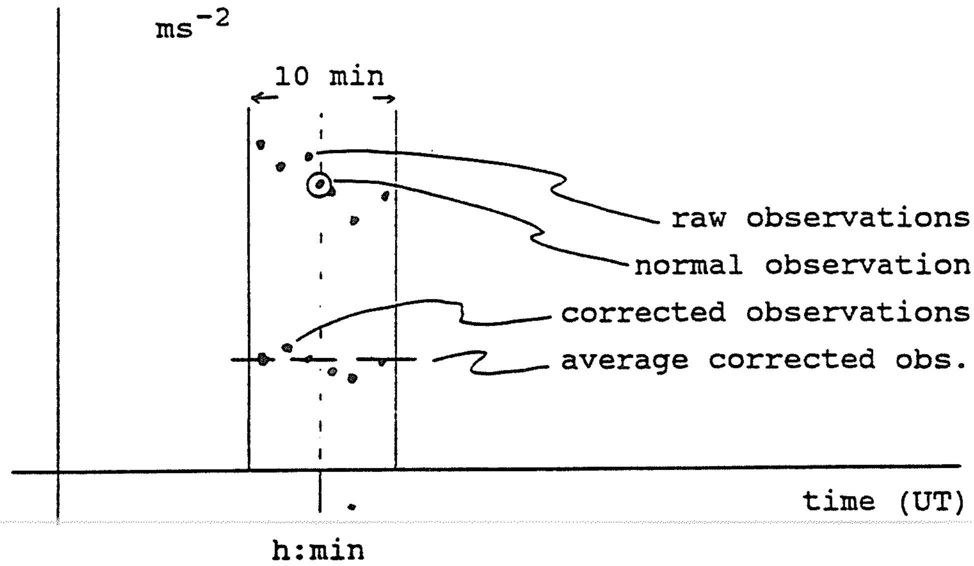
- Observation subsection

    - For single drop $r > 20\,\mu Gal$, normalized observations (explained below), for single drop $r < 20\,\mu Gal$, all observations should be recorded including:
    - Time h:min

- Original or normalized gravity observation to 1 * 10^{-9} ms^{-2}, also for the corrections
- Number of drops included
- Standard deviation (for normalized observations only)
- Height of definition point above marker
- Air pressure
- Pressure inside vacuum chamber
- Temperature
- Correction for light travel time
- Correction for earth tides
- Correction for oceanic tides
- Correction for earth rotation changes (polar motion)
- Correction for atmospheric masses
- For whole data set: Histogramm with 1 * 10^{-7} ms^{-2} slots

Remarks on the observation subsection:

* The construction of normalized observations is taken from satellite geodesy, where the normal points are intermediate filtered values for observed points along the satellite's trajectory. They are fictitious observations that permit at a high accuracy level the analysis and later re-analysis of all significant effects.



As also explained in the above sketch, each observation within 10 minutes (5 min before to 5 min after h:min hours) individually undergoes the full correction and evaluation procedure. These values, which should be rather constant except for noise, are taken (averaged) to yield the representative gravity value for h:min hrs. UT. Then in reverse sign the various corrections are applied again to give the fictitious filtered observation at h:min hrs. UT.

The interval of 10 minutes seems to be appropriate because

- atmospheric changes can sufficiently be traced
- groundwater or soil moisture changes also can be sufficiently traced
- any later changes of earth tide models are un likely to occur in a higher frequency band

Information letter :

ABSOLUTE DETERMINATION OF THE VERTICAL GRADIENT OF GRAVITY

(Prof. A. Sakuma, BIPM, Sèvres, France)

Using our BIPM type absolute gravimeter, we are now capable of measuring the vertical gradient of gravity, γ, with an accuracy approaching that obtained by calibrated relative spring gravimeters. The latest preliminary result for γ at SEVRES POINT "A" is : $(3106 \pm 31) \times 10^{-9}$ s^{-2} or (310.6 ± 3.1) μGal/m where the numbers represent the mean value and the standard deviation of the mean of approximately 200 measurements throughout the trajectory of about 0.4 m. This value is in good agreement with the accepted value at this point, $(3118 \pm 6) \times 10^{-9}$ s^{-2}, which was obtained as the mean of a large number of relative measurements using 14 spring gravimeters on the occasion of the second international comparison of gravimeters at Sèvres in 1985. This increase in accuracy in the measurement of γ is due to a recent improvement in the catapult and the anti-vibration devices which now make it possible to extract γ (involving a t^4 term) with low noise level from the free-rise-and-fall motion (t^2 term). It is worth noting here that in a series of g measurements where each γ value is well determined, the scatter of each g value decreases to the ± 2 to ± 4 nm.s^{-2} level (near the present resolution limit) and these g values are very close to the mean of all. Thus we can consider that the g value obtained together with a well measured γ value has a high probability of being very near to the real value. A full report of this work is now in preparation.

<u>*August 5, 1989*</u>

DETERMINATION OF ABSOLUTE GRAVITY VALUE ON MADAGASCAR IN 1988

Arnautov, G.P., Kalish, E.N., Stus, Yu.F., Tarasjuk, V.G., Scheglov, S.N.

