

Andrzej PACHUTA

Institute of Higher Geodesy and Geodetical Astronomy, Warsaw  
Technical University, Warsaw

## Preliminary gravimetric investigations in Bunger Oasis nearby of Dobrowolski's Station (Antarctic) \*)

**ABSTRACT:** A surface gravimetric survey in Dobrowolski Station in Bunger Oasis was made. The maps of free-air anomaly, Bouguer anomaly and residual Bouguer anomaly were prepared as result of compiling the gravimetric data. An image of isoanomalies proved an occurrence of gravitational disturbances in the studied area. The depth of Mohorovičić discontinuity was also defined on the ground of Woolard's theories.

**Key words:** Antarctic, gravimetry

### 1. Introduction

The scientific program of the Expedition to the Polish Station Dobrowolski in Bunger Oasis (Antarctic) in 1978/79 included a reconnaissance surface gravimetric survey of the Station surroundings. The research program expected an use of pendulum data collected by Z. Ząbek and J. Śledziński in 1959 during the First Polish Antarctic Expedition to Dobrowolski Station (Ząbek and Śledziński 1960).

The acceleration of gravity was defined by a four-pendulum apparatus of Askania firm at that time. This value was taken from the main gravimetric point of Warsaw Technical University, and the value of acceleration in Bunger Oasis equall (in the Potsdam system):

$$g = 982438.4 \pm 0.4 \text{ milliGals}$$

The pendulum gravimetric point situated in the vestibule of seismic pavilion (Fig. 1) was the starting point for all measurements in the Oasis.

---

\*) This work was made during the Second Polish Expedition to Dobrowolski Station organized by Polish Academy of Sciences.

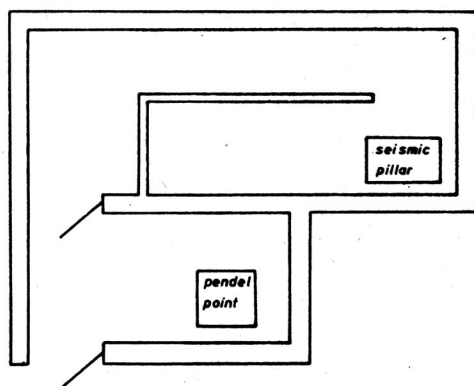


Fig. 1. The pendulum point in the seismic pavilion

## 2. Determination of altitudes, orthogonal coordinates in the local system and geographical coordinates of geodetic network in Bunger Oasis

An altitude and latitude of every measurement point should be known for a reduction of gravimetric data. A geodetic network was installed, the elements of which (angles and distances) were measured by a polar method. The distance was defined by an electrooptical telemeter EOK 2000 of Carl Zeiss (Jena). Horizontal and vertical angles were measured with a Swiss theodolite Wild T-2. Altitudes of points were found by accepting the altitude of the pendulum point defined in 1959 ( $H = 35.4$  m a.s.l.) as the starting one, and then, with the use of technical or trigonometric levelling. The scheme of geodetic net is presented on Fig. 2. The geographical coordinates in the ASTRO point were defined by star observations whereas the approximate azimuth of the M-ASTRO point was determined by observations of the sun.

The calculated values of coordinates  $xy$  in the local system, of latitude  $\varphi$ , altitude  $H$  of geodetic points and the measured values of acceleration of gravity  $g$  are presented in the Table I. The network was also used for preparing a photogrammetric map, so a symbol  $F$  means photopoints and  $PG$  — gravimetric points. The gravimetric data were collected in all these points.

