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DIGITAL ESTIMATION OF THE GRAVITATIONAL EFFECT OF THE CRYSTALLINE BASEMENT OF THE YEVLAKH-AGJABADI BASIN (MIDDLE-KUR DEPRESSION, AZERBAIJAN)

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Keywords: *algorithm, block-diagram, gravity anomaly, structural map, assessment of gravitational effect, gravity model, digital modeling*

Summary. The paper is devoted to an assessment of the gravitational effect of the crystalline basement of the Yevlakh-Agjabadi Basin of the Middle Kur Depression of Azerbaijan. The Yevlakh-Agjabadi trough is characterized by a thick layer of sedimentary deposits of the Mesozoic and Cenozoic age, lying on a crystalline basement. According to the data of deep seismic sounding, a structural map on the surface of the crystalline basement was plotted. The trough itself is oriented in the Caucasian direction. In this area well-known Muradkhanly and Jafarly oil and gas deposits occur. The crystalline basement, as well as the Meso-Cenozoic deposits, have excessive density and therefore are well reflected in the gravitational field as local gravity anomalies. It can be said that most of the areas of Azerbaijan, including the territory of the Yevlakh-Agjabadi trough, are covered by a general and detailed gravimagnetic surveys. Based on these results, a number of local anomalies were identified here, including in the Muradkhanly and Jafarly areas. High-precision gravimetric and magnetometric surveys are carried out here using digital gravimeters and magnetometers, which disclose great opportunities for gravimetric and magnetometric explorations in the study of this region. In addition, the Department of Geophysics of Azerbaijan State Oil and Industrial University has developed software for various transformations of gravimagnetic fields, as well as solving forward and inverse problems of gravity and magnetic exploration. Therefore, the study of this trough by digital gravity modeling is a very essential problem.

Introduction

In the search, exploration and study of the geological structure of promising oil and gas areas, the gravimetric exploration method is of great importance, and is based on studying the distribution pattern of gravity fields created by some structural uplifts which are characterized by an excess density contrast of rocks their composing. At the stage of gravimetric data quantitative interpretation, a very important problem is modeling of gravitational anomalies, which has a great importance for the geological interpretation (e.g., Искандаров, 2018, 2011, 2005; Hirt, 2016; Nava-Flores, 2016; Hinze et al., 2013; Chakravarthi, 2003). Currently, this problem is being solved in the form of digital modeling using modern graphic programs in two-dimensional and three-dimensional versions based on the results of computer calculations of the observed and theoretical gravitational fields using developed algorithms and programs, which provide the most complete picture of the shape, depth and size of the desired geological facilities and oil and gas fields.

Currently, high-precision gravity exploration using digital gravimeters is being carried out all over the world, as well as in Azerbaijan, which makes it possible to solve finer structural problems and give a more accurate solution to the problem of direct searches for oil and gas deposits. One of the areas with a promising oil and gas potential in the Middle Kur Depression of Azerbaijan is the Yevlakh-Agjabadi trough, which is characterized by a thick layer of sedimentary deposits of the Mesozoic and Cenozoic age, lying on a crystalline basement. According to deep seismic sounding data, a structural map is constructed here on this surface (Fig.1). The Yevlakh-Agjabadi Basin is oriented in the Caucasian direction and is characterized by the depths isohypses from 9 to 15 km. So the vertical amplitude of the basin reaches about 6 km. The Mesozoic rocks are represented by the volcanic-sedimentary deposits. There are well-known Muradkhanly and Jafarly oil and gas deposits, which are reflected in the gravitational and magnetic fields. The Yevlakh-Agjabadi Basin and the overlying sedimentary cover structures are well reflected in the gravitational field. According to the seismic and gravity surveys, deep faults and gaps are observed here, crossing not only the crystalline basement, but also Mesozoic deposits. Therefore, the study of this basin by the gravity exploration using digital modeling is very important. A lot of works have been devoted to the study of this region (e.g. Гадиров и др., 2016; Салманов, Юсифов, 2013; Eppelbaum and Khesin, 2012).

The purpose of this research is to describe an algorithm for calculating the gravity effects from the Yevlakh-Agjabadi Basin and profile and areal gravity digital modeling of the values of the gravity in the aforementioned basin and the Middle Kur depression.

