Problems of the evolution of the figure and the earth's gravitational field

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Abstract. The relevance of geoid research involves examining a number of problems, the consideration of which reveals the evolution of the geoid. Measurements of the geoid help to understand the internal structure of our planet.

1 Introduction

Geoid is a surface that coincides in the oceans with the mean level of undisturbed wave and tidal water and extends beneath the continents according to the law of potential constancy. This surface is continuous, closed, and everywhere convex.

As the shape of the geoid depends on the unknown distribution of masses inside the Earth, it is strictly indeterminate. The precise shape of the geoid can only be determined from calculations of the gravitational potential.

The problem of evolution of the geoid shape involves investigating the following problems:

1. Finding levels of placement of horizontal inhomogeneities in the body of the planet.
2. Determining the physical nature, dimensions, and formation of horizontal dense inhomogeneities.

2 Geoid modelling

The solution of these problems, and the problem as a whole, requires a systematic approach that considers the geoid as a reflection of the evolution of a single dynamic subject, the planet Earth, which has various interrelated levels of structural-material organization.

Each level of structural-material organization of the planet is reflected on the Earth surface in movements, crustal structural-material complexes and geophysical anomalies of a certain rank differ from each other by their spectra. In the structural material organization, the main ranks can be divided into global, mega, macro, meso, microregional and channel [3].

In accordance with this the problem of the geoid evolution requires the establishment of the links between geoid anomalies of different ranks with the corresponding structural-material complexes of the planet and the study of the development patterns of these complexes.

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Global anomalies of the geoid are the development of a broad continuous field of a single positive anomaly, within which large inclusions of negative anomalies are distinguished. The anomalies of gravity anomalies arising due to uneven distribution of Earth's masses provide material for finding the distances of the geoid level surface from the relativity ellipsoid, and the values of anomalies characterize the degree of divergence of the level surfaces.

A single anomaly corresponds in its spatial position to the World Ocean. Negative anomalies correspond to continents and their groups. This pattern is most clearly seen in the relief of the geoid obtained by S.K. Runcorn by excluding the isostatic geoid from the geoid.

Surface approximation is used to investigate the numerical characteristics and qualitative properties of the geoid.

At the same time, correlation, component and other types of statistical analysis used showed a stable global relationship between the topography of the compensated geoid and tectonic structures of the first order - continents and oceans. It means that the formation of the global relief of the geoid and global tectonic structures is caused by the same reasons and is related to the same global geodynamical processes that take place in the interior of the Earth [6].

Depth of the global geodynamic processes, which form the largest horizontal density inhomogeneities, is determined by calculating the depth of the perturbing sources, responsible for the appearance of large geoid anomalies with closed contours, having a length of several thousand kilometres. Such anomalies are identified both in the field of global positive anomalies (North Atlantic, Western Pacific, etc.), and in the areas of negative anomalies (North American, Siberian, Indian, etc.). Quantitative calculations show that perturbing masses lie at a depth of 560-1350 km, i.e., are confined to A.E. Ringwood phase transition zones in the middle mantle.

These large confined anomalies are only part of the global geoid anomalies. Therefore, the perturbed geoidal masses are located much deeper. The most probable depth of their location is the core-mantle boundary.

This conclusion is based on the fact that seismological data show the absence of large horizontal area inhomogeneities within the lower mantle. At the same time at the core-mantle boundary there is a sharp increase of matter density by 4 g/cm3 , and in A. Cook's opinion rather small fluctuations of this boundary may well be a source of gravitational anomalies with length about 4000 km and more.

Thus, the main level of occurrence of the largest on the Earth horizontal density inhomogeneities is the core-mantle boundary. Above it, in the middle mantle, there is a second level of occurrence of disturbing masses, responsible for occurrence of the largest anomalies of the global geoid relief.

Statistical analysis shows that these major geoid anomalies are not systematically associated with any geological and geophysical parameters on the Earth's surface. They reflect the inhomogeneity of the global relief of the geoid, due to the unevenness of the geodynamic processes at the core-mantle boundary, under the influence of which is formed disturbing mass in the middle mantle.

3 Results

As studies have shown, the correlation between higher rank geoid anomalies and geological-geophysical parameters is variable. The correlation between positive anomalies and areas of Quaternary mechanism is most stable. In general, the development of the Earth's crust in both oceans and continents takes place in conditions close to isostatic. However, during the transition to structural anomalies of meso- and microregional rank in the mobile belts and adjacent platform areas, a pair (or a group) of gravity anomalies of different signs, which spatially coincide with the coupled pairs (or groups) of tectonic structures of uplift-

deflection, are observed. Positive gravity anomalies coincide with uplifts and negative gravity anomalies coincide with troughs (depressions).

Thus, qualitative and quantitative analyses of geological-geophysical data show that the geoid relief is formed by perturbing masses located in the core-mantle boundary, in the middle mantle and finally, in the upper mantle and crust, where they are connected with volcanism and lateral movement of deep matter from sags to uplifts. In addition, the isostatic structure of the Earth's crust contributes.

These are the main factors shaping the geoidal topography. However, another level of location of large density inhomogeneities is known from seismological data - it is the level of asthenospheric layers (or asthenosphere) of upper mantle. The asthenosphere has the most powerful development in zones of volcanism inside the oceans and on their margins, and minimum - on shields of ancient platforms. The gravitational effect of the asthenosphere is negative in the oceans and positive on the metrics. In the geoid relief, it is practically not expressed because it is suppressed by stronger gravitational effects of other levels of horizontal density inhomogeneities. But this effect should be taken into account in the modeling of the geoid and its paleo- and futuromodels.

Modeling of the geoid should be based on the knowledge of spatial and temporal regularities of the formation and evolution of all the above factors at different levels of the planet. The formation of all levels of horizontal density inhomogeneities is caused by the development of two global geodynamic systems: the warming system and the cooling system. The first one is responsible for the formation of the global positive relief of the geoid and tectonic structures of the oceanic type and the second one - for the negative relief of the geoid and tectonic structures of the platform type.

4 Conclusion

Thus, the knowledge of geodynamic regularities of the geoid development gives the possibility to set and solve fundamental problems about the Earth's figure and gravitational field evolution.

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