## 3. The gravimetric measurements

Differences of gravity acceleration were measured with the statical quartz gravimeter Sharpe CG-2 No. 156. The constant  $k$  of the instrument was estimated at Mirnyj Station by the tilt method with the use of

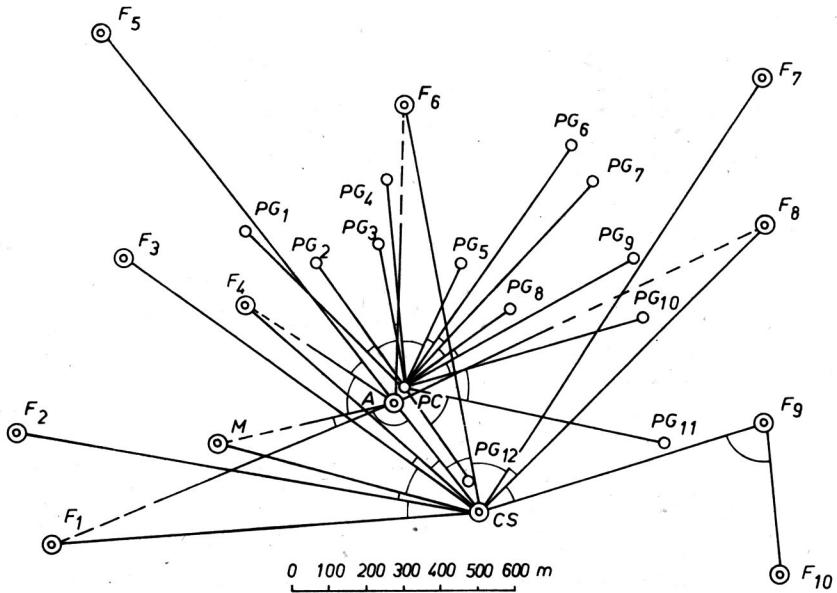


Fig. 2. Scheme of the geodetical net in Bunger Oasis

the apparatus constructed on the base of the theodolite Wild T-4 at Institute of Higher Geodesy and Geodetical Astronomy of Warsaw Technical University (Barlik and Czarnecki 1971),

The following value of constant  $k$  was obtained:

$$k = 0.18237 \pm 0.0007 \text{ milliGal/division}$$

The measurements were done by a profile method (Jung 1961) what enabled to eliminate a changeable drift of the gravimeter. Each sequence of measurements started and finished at the pendulum point.

The data were collected twice at the mainpoints of the network (at the photopoints) at least, at the profile points only once.

The lunisolar corrections were introduced (Bilski 1971) to the calculation of the differences of gravity acceleration between the points of measurements. These corrections reflected an influence of the Sun and the Moon masses of gravimeter readings. The diagram of lunisolar corrections for 12th and 15th February 1979 is presented on Figure 3.

The mean error of measurement  $g$  was defined by the formula:

$$m = \sqrt{\frac{[d^2]}{2n}} = \pm 0.07 \text{ milliGal,}$$

(on the ground of received, result values  $g$  obtained in all  $n$  points of measurements).

Table I.

Coordinates of geodetical net points and measured acceleration of gravity

Nr	Coordinate <i>x</i>	Coordinate <i>y</i>	Geograph. latitude	Altitude <i>H</i>	Acceleration of gravity <i>g</i>
ASTRO	5000.00	5000.00	66° 16' 30.0	35.26	982 438.41
CS	4704.62	5235.25	39.5	59.23	431.42
F1	4617.70	4084.38	42.3	52.16	—
F2	4905.18	3988.64	33.1	24.91	439.46
F3	5382.02	4290.39	17.7	76.16	428.85
M	4886.99	4533.26	33.6	48.52	434.12
F4	5253.99	4604.34	16'21.8	76.03	428.74
F5	5988.78	4223.39	15'58.1	80.16	428.19
F6	5785.19	5032.66	16'04.7	63.49	432.14
F7	5864.13	5984.15	16'02.1	50.41	434.73
F8	5373.48	5994.72	14.7	80.46	427.66
F9	4947.06	5997.41	31.7	55.84	432.35
F10	4550.33	6040.11	44.5	29.62	437.95
PC	5038.59	5025.10	28.4	38.20	437.60
PG1	5461.48	4604.59	15.1	51.05	434.49
PG2	5373.71	4788.87	17.9	41.81	436.13
PG3	5425.25	4953.83	16.3	45.96	435.40
PG4	5594.60	4977.57	10.8	55.60	433.49
PG5	5364.95	5175.63	18.2	31.02	438.18
PG6	5686.30	5469.55	17.9	84.74	426.56
PG7	5592.20	5528.32	10.9	50.12	434.43
PG8	5247.25	5308.19	22.0	34.32	437.16
PG9	5387.80	5638.50	17.5	40.06	436.57
PG10	5225.66	5665.24	22.7	57.21	432.11
PG11	4895.34	5723.13	33.4	28.13	438.35
PG12	4792.26	5196.24	36.7	11.72	442.40