The International Gravimetric Commission in cooperation with the Geodetic Commission for Africa of IAG have worked out a project for setting up a high-accuracy gravimetric network on the territory of Africa and on the surrounding islands with the initial basic points determined by means of the laser ballistic gravimeters. In consideration of this project, the USSR Academy of Sciences adopted a resolution to carry out absolute gravity determinations on Madagascar and through the Soviet Geophysical Committee requested the National IUGG Committee of Madagascar of their view on the possibility to carry out these observations.

The National IUGG Committee of Madagascar granted the permit for the Soviet Gravimetric Expedition. After preliminary technical regulations, the Soviet specialists arrived in Antananarivo in the beginning of November 1988 and carried out measurements of absolute gravity values using the laser ballistic gravimeters (GABL) constructed at the Institute of Automatics and Electrometry of the Siberian Department, USSR Acad. of Sci., in Novosibirsk.

The gravimetric measurements on Madagascar would not have been accomplished without the great assistance and interest shown to these studies on behalf of the National IUGG Committee and of Dr. S. Andriamihaja, its President. Dr. S. Andriamihaja and his collaborators have prepared an excellent observation site in a church where a concrete pillar 1 x 1 m was set on level with the floor and easy access to running water and electricity of 220 and 380 V.

The description of construction of the laser ballistic gravimeter and of measurement technique and the analysis of its possible errors are given in several publications, in particular in paper /1/.

The principle of operation of GABL is based on measurement of intervals of path and time of free fall of the optical angle reflector in a vacuum chamber. The free fall of the angle reflector is provided by an automated system of control with a given program. The movement of the angle reflector is measured by a laser interferometer. To reduce vibration and seismic effect on measurement results, the reference angle reflector is suspended in the center of swinging of a low-frequency seismograph. The modulation of brightness of interfering bunches as a result of movement of the angle reflector is transformed by a photo-receiver into an electric signal whose period of change corresponds to the movement of the angle reflector for a half of the laser wavelength. Therefore, the path traversed by the falling body is designated by the wavelength of the laser ray. The helium-neon laser, stabilised by iodine absorption cell, is used to measure the path of the falling body.

The time intervals were measured by the rubidium frequency standard.

The signals from the photo-receiver and from the rubidium frequency standard are recorded by a computer unit, which calculates the values of path and time intervals. These data are fed to the micro-computer which calculates gravity values and statistically generalises the results of repeated measurements.

The methods of work with GABL at the Antananarivo site were as follow. After the mounting of the gravimeter on the pillar, its adjusting and the obtaining of the necessary vacuum in the chamber where the angle reflector is installed, the gravimeter was switched on. The program determined the number of throws of the angle reflector in the series of 60 single throws during 10 minutes of automatic operation of the gravimeter. After every observation series an interval of 10-20 min. followed to check installation and adjustment of instrument.

The result of measurement of each series was entered from a computer display in a log-book where the final gravity value was calculated for every series of measurements with introduction of the necessary corrections.

The measurements at the Antananarivo site were carried out on 9,10 and 15 November 1988, with a total of 22 observation series. The maximum scatter of measurement series was 20 mcgal. The gravity value (g_o) measured by the absolute gravimeter was determined at the effective height of the instrument at the point on the vertical from the pillar (in this case $h_{eff} = 0.983$). To reduce measurement results, obtained by the absolute gravimeter, to the surface of the pillar, the vertical gravity gradient was measured at the point of GABL installation. These measurements were carried out by the Madagascar specialists with the LaCoste-Romberg DN139 gravimeter belonging to the Geological Service of Madagascar. In all, 70 measurements of Δg were made between the surface of the pillar and the point in space at the height of 1.001 m. The value of the vertical gravity gradient at this height was 354 ± 2 mcgal, whereas the reduction value of the measured g_o to the surface of the pillar was $+ 348 \pm 2$ mcgal.

In addition other corrections were also introduced into the g_o values (see Appendix 1) :

- for resistance of the residual air in vacuum chamber (Δg_p),
- for finiteness of light velocity (Δg_c),
- for tidal gravity changes (Δg_δ),
- for attraction of atmospheric masses (Δg_{pA}),
- for movement of the Pole (Δg_N).

Corrections for Δg_{pA} and Δg_N were calculated by formulas given in /2/.

The measurement technique made superfluous corrections for deviation of the measurement line from the vertical (m_ϕ), for escape of laser frequency (m_λ), for errors of time intervals (m_t). The Honkasalo correction (Δg_H) was also not introduced according to IAG Recommendations.

After accomplishment of all measurements the average absolute gravity value ($\bar{g}$) was obtained from all series and also its mean square error (M_o) by inner correlation of measurement results (accidental error). The total value of the mean square error (M) of the absolute gravity value at the level of the pillar was calculated with due account of accidental error, instrumental errors and errors connected with consideration of external factors. The major sources of errors and their values are given in Table 1.

As a result of measurements carried out at the Antananarivo site, the absolute value of gravity acceleration was obtained :

978 207 278 ± 6_o mcgal, at effective height 0.983 m

978 207 626 ± 6_3 mcgal, at the level of the pillar.

The field sketches, the description of the gravimetric site Antananarivo, and the topographic maps of the site are given in Appendix 2.

