ON BOUGUER ANOMALIES OVER THE OCEANS

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At present the principal form in which anomalies of the force of gravity are represented is their representation as Bouguer anomalies. Almost all gravimetric maps are compiled in terms of these anomalies; they are also cited in all catalogues, and often only they are given, not only for land but also for oceanic regions. The authors, in working on questions of compiling maps, storing gravimetric data, and interpreting them, have become convinced of the inadvisability of using Bouguer anomalies as the principal and, in the majority of cases, the only form of representation of the gravitational field.

Historically, the Bouguer reduction was introduced for land, originally not for geological interpretations but for regularization in solving the problem of the figure of the Earth. The meaning of the correction was interpreted as follows: to determine a closed level surface representing the Earth, it is necessary that there be no masses outside it. This is a necessary condition for solving Stokes' problem, as well as for constructing the figure of the Earth by Clairaut' s method. All measured values of the force of gravity must be reduced to a reference surface, which in this case is taken to be the geoid. The masses protruding beyond the geoid must be removed. This is the purpose of the free-air reduction with the Bouguer correction

$$\delta g = 2\frac{\gamma}{R}H - 2\pi f\sigma H = 0.3086H - 0.0418\sigma H.$$

According to this classical definition, the Bouguer correction over the ocean is equal to zero, since in the oceans no masses protrude beyond the geoid. Subsequently it became clear that removal of the masses protruding beyond the geoid deforms it very perceptibly, and the Bouguer correction, when anomalies are used for geodetic purposes, only interferes. Then Bouguer anomalies were excluded in solving geodetic problems. But for geological interpretations they were retained, since, by excluding the attraction of the intermediate layer, we as it were remove the influence of masses known to us, which to some extent masks the manifestation of the anomalous masses sought.

The introduction of the Bouguer reduction in the accepted sense for the sea, i.e., the introduction of a correction filling the mass defect in the ocean, logically contradicts this meaning of introducing Bouguer corrections on land, since, by filling in the ocean, we artificially create an enormous background that masks this effect. In addition, on land we lower the point to sea level and eliminate external masses, whereas at sea the point is already on the reference surface. The only thing that can to some extent justify the introduction of the Bouguer reduction at sea is a certain smoothing of the influence of the forms of relief of the ocean floor in each local area. However, the smoothing is carried out in an unfavorable manner, since in doing so a large artificial regional background is created. The introduction of Bouguer reductions at sea is a question of specific processing of the material for one or another interpretation. But even in this case it should be borne in mind that Bouguer anomalies for oceanic regions, formed by "filling" the ocean to the average-density threshold without taking into account corrections for the relief of the ocean floor, may be distorted by tens of milligals.

The Earth as a whole is isostatically compensated. Precisely for this reason, just as in mountains, where there would seem to be an enormous excess of masses, there are no large positive anomalies, so in the oceans, where there would seem to be a deficit of masses, no large negative anomalies are observed. Introducing the Bouguer correction creates a false impression of a sharp difference between the fields. In fact, for oceans, where the mean depths are of the order of 4–5 thousand m, the Bouguer correction is 270–340 mgal, which are added to the natural field, of the order of $\pm$50 mgal. Thus, over the oceans an enormous background of artificial positive anomalies of the order of 200–500 mgal is created. Having artificially created such anomalies, we begin to interpret them and to derive all sorts of interrelations. By introducing, through the Bouguer correction, an element of depth into the anomaly, attempts are sometimes even made to reconstruct this relief from the anomalies, forgetting that what is being used here is secondary, already impoverished information. The introduction of the Bouguer correction at sea only introduces confusion and is therefore harmful. Considerably more information can be extracted from uncorrected depths and real anomalies than from a complicated mixture of the one and the other, called a Bouguer anomaly.

On land, Bouguer anomalies also behave in a very specific way. The large negative anomalies of mountainous regions by no means indicate an anomalous gravitational field, but only an anomalous relief.

It is customary to believe that free-air anomalies reproduce the relief, whereas Bouguer anomalies, with the proper choice of densities, do not depend on the relief. However, this is true when one is dealing with small local areas within which individual characteristic features have no compensation; each individual mountain is, as it were, an excess mass. Above it the force of gravity will be greater than at the nearest points in the valley. Within this small area, free-air anomalies depend on the relief. If this mountain is removed—which the

Bouguer correction approximately does, with the proper choice of density—then the dependence on the relief also disappears. In this sense Bouguer anomalies do not depend on the relief and are convenient for interpretation. However, when we pass from one region to another and study regional anomalies over extensive areas, Bouguer anomalies, for the most part, become carriers of information about the relief, which is already known to us anyway.

Hence the conclusion: within small areas, Bouguer anomalies reflect the structural makeup of the Earth' s crust, and therefore their geological interpretation is possible. In these cases the general level of the anomalies is unimportant, and the introduction of Bouguer corrections weakens the influence of relief; this is convenient. For large regions, Bouguer anomalies primarily reflect the structure of the relief, and their connection with the geological structure of the Earth' s crust is apparent. In these cases Bouguer anomalies prove to be a function of the relief and lose their gravitational informativeness. Consequently, their use is justified only in the case of local areas. But then, evidently, they cannot be regarded as the principal form of representation of the gravitational field.

Recently many works have appeared in which a dependence is established between the thicknesses of the Earth' s crust and gravity anomalies, and diagrams of the structure of the Earth' s crust are also constructed from gravity anomalies and relief. The dependence of Bouguer anomalies on the thickness of the Earth' s crust may be represented as follows:

$$M = M_0 + k\Delta g_{\mathrm{b}} = M_0 + k[\Delta g_{\mathrm{f.a.}} - 0.0418\sigma H],$$

where Δg_{b} is expressed through $\Delta g_{\mathrm{f.a.}}$ and the correction for the intermediate layer.

Taking the values $\sigma = 2.7 - 1.03$, where 2.7 is the density of the crust beneath the ocean and 1.03 is the density of water, we obtain

$$M = M_0 + k\Delta g_{\mathrm{f.a.}} - k0.07H.$$

With rare exceptions, the first term in the square brackets lies within the first ten milligals. The second, for oceanic regions, is of the order of 200–300 mGal. We do not deny that at times it is useful to interpret leveling data and gravimetric measurements simultaneously; however, one must never lose sight of the physical essence of both.

The principal information about the gravitational field is carried by free-air anomalies, formed on the physical surface of the Earth as the difference between the observed value of gravity and the normal value of gravity reduced by means of the system of normal heights. These mixed anomalies reflect the internal structure of the Earth and the deviations ζ of the quasigeoid from the reference surface. If it is possible to introduce corrections for the height of the quasigeoid, then we obtain a system of anomalies that reflect only changes in density.

Now, when gravimetric information is accumulating at an enormous rate and its processing is becoming more and more automated, it is very important to establish which material has the greatest gravitational information content and, consequently, in what form it should be stored as source material suitable for all subsequent interpretations. From all that has been said, it is evident that such a form is free-air anomalies. The use of Bouguer anomalies is admissible and useful in particular special cases—for example, in geological interpretation in local areas. In other words, the introduction of Bouguer corrections should be regarded as one form of interpretation, which removes the gravitational background of known structures and makes it possible to distinguish the residual field more clearly.

We believe that basic gravimetric maps should be compiled in two versions —in free-air and Bouguer anomalies. When constructing maps with Bouguer reduction for the sea, the anomalies should be taken to be the difference $g_0 - \gamma_0$, without corrections for an intermediate layer, since at sea there is none.

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