#### 4. Analysis of results of gravimetric measurements

##### 4.1. Calculation of free-air reductions and anomalies

The free-air anomaly of gravity acceleration can be expressed by the formula:

$$A_F = g + R_F$$

in which:  $R_F = 0.3086$ ,  $H$  — means free-air reduction,

$\gamma_0 = 978030 (1 + 0.005302 \sin^2 \varphi - 0.00007 \sin^2 2\varphi)$  — is the normal acceleration after Helmert's formula obtained in 1909.

Calculations of values of free-air anomalies for each point are presented in the Table II. The map of the free-air anomaly was prepared in the scale 1 : 10000, with isoanomalies at every 0.5 milliGal (Fig. 4). The map of Faye's anomalies can be prepared by using the topographic reduction of gravity acceleration in addition using these data. It will be possible after

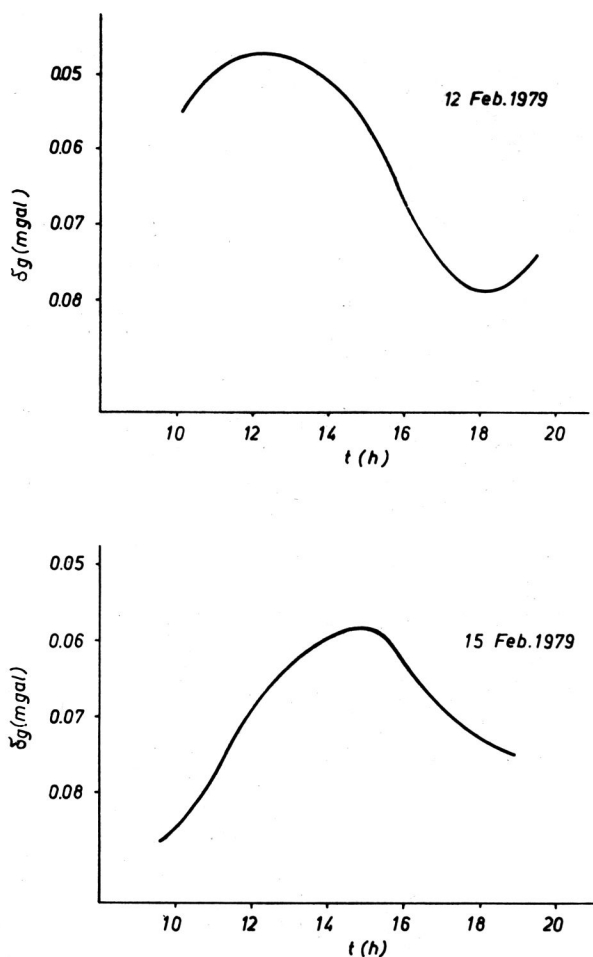


Fig. 3. Diagram of lunisolar corrections

preparation the topographic map of the Station surroundings (such a map is under preparation now).

#### 4.2. Bouguer reduction and anomalies

Bouguer anomaly of gravity acceleration is expressed by the formula:

$$A = g + (0.3086 - 0.0419 \sigma) H - \gamma_0$$

in which:

- $g$  — is the measured value of gravity acceleration,
- $\sigma$  — density of subsurface parts of the Earth's crust,
- $\gamma_0$  — normal gravity acceleration.

Thus, to find the Bouguer anomaly, density of subsurface parts of the Earth's crust should be known. It was evaluated by the Nettleton's method (Nettleton 1940). Several sections approximately transversal to a natural

Table II.