Table 1

Sources of errors	Symbol	Value of error (mcgal)
Measurement errors of time intervals	m_t	±1
Error of laser wave-length reproduction	m_λ	±4
Error due to resistance effect of residual air in vacuum chamber	m_p	±3
Error of the vertical and non-ideal character of the wave front	m_ϕ	±2
Error due to tidal variations of gravity	m_δ	±2
Error of reduction of the measured gravity value to surface pillar	m_h	±2
Accidental error of absolute gravity value measurement	M_o	±1.2
Total (full) error of determination of the mean value of absolute gravity value at the level of pillar	$M = \pm\sqrt{[m_i^2]}$	±6.3

In conclusion the authors wish to express their sincere gratitude to Dr. S. Andriamihaja, President of the National IUGG Committee of Madagascar, and to his collaborators for their great assistance in the organisation and accomplishment of measurements and for an extremely hospitable reception of our Expedition.

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Appendix 1

Results of absolute gravity measurements at Antananarivo-0512 point in 1988

Effective height: h = 0,983 m

Corrections for finiteness of light velocity: $\Delta g_c = -22$ mcgal

	Time of meas. by Greenwich	Measured value	Mean square error	Number of falls	Corrections for resistence of air	Corrections for tide	Corrected value	Air pressure value (mm Hg)
N	T_o	$\Delta g_o + \Delta g_c$	m_o	K	Δg_p	Δg_δ	g	P_A
1	2	3	4	5	6	7	8	9
	9.XI.1988							
1	$17^h40^m-17^h55^m$	978 207 259	± 5	90	+ 16	− 5	978 207 619	651
2	18 15 –18 25	239	6	60	+ 16	+ 20	624	"
3	18 40 –18 50	224	7	60	+ 16	+ 38	627	"
4	18 55 –19 05	208	7	60	+ 16	+ 47	620	"
5	19 20--19 30	191	6	60	+ 16	+ 60	616	"
6	19 50 –20 00	187	7	60	+ 16	+ 71	623	"
7	20 15 –20 25	194	6	60	+ 16	+ 76	635	"
8	20 35 –20 45	181	7	60	+ 16	+ 77	623	"
9	21 05 –21 15	189	6	60	+ 16	+ 72	626	"
10	21 35 –21 45	200	5	60	+ 15	+ 62	626	"

Cont. App. 1

1	2	3	4	5	6	7	8	9
11	$22^h05^m-22^h15^m$	978 207 222	± 7	60	+ 15	+ 46	978 207 632	651
12	22 35 - 22 45	249	7	60	+ 14	+ 26	638	"
13	23 05 -23 15	260	6	60	+ 14	+ 3	626	"
14	23 35 -23 45	288	6	60	+ 14	- 21	630	650
	10.XI.1988							
15	0 05 - 0 15	308	5	60	+ 14	- 44	627	650
16	0 35 - 0 45	323	7	60	+ 14	- 65	621	"
17	0 55 - 1 05	342	6	60	+ 14	- 77	628	"
18	1 15 - 1 25	348	7	60	+ 13	- 86	624	"
19	1 35 - 1 45	367	7	60	+ 13	- 93	636	"
20	1 55 - 2 05	355	7	60	+ 13	- 97	620	"
	15.XI.1988							
21	16 05 -16 15	212	6	60	+ 13	+ 50	624	"
22	16 25 -16 35	228	7	60	+ 13	+ 38	628	"

Constant corrections:

Δg_h = + 348 mcgal

Δg_N = - 2 mcgal

Δg_{PA} = + 3 mcgal

Average: $\bar{g}$ = 978 207 626

m = ± 5,6

M_o = ± 1,2

M = ± 6,3

INTERNATIONAL ABSOLUTE GRAVITY BASESTATION NETWORK

(I A G B N)

Station: 0512

Station location: AMBOHIMANORO CATHEDRAL (S[t] Laurent)

City : ANTANANARIVO

Country : MADAGASCAR

$\varphi = 18°54'59''$ South $\lambda = 47°30'59''$ East Greenwich

H = 1382,445 m

g = 978 207,278 ± 0,0060 mgal for $h_{eff.}$ = 0,983 m

g (Station) = 978 207,626 ± 0,0063 mgal

Date: November 1988

DESCRIPTION OF THE STATION 0512

One rivet, studdet at the center of a slat of marble (1 m x 1 m), marks the station which is located in the sacristy of the Anglican Cathedral (ST LAURENT) at Ambohimanoro, in Antananarivo.

OPERATORS

All the measures have been done by:

- the scientific Soviet shift
  - Dr Arnautov G.P.
  - Dr Kalish E.N.
  - Dr Stus Ju.F.
  - Dr Tarasyuk V.G.
  - Dr Sceglov S.N.

from the USSR Academy of Science

- and the scientific Malagasy shift
  - M. Bezandry Charles
  - M. Rabemalazamanana
  - M. Rakotondraompianina Solofo
  - M. Rakotoary Jean Chrysostome
  - M. Sylvain Juin
  - M. Ramilison Andrianarimalala

EQUIPMENT

One absolute gravimeter GABL from the Institute of Automatics and Electrometry, Siberian Department of the USSR Academy of Sciences has been used.

