P325

Nature of Gravitational Anomaly in the South Caspian Basin

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SUMMARY

The South Caspian Basin (SCB) at present attracts increased attention of researchers in connection with its exceptionally rich oil and gas resources. This paper presents an evaluation for predicted gravity anomaly in the SCB, that may have formed as a result of the continental plate subsidence at its central part. The gravity anomaly formed as a result of subsidence of plate has been appraised through its comparison with Earth crust of the Russian Craton. This anomaly has been revealed to be equal to -193 mGal and strongly differs from those observed in the SCB. In fact these 193 mGal appear to be possible compensated due to an action of the strata located beneath the Moho partition with considerably higher density than that of mantle material. The gravitational action of the excessive masses located in the upper mantle was considered as an action of the horizontal cylinder shaped body and depth interval of the consolidated part of the upper mantle has been evaluated. On creating the geodynamic evolution model for the SCB one needs to take into account an astenospheric projection which is predicted to occur at 36-87 km interval.
Introduction.

The South Caspian Basin (SCB) is a unique tectonic structure. First of all it relates to the unprecedented depth of sedimentary filling, and accordingly, the top of consolidated crust – 20-30 km. An important feature of the basin is unusually widespread mud diapirism and volcanism.

The SCB at present attracts increased attention of researchers in connection with its exceptionally rich oil and gas resources. In recent years new data have been obtained and new ideas emerged regarding its structure and geohistory. However, on the whole the question of origin of the basin as a single structure still remains debatable.

In this connection, the paper presents results of gravity studies, computation of the gravity anomaly resulted from subsidence of continental type plate and formation of the SCB, and nature of the observed gravitational anomalies is addressed.

Gravitational anomalies in the SCB. The map of gravitational field in the SCB in Bouguer reduction is given in Fig.1. The zone of maximum sedimentary thickness (Pre-Elborz depression) is characterized by weak negative anomaly.

Fig. 2 demonstrates gravity anomalies of the region re-calculated with the application of Hartley transform (Sundararajan, 1995) for the height of 10 km.

Fig.1. Bouguer gravity anomalies map

Fig 2. Distribution of gravity field in the Caucasian-Caspian region calculated for altitude of 10 km.
According to Artyushkov (1993), Brunet et al. (2003) formation of deep depressions of intracontinental seas, in particular the depression of Caspian Sea is similar to the formation scheme of a depression on platforms (cratons). By this model prior to the recent subsidence a continental type plate lay in the area.

What type of gravity anomaly should we see in the SCB subsidence and formation model and what is nature of the gravity anomalies observed?

**Computations of the SCB gravitational anomalies in the subsidence model of continental type plate.** To conduct computations enabling determination of gravitational anomaly we adopt depth structure model of the Russian platform and the SCB (Knapp et al., 2004).

Let structure of the Russian platform be as follows: total thickness of the crust equals 40 km, “granitic” layer 20 km with density of 2.7 g/cm$^3$ and “basaltic” layer 20 km thick as well, but with higher density, 2.9 g/cm$^3$, the density of subcrustal substratum – 3.3 g/cm$^3$.

In the SCB under 500 m deep seawater lies 10 to 25 km thick sedimentary section characterized by the longitudinal seismic wave velocity of $V_p=3.5$ km/s. Density of these sediments averages about $\rho=2.3$ g/cm$^3$. Underneath the sedimentary strata lies “basaltic” layer, thickness of which is 10 km in the central SCB. Longitudinal seismic wave velocity in the layer is 6.7 km/s, with density 2.9 g/cm$^3$. “Basaltic” layer is underlain by subcrustal substratum, where $V_p=8$ km/s, and $\rho=3.3$ g/cm$^3$ (Fig. 3).

Let us make a comparison between the above described earth crust in the SCB and typical average crustal structure of platform type.

Gravity anomalies in Bouguer reduction in the Russian platform on average are close to normal value. The observed values in the central SCB are also close to normal value.

Let us determine what should be the gravity anomaly in the SCB, an epicontinental formation in comparison with the Russian platform. On evaluation of magnitude of gravity field anomalies we use the formula for plane-parallel layer.

![Fig. 3. Depth structure model of the Russian platform and the South Caspian basin.](image)

When comparing models of a structure of a continental earth crust and SCB we see that on transition from the former to latter the following constituents of gravity force anomalies should be formed.

The upper 500 m water layer has density of 1.03 g/cm$^3$, its excessive density relative to platform “granitic” layer is 1.67 g/cm$^3$, and respective value is -35 mGal. The 19.5 km thick sedimentary pile with excessive density of -0.4 g/cm$^3$ (compared to “granitic” layer) gives an
anomaly of -326.8 mGal.
“Basaltic” layer of 10 km thickness gives an anomaly equal to zero. The lower 10 km layer of subcrustal material (peridotite, eclogite etc.) with excessive density of 0.4 g/cm³ creates an anomaly of +168 mGal.

Thus, if to suggest that below 40 km there are no density heterogeneity and variations, overall cumulative anomaly over the central SCB will amount to -193 mGal. In actuality the observed anomalies are close to normal value. These -193 mGal in fact turn out to be compensated in some way. Such compensation is possible due to action of the material lying under the Moho discontinuity substantially denser than that of mantle. Taking into consideration linear extension of the deep-water SCB, we may regard the gravitational action of the excessive masses located within the upper mantle as an action of a body shaped as vertically cylinder. The positive action of masses above its axis equates to

\[
\Delta g = 2\pi \rho G \left( h_2 - h_1 - \sqrt{h_2^2 + R^2} + \sqrt{h_1^2 + R^2} \right) = 193 \text{ mGal}, \quad (2)
\]

Where \( h_2 \) depth of the bottom part of the cylinder, \( h_1 \) depth of the top part of the cylinder, \( R \)- radius of cylinder. Calculations carried out under this formula (when \( \Delta \rho =0.2 \text{ g/cm}^3 \)) it is resulted in the bottom table:

<table>
<thead>
<tr>
<th>( h_1 (km) )</th>
<th>( h_2 (km) )</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>( R = 60km )</td>
</tr>
<tr>
<td>36</td>
<td>144.37</td>
</tr>
<tr>
<td>38</td>
<td>157.81</td>
</tr>
<tr>
<td>40</td>
<td>172.96</td>
</tr>
</tbody>
</table>

Region of consolidated subcrustal matter possibly occurs at 36-87 km depth interval.

Conclusions.
In the model of subsidence of continental type plate and formation of the SCB the magnitude of gravitational anomaly should be -193 mGal. However, here a weak gravitational field is observed which is typical for the earth crust of continental type. It is suggested that the indicated gravitational anomaly is compensated owing to the action of 36-87 km deep rock layer underlying the Moho discontinuity (asthenospheric projection) and being considerably denser than mantle material.

Literature