## Calculated anomalies of gravity

Nr	Free-air anomaly	Bouguer anomaly $\nu = 2.0$	Regional anomaly	Residual anomaly
ASTRO	76.94	73.98	72.90	+ 1.08
CS	77.17	72.20	72.34	- 0.14
F1	-	-	-	-
F2	74.74	72.65	72.72	- 0.07
F3	80.23	73.84	73.54	+ 0.30
M	76.67	72.60	72.69	- 0.09
F4	80.00	73.63	73.34	+ 0.29
F5	81.17	74.45	74.41	+ 0.04
F6	79.85	74.53	74.14	+ 0.39
F7	78.46	74.23	74.25	- 0.02
F8	80.43	73.69	73.69	0.00
F9	77.20	72.52	72.80	- 0.28
F10	74.47	72.00	72.03	- 0.03
PC	77.06	73.86	72.96	+ 0.90
PG1	78.17	73.89	73.67	+ 0.22
PG2	76.91	73.41	73.53	- 0.12
PG3	77.48	73.62	73.61	+ 0.01
PG4	78.66	74.01	73.87	+ 0.14
PG5	75.62	73.02	73.52	- 0.50
PG6	80.77	73.67	74.00	- 0.33
PG7	77.90	73.70	73.86	- 0.16
PG8	75.55	72.67	73.32	- 0.65
PG9	76.81	73.45	73.55	+ 0.10
PG10	77.55	72.76	73.28	- 0.52
PG11	74.61	72.26	72.70	- 0.44
PG12	73.55	72.57	72.51	+ 0.06

orientation of the area undulations were fixed, using the measurements points. The Bouguer anomalies were calculated using various densities. In the case of agreement of assumed and real densities the anomaly should be approximate by a straight line. The carried analysis proved that the mean density of subsurface sediments is equal about  $2.0 \times 10^3 \text{ kg/m}^3$ . Detailed gravimetric sections should be analyzed for a precise evaluation of density.

The Bouguer anomalies were calculated for the all points of network in Bunger Oasis, with the use of evaluated density. Figure 5 presents a map of Bouguer anomalies in the scale of 1 : 10000, the isoanomalies are at every 0.1 milliGal.

#### 4.3. Evaluation of local and regional Bouguer anomaly

Looking on the map of Bouguer anomalies (Fig. 5) it can be noticed that the anomalies have almost the same orientation as the parallels of latitude. The regional Bouguer anomaly was therefore assumed to be