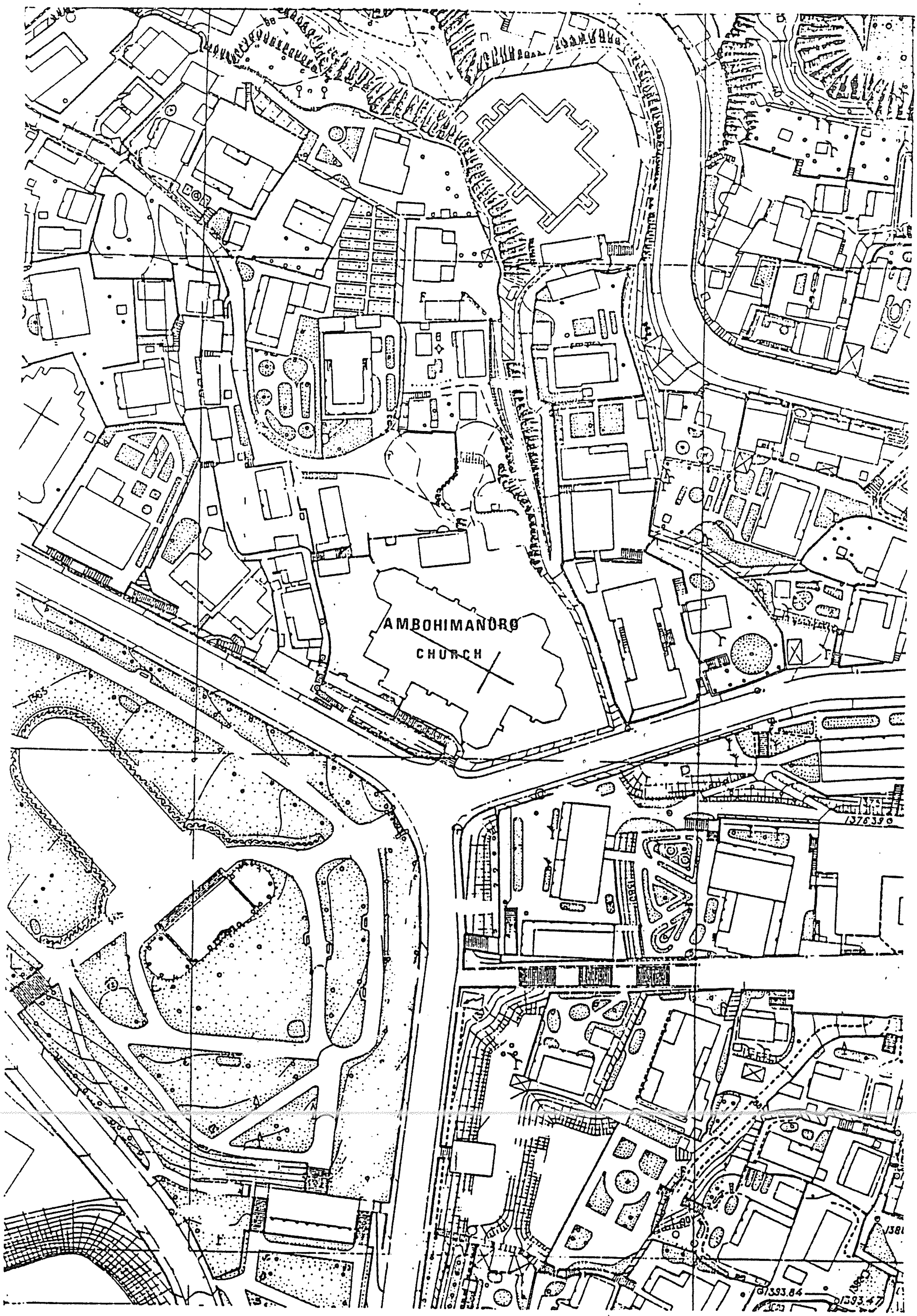
g = 978 207 278 $\pm$ 6,0 mcgal at 0,983 m above the station.

One gravimeter La Cost-Romberg D 139 has been used to determine the gradient of the gravity in order to have gravity value of the station:

$g_{station}$ = 978 207 626 $\pm$ 6,3 mcgal

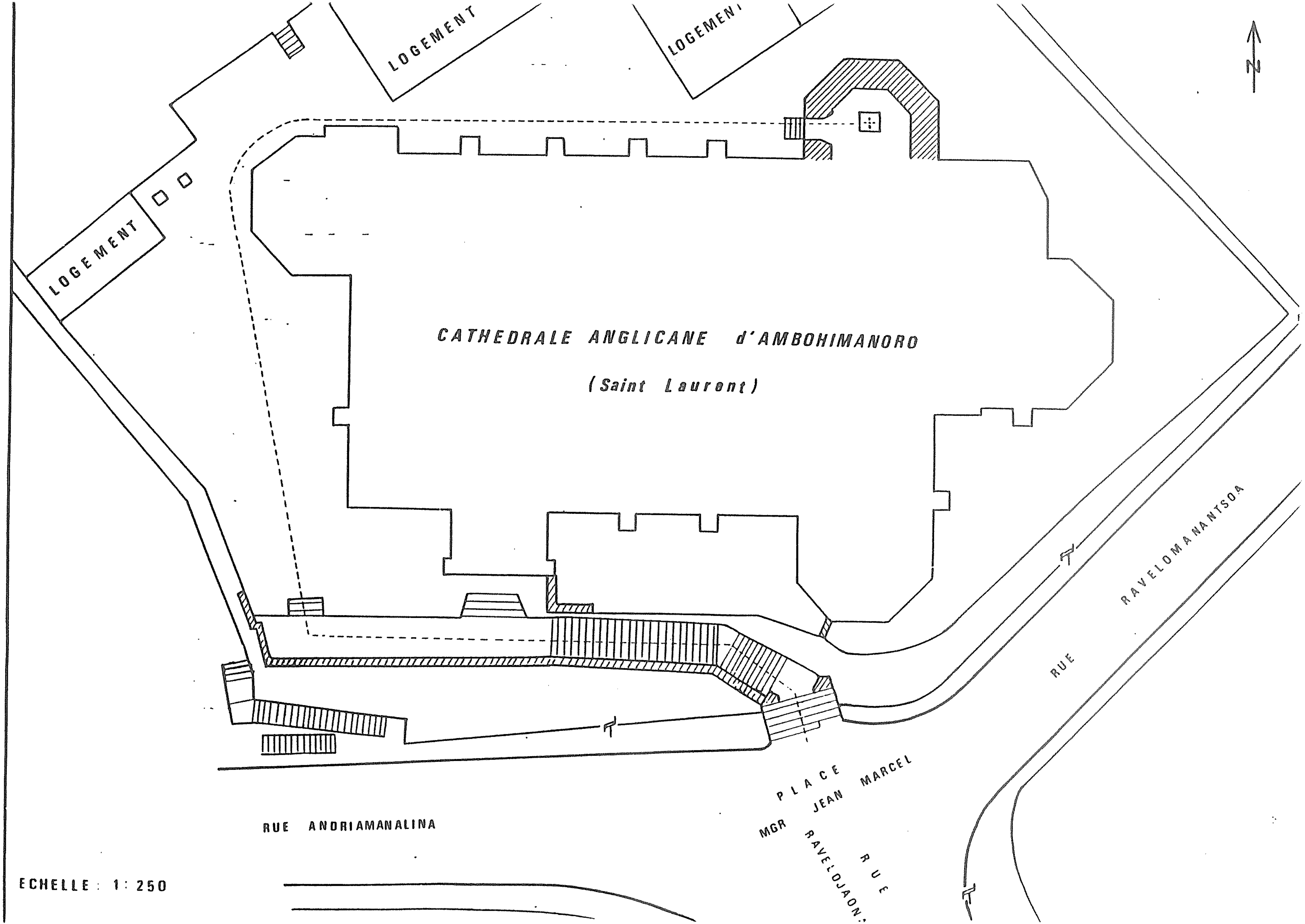
ECHELLE : 1: 5000

ANTANANARIVO



ECHELLE: 1:1000

ANTANANARIVO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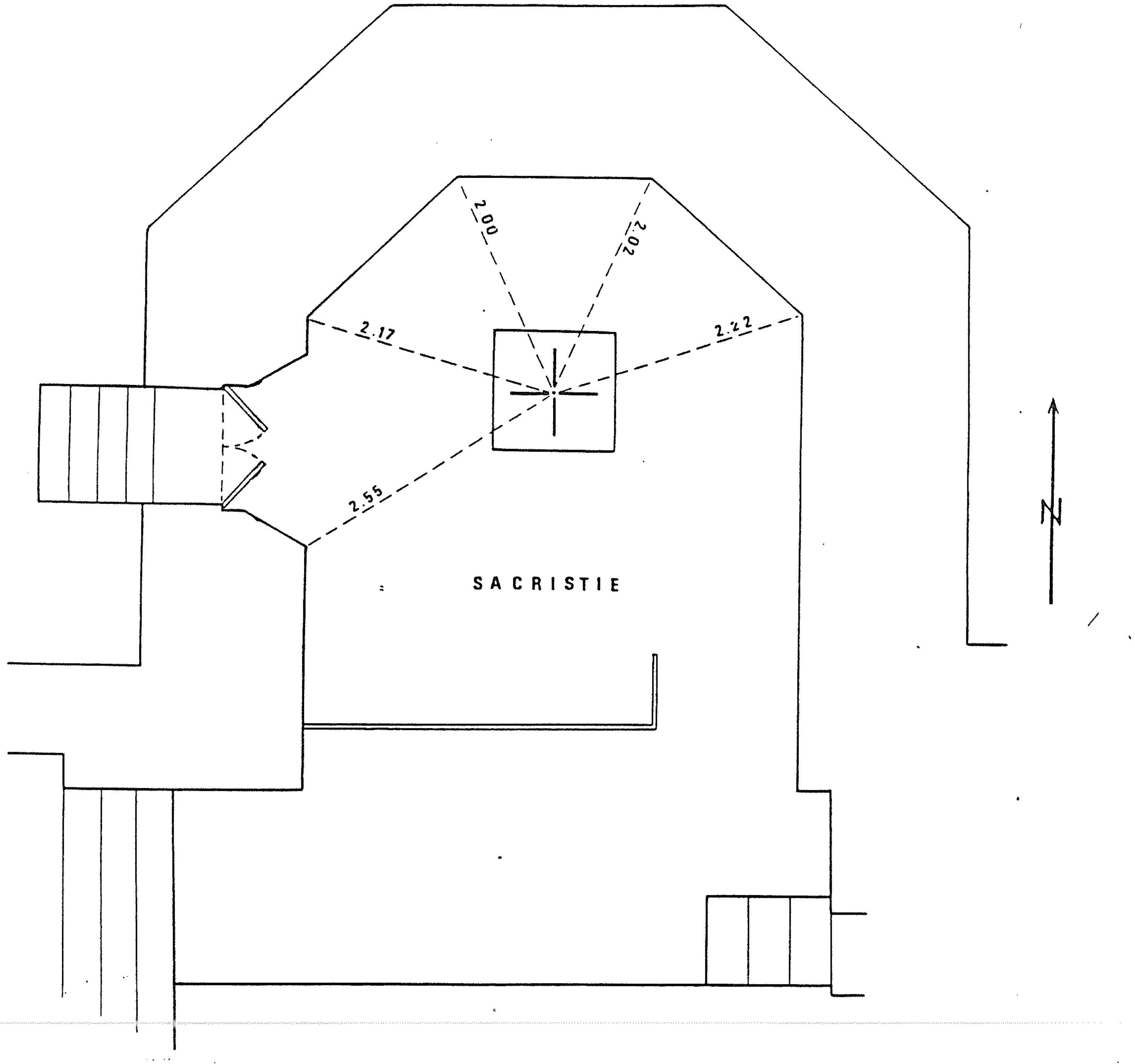
