SECULAR CHANGES IN GRAVITY ON THE RUSSIAN PLATFORM

GEOPHYSICS

1969

SovietRxiv

Abstract

Full Text

UDC 550.312

GEOPHYSICS

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SECULAR CHANGES IN GRAVITY ON THE RUSSIAN PLATFORM

(Presented by Academician V. V. Menner, 13 VI 1969)

Secular changes in gravity, unlike the periodic changes caused by the tidal action of the Moon and the Sun, can in principle occur as a result of deep-seated processes that determine the evolution of the Earth and the geological history of its surface layers. Whereas variations in gravity due to the influence of cosmic bodies have been well studied, it has so far not been possible to obtain a reliable picture of secular changes in gravity over an area ([1]). The difficulty lies in the fact that there is no objective criterion for attributing discrepancies in gravity detected at individual points, or even along profiles, not to metric errors but specifically to geological phenomena. In the present article an attempt is made to overcome this difficulty and to reveal the pattern of distribution of secular changes in gravity (Δg_t) over an area, using as an example two extensive regions of the Russian Platform—the Middle Volga region and the Baltic region.

Principle of detecting the secular trend. The Earth' s crust is a medium in which geological processes occur, or on which they act, processes that also encompass the deep zones of the Earth' s crust and the upper mantle. Therefore, some influence of the structural features of the crust on the course of geological processes is possible. For the Russian Platform this is confirmed by inheritance, in the structure of the platform cover, of certain features of the internal structure of the Precambrian crystalline basement; in particular, the influence of sign-variable movements of basement blocks, whose position is reflected in gravitational and magnetic anomalies, on the formation of the platform cover throughout the entire history of its development has been established ([2]). Thus, definite relationships should exist between the elements of the Earth' s crustal structure that we see on geological and geophysical maps and the pattern of distribution of Δg_t over the area.* Similar relationships may be expected between the values of Δg_t and the distribution pattern of seismicity, modern and recent movements, etc. The existence of common features (extent, contours) of the main zones shown by geological-geophysical maps and by the regularity of the distribution over the area of the assumed values Δg_t may indicate a real connection between the gravity differences revealed as a result of repeated measurements and secular variations. Establishing these relationships is possible, of

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course, if repeated measurements of gravity are carried out over a broad area and with a sufficiently dense network of points. The presence of such a geological correlation, and sometimes merely the detection of a regular pattern over the area (caused by that component of the influence of geological processes which does not correlate with known geological data),

* This seems also to be indicated by data from gravity measurements along the Kharkov-L' vov profile, of which we became aware upon completion of the present work ([3]).

should greatly increase the reliability of detecting small quantities that evidently characterize secular variations over short periods (a decade, a year).

The material used includes gravimetric measurements carried out on the Russian Platform in 1949-1968. Initially such measurements were made in connection with the solution of geological-exploration problems. In the Middle Volga region (Fig. 1), a considerable part of the investigations was carried out by the Spetsgeofizika trust from 1949 to 1957 with the participation of L. A. Yurkova, R. F. Volodarsky, the author, and others. In the region north of the Volga the work was carried out by the Geofiznefteuglerazvedka trust in 1958-60 with the participation of Yu. S. Dezhanova, N. G. Filippovich, V. A. Krasnov, and others; in the area south of Penza, by the Lower Volga geophysical trust. The root-mean-square error of gravity measurements in this period is of the order of $\pm$0.5 mgal. The performance of the work in one level was ensured by the use of common initial points, by control along the boundary of the surveys, and by tying the initial points to high-precision stations established, on the initiative of Yu. D. Bulanzhe, by an expedition of the Institute of Physics of the Earth, Academy of Sciences of the USSR. On the whole, it may be considered that the southern part of the area under consideration was carried out in the epoch 1951-52, the middle part in the epoch 1957, and the northern part in the epoch 1959.

Fig. 1. Diagram of isolines of Δg_t for the Middle Volga region.
1 –values of Δg_t in mgal; in parentheses, the mean time interval (in years) between observations; **2** –isolines of Δg_t at intervals of 1 mgal; **3** –axes of geophysical anomalies and zones.

In the Baltic region, in 1958, gravimetric stations were determined by the Spetsgeofizika trust with the participation of the author; their system was tied to the high-precision stations of the Institute of Physics of the Earth. This system also included the work of V. Ya. Maazik in Estonia and of S. I. Blinstrubas and A. K. Razhinskas in Lithuania.

