

# ON THE RELATION OF THE GRAVITATIONAL FIELD TO THE GEOLOGICAL STRUCTURE OF THE INVESTIGATED REGIONS OF ANTARCTICA

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Abstract

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GEOPHYSICS

S. A. USHAKOV

## ON THE RELATION OF THE GRAVITATIONAL FIELD TO THE GEOLOGICAL STRUCTURE OF THE INVESTIGATED REGIONS OF ANTARCTICA

*(Presented by Academician D. I. Shcherbakov, 30 X 1961)*

At the present time it has been established <sup>(9)</sup> that, despite the excess load of ice, Antarctica is for the most part in a state of isostatic equilibrium, and that this state arose as a result of the bending of the Earth's crust under the weight of the ice. In this connection the question arises whether the major geological structures of the sixth continent are reflected in regional Faye anomalies, or whether the ice load levels out their gravitational effect. To clarify this question, an averaging was carried out of gravity anomalies published in Soviet <sup>(7,11)</sup> and foreign <sup>(12)</sup> editions, as well as those obtained with the participation of the author\*. The averaging was performed by cells whose width was  $\sim 222$  km ( $2^\circ$  in latitude) and approximately equal to the length (from  $5^\circ$  to  $30^\circ$  in longitude). Such averaging is close to averaging over a circle with radius  $\sim 120$  km. It is known <sup>(4)</sup> that with such averaging the value of the averaged Faye anomaly is closest to the value of the isostatic anomaly. On the other hand, such averaging makes it possible to identify regional Faye anomalies, which are usually characteristic of large geological structures.

Despite the excess ice load within the territory of Antarctica studied in gravitational terms, a number of regions can be distinguished by the values of the averaged Faye anomalies, some of which are associated with quite definite geological structures.

Thus, the region of East Antarctica, extending approximately along the meridian  $100^\circ$  E from Pravda Coast to the South Pole, may be divided into districts:

1. From  $68^\circ$  S to  $76^\circ$  S—a region which as a whole is characterized by significant positive (+40—+50 mgal) Faye anomalies. Its uplifted part ( $68^\circ$ — $70^\circ$  S)—the subglacial Golitsyn Mountains, whose maximum height is  $\sim 1000$  m <sup>(7,9)</sup>—is characterized by large positive anomalies (on average  $\sim +80$  mgal); the downwarped part—a depression up to 1000 m deep—by negative anomalies ( $-30$  mgal). **Structurally, the uplifted part is a portion of the zone of Cenozoic block uplifts of the post-Proterozoic platform <sup>(2)</sup>, while the downwarped part is probably a graben.**

Fig. 1. Averaged Faye anomalies in the studied regions of Antarctica. 1—from  $-40$  to  $-30$  mgal, 2—from  $-30$  to  $-20$  mgal, 3—from  $-20$  to  $-10$  mgal, 4—from  $-10$  to  $-5$  mgal, 5—from  $-5$  to  $+5$  mgal, 6—from  $+5$  to  $+10$  mgal, 7—from  $+10$  to  $+20$  mgal, 8, 9—from  $+20$  to  $+30$  mgal, 10—from  $+40$  to  $+50$  mgal, 11—from  $+50$  to  $+60$  mgal, 12—from  $+60$  to  $+70$  mgal, 13—from  $+70$  to  $+80$  mgal

Figure 1: Fig. 1. Averaged Faye anomalies in the studied regions of Antarctica. 1—from  $-40$  to  $-30$  mgal, 2—from  $-30$  to  $-20$  mgal, 3—from  $-20$  to  $-10$  mgal, 4—from  $-10$  to  $-5$  mgal, 5—from  $-5$  to  $+5$  mgal, 6—from  $+5$  to  $+10$  mgal, 7—from  $+10$  to  $+20$  mgal, 8, 9—from  $+20$  to  $+30$  mgal, 10—from  $+40$  to  $+50$  mgal, 11—from  $+50$  to  $+60$  mgal, 12—from  $+60$  to  $+70$  mgal, 13—from  $+70$  to  $+80$  mgal

**Analysis of Bouguer anomalies makes it possible to conclude that the thickness of the Earth's crust within this region varies only slightly and on average somewhat exceeds  $40 \text{ km}^*$ ; moreover, the uplift does not have a compensating increase in crustal thickness, and the depression does not have a decrease.**

\* The author took part in processing data obtained by G. E. Lazarev along the profile from Komsomolskaya Station to Vostok Station and by L. I. Khrushchev along the profile from Vostok Station to the South Pole. The elevations of points along these profiles, as well as the elevations of points along the profile from Komsomolskaya Station to the Pole of Relative Inaccessibility, were recalculated relative to the new elevation of Komsomolskaya Station,  $3497 \text{ m}$  <sup>(11)</sup>, obtained by the method of geodetic leveling.