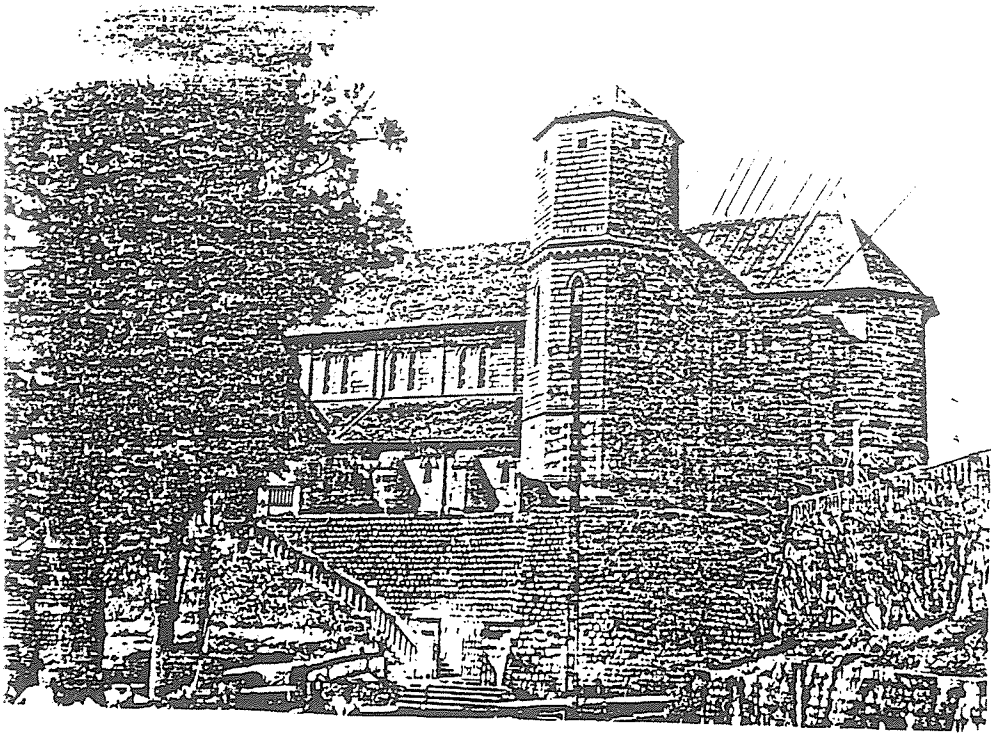
CATHEDRALE ANGLICANE d'AMBOHIMANORO
(Saint Laurent)
RUE RAVELOMANANTSOA
PLACE MGR JEAN MARCEL
RUE RAVELOJAONA
RUE ANDRIAMANALINA
ECHELLE : 1: 250
N