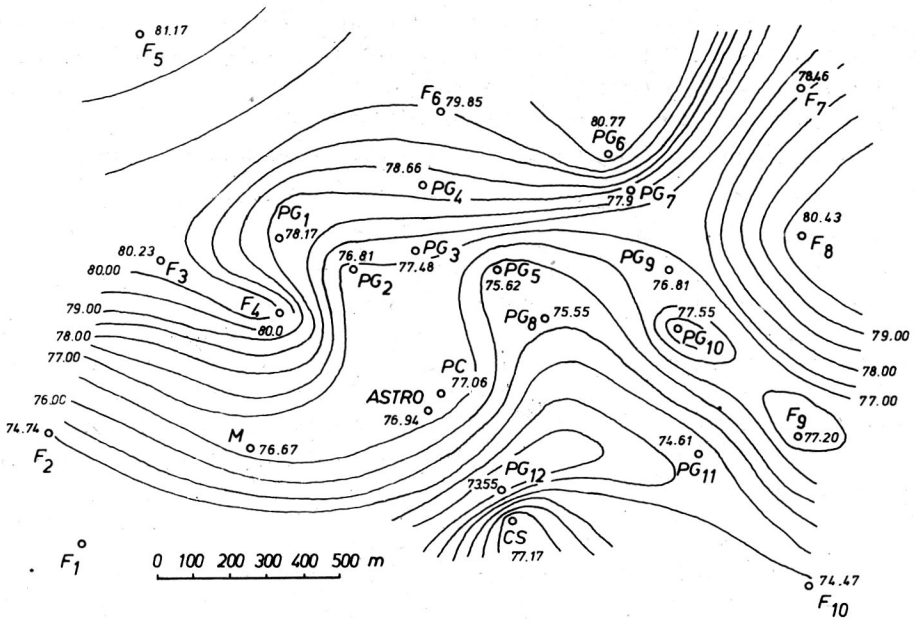


Fig. 4. Map of free-air anomalies

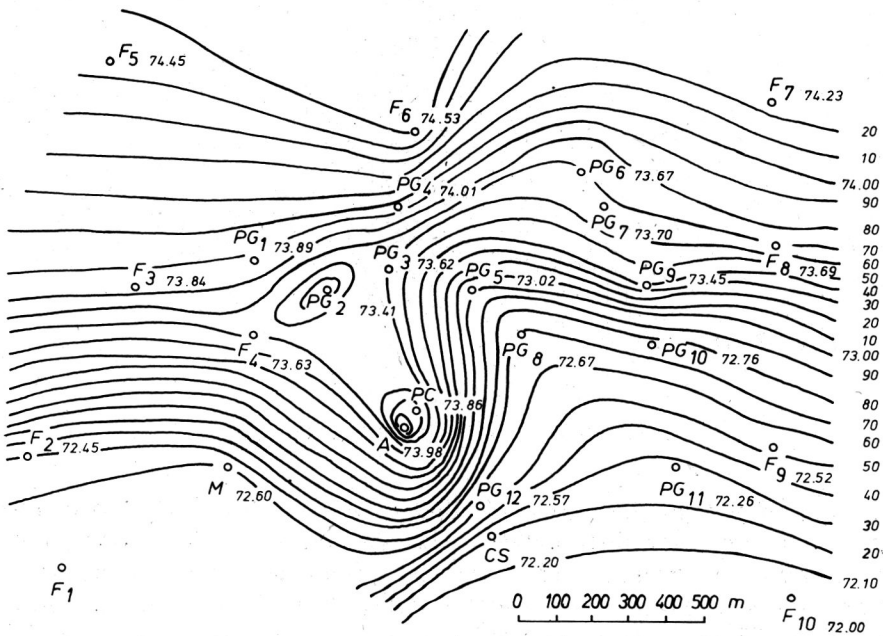


Fig. 5. Map of Bouguer anomaly

expressed by a function of a geographical latitude. The "measured" Bouguer anomaly is a sum of a local (residual) anomaly and a regional anomaly (Fajklewicz 1973). The residual anomaly was obtained by the distinguishing of regional anomaly from the measured anomaly.

To find a regional background the following equations were used:

$$A_B - v = ax^2 + bx + c$$

in which:  $v$  — residual anomaly,

$A_B$  — measured Bouguer anomaly,

$x$  — function of geographical latitude,

$a, b, c$  — formula coefficients.

There are 25 equations of that kind so the same number as of the points, in which the gravity acceleration was measured. The values of residual and regional anomalies were obtained (Table II) by solving these equations by the least square method. Figure 6 presents a map of regional anomaly, isolines are at every 0.1 milliGal.