Means and methods

To perform digital modeling, the vertical gravity component and magnetic field values for separate selected profiles on the computer were calculated. To do this, we used the GTEOR algorithm and program developed at the Department of Geophysics of the Azerbaijan State Oil and Industry University (ASOIU) and implemented using the FORSE compiler in the WINDOWS system (Fig.2). This program allows to calculate the gravity field and the vertical component of magnetic field in a two-dimensional version based on the partition of a two-dimensional body into separate homogeneous two-dimensional rectangular prisms (Fig.3) with the constant bases (partition step), and variable heights (differences between the upper and lower edges). The sum of gravitational and magnetic effects from each elementary prism is computed. SURFER programs were used to digitally present the calculation results, as well as to combine profile and areal data. In the two-dimensional case, the gravitational field from the vertical prism is calculated by the following formula:

$$\Delta g_{TEOR} = G\Delta\sigma\left[(\xi - x)\ln\left[(\xi - x)^2 + \varsigma^2\right] + 2\varsigma arctg\frac{\xi - x}{\varsigma}\right]\Big|_{\xi_1}^{\xi_2}\Big|_{\varsigma_1}^{\varsigma_2}. \quad (1)$$

Here G is the gravitational constant; $G=6.67\cdot 10^{-8}$ cm^3/g·s^2; $\Delta\sigma$ is the density contrast; $\Delta\sigma = \sigma_2 - \sigma_1$, g/cm^3; ξ is the prism abscissa; ς is the ordinate of an elementary prism, and x is the observation point abscissa.

The vertical component of the magnetic field of an elementary prism is calculated by the following formula:

$$Z_a = 2I\left[arctg\frac{2bz_1}{z_1 + x^2 - b^2} - arctgz\frac{2bz_2}{z_2 + x^2 - b^2}\right]. \quad (2)$$

Here 2b is the horizontal dimension of the prism; I is the intensity of magnetization; Z_1 and Z_2 are the depth of the upper and lower edges of the prism, respectively, and x is the observation point abscissa.

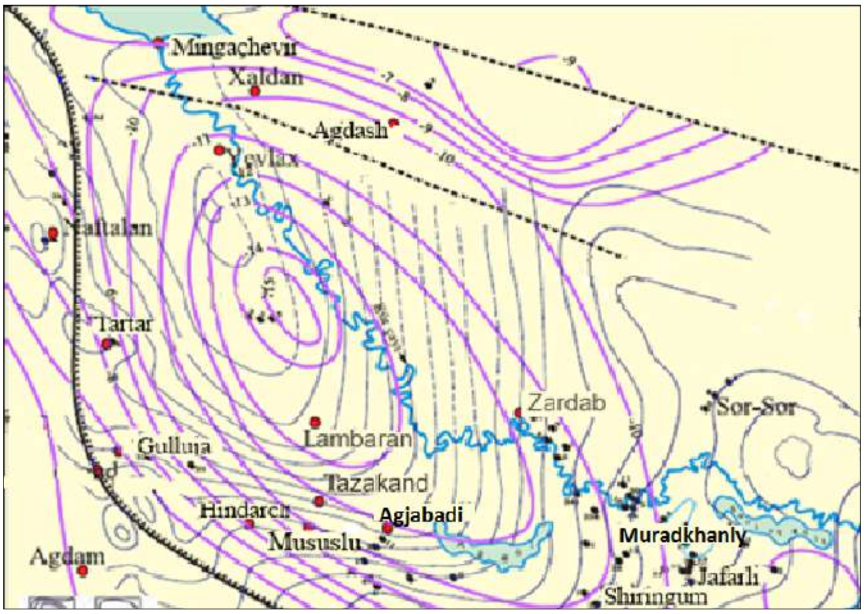

Fig. 1. Comparison of depth of the crystalline basement and gravity anomalies maps in the Yevlakh-Agjabadi depression (1 – isolines of gravity anomalies, 2 – isohypses of the surface of the crystalline basement (Алексеев и Хесин, 1985), 3 – border geological structures (a) and tectonic units (b) (Алексеев и Хесин, 1985), 4 – exploration wells; 5 – localities)