ABSOLUTE GRAVITY STATION



ECHELLE : 1 : 50

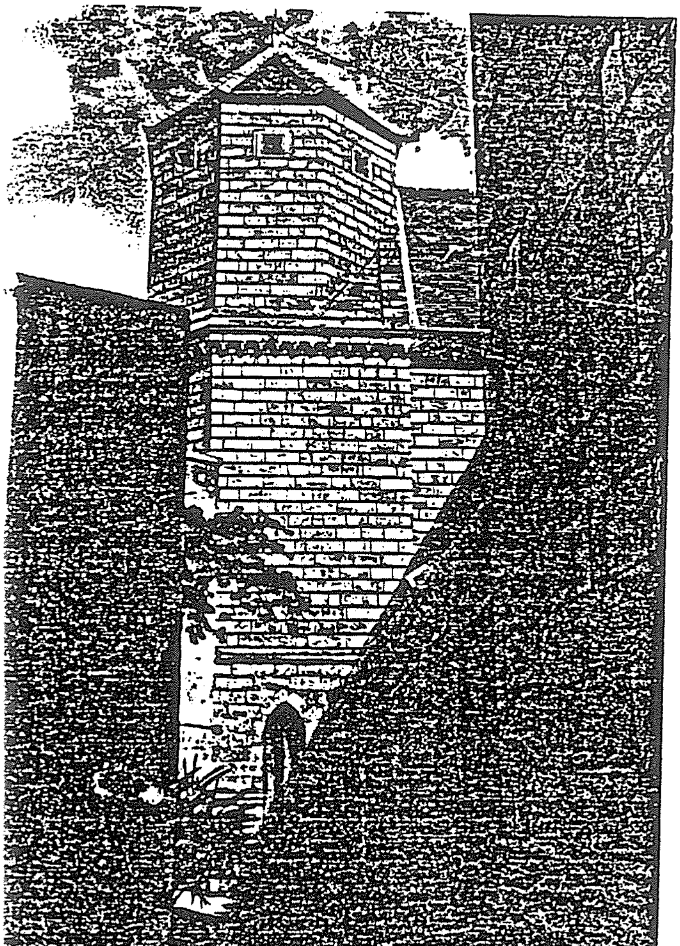


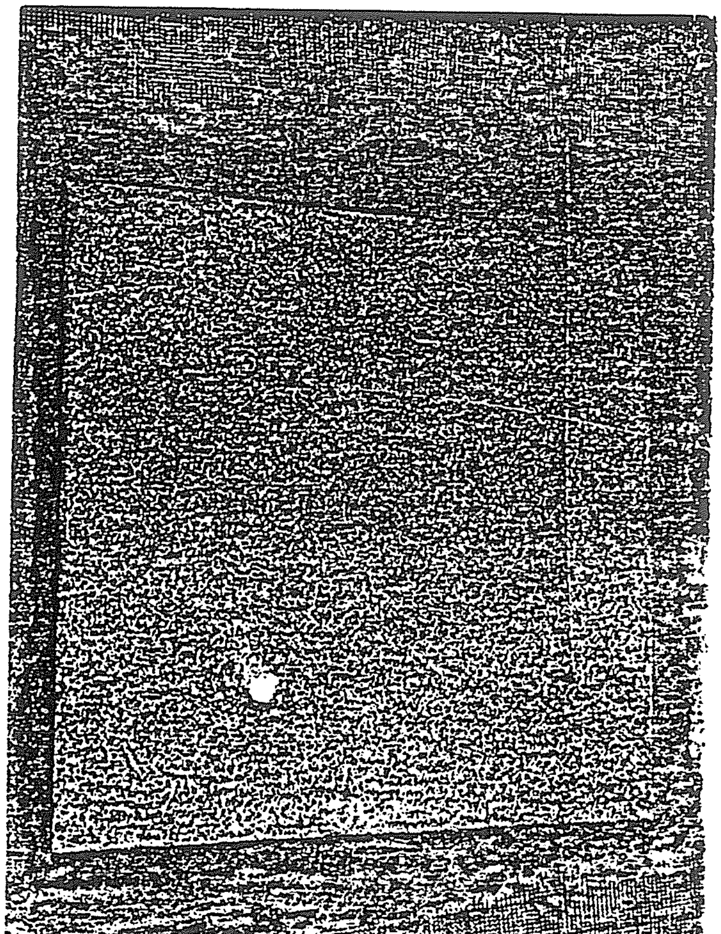
Absolute
Gravity Station

Location :
Ambohimanoro
(church).

Country :
Madagascar

ont





ess

overview

CORRECTION OF A SYSTEMATIC ERROR OF GRAVITY MEASUREMENTS WITH JILAG-3

W. Torge, R.H. Röder, M. Schnüll
Institut für Erdmessung
Universität Hannover
D-3000 Hannover, F.R.G

Abstract: Between March 1986 and January 1988 absolute gravity determinations have been carried out on some 35 stations in six european countries with the Faller-type gravimeter JILAG-3. A re-adjustment of the instrument's interferometer base in January 1988 resulted in a constant shift of the results obtained up to that time of $+22\,\mu gal$ $(1\,\mu gal = 10\,nms^{-2})$, which must be treated as a correction to these observations.

Early 1986 the *Institut für Erdmessung (IfE), Universität Hannover* has received an absolute gravimeter, constructed and built at *Joint Institute for Laboratory Astrophysics in Boulder, Colorado* by Prof. J.E. Faller and his group (Faller et al. 1983, Niebauer 1987). Between March 1986 and January 1988 some 35 stations have been observed with the instrument, having it adjusted before to our best knowledge at that time. In course of each single gravity determination a standard deviation is computed for the mean value of several thousand drops (single experiments) following the common law of error propagation. Depending on the total number of drops carried out at the stations, this resulted in values less than $\pm 3\,\mu gal$ with only a few exceptions. These standard deviations must not be regarded as the real accuracy of the obtained gravity values because of remaining systematic errors from which the existence is known, but not necessarily their amount. They are supposed to be constant during an observation but some of them might vary with time due to different instrumental and environmental conditions. From repeated measurements in 1986/87 on seven stations we estimated the accuracy of a gravity determination to be $\pm 9\,\mu gal$ on the average which is in agreement with our early statement ($\pm 10\,\mu gal$).