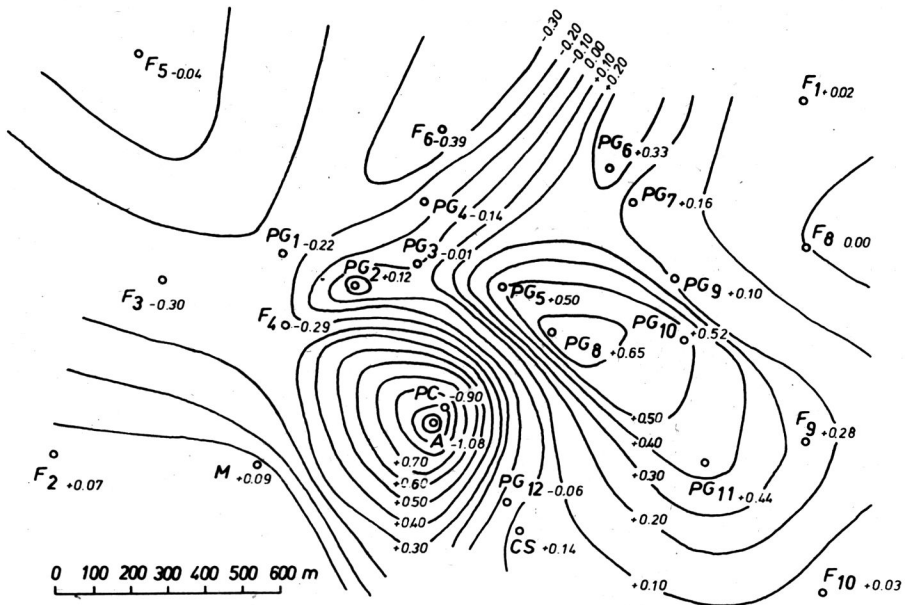


Fig. 6. Map of residual, Bouguer anomaly

It was noted in the area of Bunger Oasis there were two places with distinct anomaly disturbances. This conclusion is clear from analysis of the maps of Bouguer and regional anomalies, and it means that disturbing bodies occur, with another densities that the ones accepted to calculations. The mentioned disturbances were concentrated around the points PG8, PG10, PG5 as well as ASTRO and PC. Approximated parameters of disturbing bodies can be defined after introducing the topographical corrections to the measured values  $g$ . It should be possible after preparing



the map of the surroundings Dobrowolski Station. Such map, in the scale 1 : 5000, is under preparation now.

#### 4.4. Determination of the depth of Mohorovičić discontinuity

The values of Bouguer anomalies were found to be closely connected with the depth of Mohorovičić discontinuity (Fajklewicz 1973). Woolard (1959) considered that a dependency between Bouguer anomaly and thickness of the Earth's crust is a linear function, but in fact it is expressed by an exponential relation. The studies over the mentioned dependency resulted in finding the experimental equation for the depth of Mohorovičić boundary. Woolard proposed the following formula:

$$h_s = 32 - 0.08 A_B$$

where:

$h_s$  — depth of Mohorovičić discontinuity (km)

$A_B$  — Bouguer anomaly (milliGals)

The depth  $h_s = 26$  km for Bunger Oasis was obtained, taking the mean value of regional Bouguer anomaly. This value is not the precise one as the survey area was too small.

## 5. Conclusions and demands

a) Gravimetric surveys allowed to find a position of disturbances of anomalies in the surroundings of Dobrowolski Station. The distinguished area of gravitational disturbances are proposed to be included to detailed microgravimetric measurements in the future.

b) Gravimetric measurements on the whole area Bunger Oasis would enable to prepare a map of Faye's anomalies. Such studies in connection with regional measurements, results of observations of artificial, Earth satellites — would make possible to find the components of a vertical deflection and to carry through an astronomical-gravimetric levelling.

c) Mean density of subsurface parts of Earth's crust is smaller than it has been expected. Therefore, detailed gravimetric sections are proposed to be done for a more detailed evaluation of density. Other methods of density evaluation should be also included.

d) Gravimetric works together with geological studies, will enable a better knowledge of the geological structure of the whole Bunger Oasis and they should be planned for the future.

## 6. Summa:

A geodetic net was set up, in the area of about 4 km<sup>2</sup>, composing of 26 points (Fig. 2). Geographical coordinates and altitude of every point was found (Table I). At these points gravimetric data were collected using a quartz gravimeter Sharpe CG2 (Table I), calibrated on the Mirnyj Station by a tilt method.

The gravimetric reductions were introduced to measured values of accelerations of gravity (density of subsurface parts of the Earth's crust was evaluated by the Nettleton's method). Free-air and Bouguer anomalies were obtained (Table II) and the maps of adequate anomalies were prepared on this ground (Figs. 4 and 5).