\*\* It is precisely for this reason that the mean value of the Faye anomaly in the cell  $70^\circ-72^\circ \text{ S}$ ,  $93^\circ-100^\circ \text{ E}$  is close to zero.

\*\*\* Here and below, the thickness of the Earth's crust is calculated from Bouguer anomalies in accordance with the relation established by R. M. Demenitskaya <sup>(3)</sup>.

2. From  $76^\circ \text{ S}$  to  $86^\circ \text{ S}$ , the region is characterized by regional Faye anomalies that are close to zero and small positive ones (up to  $+14 \text{ mgal}$ ). The level of the bedrock within this region varies only slightly and on average is close to sea level (5). On the basis of the values of the averaged Faye anomalies, and especially of the Bouguer anomalies, the region may be divided into two sectors: a)  $76^\circ-80^\circ \text{ S}$ —the Faye anomalies are on average close to zero, the Bouguer anomalies are  $\sim -140 \text{ mgal}$ ; b)  $80^\circ-86^\circ \text{ S}$ —the Faye anomalies are slightly positive,  $\sim +10 \text{ mgal}$ , and the Bouguer anomalies are  $\sim -110 \text{ mgal}$ .

**Fig. 1.** Averaged Faye anomalies in the studied regions of Antarctica. 1—from  $-40$  to  $-30$  mgal, 2—from  $-30$  to  $-20$  mgal, 3—from  $-20$  to  $-10$  mgal, 4—from  $-10$  to  $-5$  mgal, 5—from  $-5$  to  $+5$  mgal, 6—from  $+5$  to  $+10$  mgal, 7—from  $+10$  to  $+20$  mgal, 8, 9—from  $+20$  to  $+30$  mgal, 10—from  $+40$  to  $+50$  mgal,

11—from +50 to +60 mgal, 12—from +60 to +70 mgal, 13—from +70 to +80 mgal.

3. From 86° S to 90° S—the region is characterized mainly by negative Faye anomalies (on average  $\sim -15$  mgal) and Bouguer anomalies of  $\sim -130$  mgal. It should be noted that the region is characterized by negative Faye anomalies despite the fact that the hypsometry of its bedrock relief is somewhat higher than in the region north of 86° S, which is characterized by positive anomalies. A very similar picture was established by the author (10) in the coastal zone of East Antarctica in the region of Oates Land and King George V Land. On the basis of geological data (6, 8), Oates Land, whose gravitational characteristic is comparable with that of the circumpolar region, was assigned to the Caledonides, whereas King George V Land, whose gravitational characteristic is comparable with that for the sector 86°–80° S, was assigned to the post-Proterozoic platform.

A large part of the traverse from Komsomolskaya Station to the Pole of Inaccessibility passes over the Gamburtsev Mountains (7), which geologists (2) assign to Cenozoic block uplifts of the East Antarctic Platform. The mean height of the Gamburtsev Mountains is about 2000 m, and that of the highest sector about 2400 m. The magnitude of the regional Faye anomalies in the region of the Gamburtsev Mountains is more than +40 mgal, and within the highest sector more than +60 mgal. The Bouguer anomalies within most of the Gamburtsev Mountains are less than  $-200$  mgal, and within the highest part about  $-280$  mgal, which indicates a crustal thickness in the region of the Gamburtsev Mountains of about 60 km. According to (1), in regions where the height of the bedrock relief is more than 1500 m, the values of the averaged Faye anomalies considerably exceed the values of the isostatic anomalies. Therefore, taking into account the height of the Gamburtsev Mountains, it may be expected that these ...