Comparisons were performed on eight gravity stations of *Deutsches Schweregrundnetz 1976 (DSGN76)*. This network is based on four absolute stations determined by *Istituto di Metrologia "G. Colonnetti"(IMGC)*, and by relative ties between the 21 network stations (Sigl et al. 1981). Other comparisons were possible by a measurement at *Bureau International de Poids et Mesures, Sèvres* in 1986, where the gravity value was determined by means of six absolute meters from five different countries in 1985 (Boulanger et al. 1986) and by a measurement in Potsdam, where the GABL-gravimeter of *Institute of Automatics and Electrometry, Sibirian Branch, USSR Academy of Sciences* has observed in the period 1976 to 1986 (Arnautov et al. 1989). From these comparisons our values resulted to be smaller by about $25\,\mu gal$, whereas this systematic discrepancy was not found when comparing directly with results of the absolute gravimeter of *Istituto di Metrologia "G. Colonnetti"* (Cannizo et al. 1978) on seven stations.

During a visit of the instrument's designer, Prof. J.E. Faller, in January 1988 at IfE, we went under his guidance through the whole adjustment procedure of the instrument's interferometer base again and detected that there was a misalignement in the laser beam path:

An essential part of the interferometer base is a frequency stabilized laser. After passing an optical isolator to prevent light reflection back into the laser, the beam is focused on a pinhole for spatial filtering, and then is collimated to become parallel again. This collimation was not properly done, i.e. the optical component "focusing lense/pinhole" was disadjusted. This was supposed to have affected our measurements systematically in the sense of being to small, but an amount of the error could not be given from the adjustment procedure.

In order to verify the amount some more repeated measurements at the stations Hannover 101 and Clausthal 522 were carried out in 1988 and 1989. A comparison with values obtained before the re-adjustment resulted in a shift of $+22 \pm 4$ μgal. This value has to be applied to all measurements made until January 1988. Its computation and an estimation of its accuracy is documented in the following (Tables 1–3):

Table 1a: Gravity observations at station Hannover 101 until January 1988.

Epoch	No.of drops	Gravity [µgal]	Std.dev. [µgal]
03/86	6000	981 263 316	1
04/86	8000	981 263 312	2
05/86	3900	981 263 303	1
06/86	6000	981 263 310	2
08/86	6000	981 263 321	3
08/86	1000	981 263 303	8
09/86	3800	981 263 306	6
12/86	11000	981 263 307	2
03/87	3000	981 263 308	2
06/87	2700	981 263 299	1
12/87	3500	981 263 303	1

Table 1b: Gravity observations at station Hannover 101 after January 1988.

Epoch	No.of drops	Gravity [µgal]	Std.dev. [µgal]
04/88	2000	981 263 337	4
07/88	1000	981 263 340	4
08/88	3000	981 263 337	5
11/88	3000	981 263 318	3

Table 2a: Gravity observations at station Clausthal 522 until January 1988.

Epoch	No.of drops	Gravity [µgal]	Std.dev. [µgal]
03/86	1037	981 115 721	2
05/87	1500	981 115 709	1

Table 2b: Gravity observations at station Clausthal 522 after January 1988.

Epoch	No.of drops	Gravity [µgal]	Std.dev. [µgal]
08/88	2500	981 115 735	1
02/89	3600	981 115 732	2

Table 3: Comparison of results obtained until and after January 1988.

Hannover 101 until 01/88, 11 determinations, 54900 drops:	Mean:	981 263 308.0	+/-	1.9	µgal
Hannover 101 after 1/88 4 determinations, 9000 drops :	Mean:	981 263 333.0	+/-	5.1	µgal
Difference:		+ 25.0	+/-	5.4	µgal
Clausthal 522 until 01/88, 2 determinations, 2537 drops :	Mean:	981 115 715.0	+/-	6.0	µgal
Clausthal 522 after 1/88, 2 determinations, 3600 drops :	Mean:	981 115 733.5	+/-	1.5	µgal
Difference:		+ 18.5	+/-	6.2	µgal
Weighted mean difference:		+ 22.2	+/-	4.1	µgal

Remark: Mean values and standard deviations of the four groups of measurements given in Table 3 have been computed from the equal weighted results listed in Tables 1a ... 2b. The standard deviations given in the last columns of these tables have not been taken into consideration because they do not represent the real accuracies due to residual systematic errors.

In the following Table we give some summarizing results of comparisons performed with other gravity data.

Table 4: Comparison of JILAG-3 observations with other data.

Reference gravity values	Mean difference JILAG-3 - reference [μgal]	R.m.s. discrepancy [μgal]
DSGN 76 (8 stations)	- 3	+/- 7
Sevres A (1976 - 1985, 7 instruments, 18 determinations)	+ 4	-
Sevres A (1985, 6 instruments, 7 determinations)	- 3	-
Potsdam S14 (GABL 1976 - 1986)	- 5	-
IMGC with IfE-gradients (7 stations)	+ 11	+/- 19

From this comparison we may state that the $22 \mu gal$ correction has remarkably reduced the systematic bias in the JILAG-3 results, found before.

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SCHAFTEN
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21. 8. 1989

Torge, Wolfgang
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Dr. Ing. Wolfgang Torge, Professor am Institut für Erdmessung, Universität Hannover, FRG.

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