Since the beginning of the 1960s, in the Volga and Baltic regions a second cycle

Fig. 2

Figure 2: Fig. 2

of gravimetric measurements has been conducted, performed under the direction of E. A. Azarkina and B. A. Krasnov by parties of the Spetsgeofizika and Geofiznefteuglerazvedka trusts. In the Middle Volga region these determinations were carried out mainly in 1965; in the Baltic region, in two stages: in 1963 and in 1967-68. In 1963, Yu. D. Bulanzhe and M. E. Kheifets made observations of gravity at points previously (in 1958) determined in the Baltic region. The root-mean-square error of these measurements is estimated as $\leq \pm 0.2$ mgal. Thus, it may be considered that a repeated series of gravity measurements in the regions of the Vol–

the Volga region and the Baltic region was carried out after 5-10 years. In view of the insignificant differences between the values of gravity over this time, we considered it possible to plot them on the map without reducing them to a normalized time interval.

Maps of secular changes in gravity. The values Δg_t were calculated, in cases where points of repeated and primary measurements coincided, from the observed values; otherwise, from anomalies (in the first case the mean square error of Δg_t is about ± 0.3 mgal, in the second $\pm 0.5 \div \pm 0.8$ mgal). Maps of Δg_t were then constructed with isolines spaced at 1 mgal.

Fig. 2. Diagram of isolines of Δg_t and tectonic elements of the Baltic region. The average interval between primary and repeated observations is 5 years.
1 –values of Δg_t in mgal for the interval 1958-1963; 2 –values of Δg_t in mgal for the interval 1963-1967, 1968; 3 –isolines of Δg_t at 1 mgal intervals; 4 –areas of uplifts (I –slope of the Baltic Shield, II –Lokno uplift, III –slope of the Belorussian massif); 5 –ancient depressions on the Precambrian basement, distinguished by their structure (in the north –the Riga depression, in the south –the Curonian depression); 6 –certain fault zones (A-A –Latvian, B-B –Pinsk-Pregolya); 7 –axis of the Devonian trough.

The smooth course of Δg_t over the area and the absence of deviations from this course show that the network of repeated observations and the accuracy of the Δg_t values are sufficient, in a first approximation, for constructing maps with the indicated interval and for comparing them with geological and geophysical elements. The time interval of Δg_t for the Middle Volga region varies from 13-15 years in the south to 5 years in the north; for the Baltic region, Δg_t values were plotted for the periods 1958-1963 and 1963-1968. However, all the Δg_t values agree well with one another, being located in fairly extensive zones of elevated or reduced values of this quantity. The largest values of Δg_t in the Middle Volga region are negative (< -2 mgal in the southern part of the area), while in the Baltic region they are positive (+1.5 mgal in the southwestern part of the area). In general, however, the changes in Δg_t lie within the limits from +1 to −1 mgal. The good agreement of the values for different time intervals apparently indicates the reality and a definite regular character of these changes. The independence of the location of the Δg_t zones from the contours of individual surveys is noted, as well as the independence of the magnitude and sign of Δg_t from the magnitude of gravity, which may mean an insignificant influence of the systematic component of the metric error (however, it is clear that reliable exclusion of errors can be ensured only by carrying out a special program of Δg_t observations). At the same time, one may note the spatial agreement of the isolines of Δg_t and the axes of geophysical (gravitational and magnetic) anomalies for the Middle Volga region (Fig. 1), and of the positions of zones of elevated and reduced Δg_t values and tectonic elements for the Baltic region (Fig. 2). Therefore, pre-

it appears highly probable that, in the calculated values of Δg_t, the influence of secular changes in the force of gravity predominates.

Conclusions. The materials presented apparently indicate the possibility of detecting secular changes in the force of gravity over large areas within short periods of time. This is of great importance for the study of contemporary geological phenomena and for understanding the nature of the deep-seated processes underlying them, and will also, possibly, make it possible to reduce gravimetric observations carried out at different times to a single epoch.

The author expresses gratitude to N. G. Filippovich and E. L. Cherkasova for assistance in analyzing the materials, to the head of the laboratory of VNIIGeofizika L. A. Yurkova, to Corresponding Member of the USSR Academy of Sciences Yu. D. Bulanzhe, and to Corresponding Member of the USSR Academy of Sciences V. V. Fedynsky for their attention to the work and for valuable comments during discussion of its results.

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Received
13 VI 1969

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