region is characterized by small negative ( $\sim -20$  mGal) isostatic anomalies and, consequently, is in a state very close to equilibrium. However, it should be noted that the correlation between the difference of the regional Faye anomaly and the isostatic anomaly and the relief elevation for the continent, and with the depth of the bottom for the ocean (<sup>1</sup>), is valid only with respect to the elevations of the bedrock relief. It cannot be extended to those same regions of Antarctica whose elevation above sea level, although great (3–4 km), is due mainly to the thickness of the ice, whereas the level of the bedrock in these regions is close to sea level. Practically among all the regions of Antarctica investigated, large discrepancies between the regional Faye anomalies and the isostatic anomalies may be expected only for the region of the Gamburtsev Mountains. The elevations of the bedrock relief in the other regions investigated are such that there should not be large discrepancies between the values of the Faye anomalies and the isostatic anomalies.

Thus, by the character of the gravitational field within the investigated part of East Antarctica, at least four different regions may be distinguished. It should

be emphasized that the Golitsyn Mountains and the Gamburtsev Mountains, assigned by geologists <sup>(2)</sup> to a single zone of Cenozoic block uplifts, differ substantially both in their isostatic state and in the thickness of the Earth's crust, which suggests different causes for the activation of these parts of the platform.

The territory of West Antarctica studied in gravimetric respect may be divided, according to the magnitudes of the regional Faye anomalies, into three regions:

1. From 76° S. lat. to 86° S. lat., approximately along 90° W. long.—a region characterized by significant positive regional Faye anomalies from +40 to +50 mGal and Bouguer anomalies averaging from −40 to −60 mGal (crustal thickness 36–40 km). The region is confined to quite definite geological structures, namely to the Sentinel Mountains and to uplifts of the bedrock relief extending approximately along the meridian 90° W. long. from the Sentinel Mountains to the Horlick Mountains. The mean elevation of the bedrock relief along the line of investigation is about 400 m; it is precisely this elevation of the bedrock relief that corresponds to Faye anomalies of the order of +40 to +50 mGal. Structurally this region is regarded <sup>(2)</sup> as part of a zone of Cenozoic block uplifts, which does not contradict the results of geophysical investigations (for the gravimetric characteristic of the region corresponds to the characteristic of the studied sectors of the zone of peripheral Cenozoic block uplifts of East Antarctica).
2. A region of negative (down to −40 mGal) regional Faye anomalies, which corresponds to the subglacial Ross-Bellingshausen depression. Bouguer anomalies within this depression are, as a rule, from +30 to +50 mGal, and even in the deepest parts of the depression do not exceed +65 mGal, which indicates a crustal thickness of about 30 km.
3. A region of averaged Faye anomalies close to zero (110°–130° W. long., 76°–80° S. lat.), within which the values of Bouguer anomalies vary from +40 to −30 mGal. This fact is explained by the circumstance that one part of the region structurally belongs to the Ross-Bellingshausen depression, whereas the other belongs to the zone of volcanic uplifts of Marie Byrd Land, which is clearly reflected both in the morphology of the bedrock relief and in the character of the gravitational anomalies (Faye and Bouguer). It should be noted that the individual volcanic mountains of the Kohler Range (76° S. lat., 112° W. long.), whose elevation is only about 1000 m, are characterized by large (over +100 mGal) positive Faye anomalies and, consequently, these mountains are far from isostatic equilibrium.

In view of the fact that individual large geological structures of Antarctica are characterized by quite definite values of the regional Faye anomalies, it is of interest to estimate the mean value of the isostatic anomaly of the entire investigated territory of the sixth continent. Taking...

...assuming that, in the region of the Gamburtsev Mountains, the isostatic anomaly is 60–70 mgal smaller than the averaged Faye anomaly, while in the

remaining regions they are close in magnitude, we obtain for East Antarctica an average isostatic anomaly of  $\sim +10$  mgal, and for West Antarctica  $\sim 0$  mgal.

Thus, despite the fact that Antarctica as a whole is isostatically compensated rather fully, large inhomogeneities in the structure of the Earth's crust are reflected in the character of the gravitational field of the sixth continent, and large geological structures are characterized by quite definite regional Faye anomalies. This fact can be successfully used in the tectonic regionalization of Antarctica.

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Moscow State University  
named after M. V. Lomonosov

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*Note: Figure translations are in progress. See original paper for figures.*

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