Assuming that the regional anomalies has orientation agreeable with parallels of latitude, the residual Bouguer anomalies were calculated (Table II, Fig. 6). The isoanomaly curves proved an occurrence of gravitational disturbances in the studied area. A thickness of the Earth's crust was evaluated by application of Woolard theory and formulae in Bunge Oasis. The Mohorovičić discontinuity occurs there at the depth of about 26 km.

## 7. Резюме

На площади около 4 км<sup>2</sup> заложено геодезическую основу складывающуюся из 26 пунктов (рис. 2).

Установлено географические координаты а также высоту каждого из пунктов (таблица I). На этих пунктах проведено гравиметрическое измерение (таблица I) кварцевым гравиметром калиброванным в Станции Мирный методом наклоения.

После введения до измеряемых величин ускорения гравиметрических редукций (плотность поверхностных слоев земной коры определенных методом Неттлетона) получено аномалии в свободном воздухе а также аномалии Бугера (таблица II), на основании которых сделано карты ответствующих аномалий (рис. 4 и 5).

Принимая широтный ход аномалий региональных определено элювиальные аномалии Бугера (таблица II, рис. 6). Ход этой аномалии свидетельствует о выступлении гравитационных возмущений на исследованной площади.

Используя теории и формулы Воолярда подсчитано толщину земной коры в Оазисе Бунгера. Граница разрыва Мохоровицица находится здесь на глубине около 26 км.

## 8. Streszczenie

Na obszarze około 4 km<sup>2</sup> założono osnowę geodezyjną składającą się z 26 punktów (rys. 2). Wyznaczono współrzędne geograficzne oraz wysokość każdego z punktów (tabela I). Na punktach tych wykonano pomiar grawimetryczny (tabela I), grawimetrem kwarcowym Sharpe CG2, wycechowanym w Stacji Mirnyj metodą nachylenia.

Po wprowadzeniu do mierzonych wartości przyspieszenia redukcji grawimetrycznych (gęstość przypowierzchniowych warstw skorupy ziemskiej wyznaczono metodą Nettletona) otrzymano anomalie wolnopowietrzne oraz anomalie Bouguera (tabela II), na podstawie których wykonano mapy odpowiednich anomalii (rys. 4 i 5).

Przyjmując równoleżnikowy przebieg anomalii regionalnych wyznaczono anomalie rezydualne Bouguera (tabela II, rys. 6). Przebieg tej anomalii świadczy o występowaniu zaburzeń grawitacyjnych na badanym obszarze.

Wykorzystując teorię i wzory Woolarda obliczono grubość skorupy ziemskiej w Oazie Bungeera. Granica nieciągłości Mohorovičića znajduje się tu na głębokości ok. 26 km.

## 9. References

1. Barlik M., Czarnecki K. 1971 — Cechowanie grawimetrów typu GAK 7T i Sharpe CG metodą nachylenia w laboratorium grawimetrycznym Politechniki Warszawskiej — *Geodezja i Kartografia*, 20: 199—207.

2. Bilski E. 1971 — Geofizyka — Wyd. Politech. Warsz., Warszawa, 360 pp.
3. Fajkiewicz Z. 1973 — Grawimetria poszukiwawcza — Skrypt uczelniany AGH 335, Warszawa, 415 pp.
4. Jung K. 1961 — Schwerkraftverfahren in der angewandten Geophysik — Leipzig, 348 pp.
5. Nettleton L. 1940 — Geophysical prospecting in oil — New York, 444 pp.
6. Woolard G. P. 1959 — Crystal structure from gravity and seismic measurements — J. Geoph. Res., 64: 1521—1544.
7. Ząbek Z., Śledziński J. 1960 — Nawiązanie grawimetryczne Warszawa-Stacja im. A. B. Dobrowolskiego na Antarktydzie — Geodezja i Kartografia, 9: 197—208.

Paper received 12 December 1979

**AUTHOR'S ADDRESS:**

Mgr inż. Andrzej Pachuta  
Instytut Geodezji Wyższej  
i Astronomii Geodezyjnej  
Politechniki Warszawskiej  
Pl. Jedności Robotniczej 1  
00-661 Warszawa, Poland