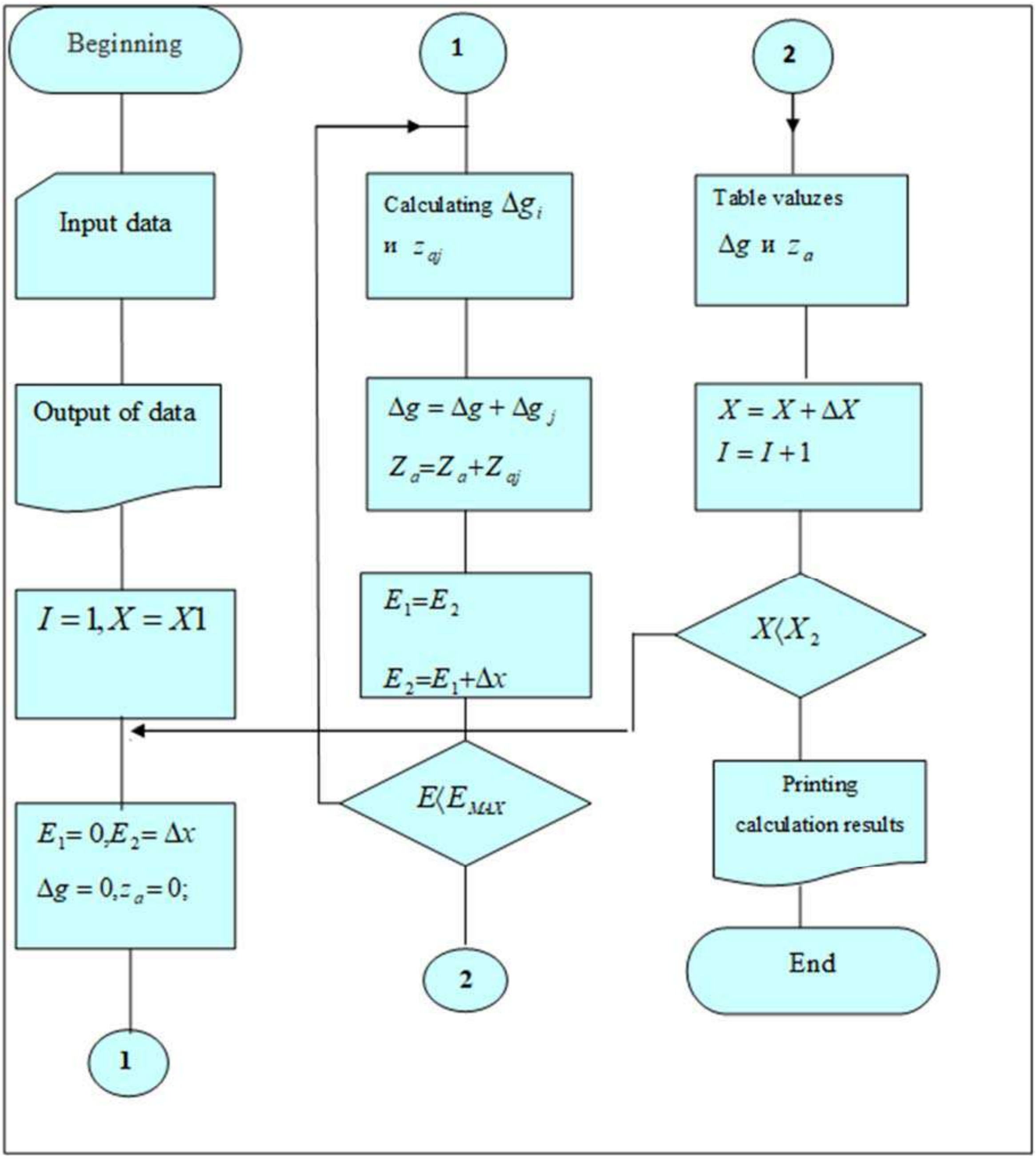

Fig.2. The block-diagram of GTEOR algorithm

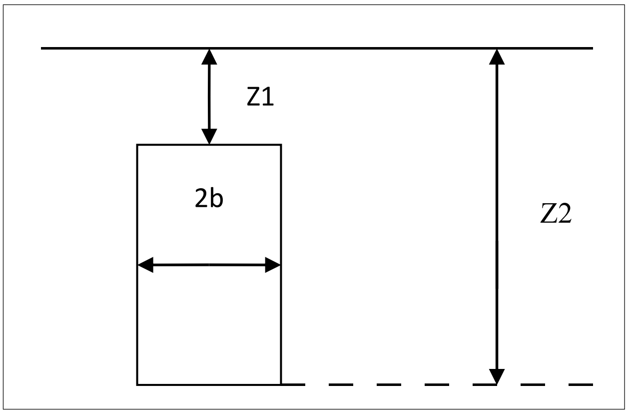

Fig. 3. Vertical prism parameters

To implement the task on a computer, the source data in accordance with the algorithm are entered in the following order:

1) N, X1, X2, EMAX, DX, SIG, Y.

Here N is the number of elementary prisms; X1, X2 – start and end coordinates of the observation point; EMAX – the abscissa of the extreme point of the structure; DX – step of separation of the structure in km or step of the observation point (calculation); SIG – excess density of the geological body; J is the intensity of the prism magnetization.

2) Z1 (I) – the set of depths of the upper edges of the elementary prisms (data array) in km.

3) Z2 (I) – the set of depths of the lower edges of elementary prisms (data array) in km.

Results:

Based on seismic data, we first performed a digital simulation of the Yevlakh-Agjabadi trough and compiled a structural model of the Yevlakh-Agjabadi Basin using the SURFER multi-task program (Fig. 4). Then six profiles crossing the Yevlakh-Agjabadi basin were developed (Fig. 5-6). Based on these six profiles, deep sections of the surface of the crystalline basement were constructed (Fig.7). In the next step modeling gravity field was calculated on a PC using the GTEOR Fortran-program (Искандаров, 2005, 2011, 2018). Moreover, the theoretical values of the first vertical derivative of gravity potential (Vz) – vertical component of the gravity force were calculated for separate profiles. Below, as an example, profile No.1 shows the initial data prepared for calculating the theoretical values of the vertical component of the gravity force, as well as the calculation results using the GTEOR program (Tables 1-3). Then, using the SURFER program (Силкин, 2008), theoretical values of the gravity field were digitized according to the profile section and a map of the theoretical values of the gravity field was constructed in 2D and 3D variants (Figs. 8-9). A combination of these maps is presented in Fig. 10.

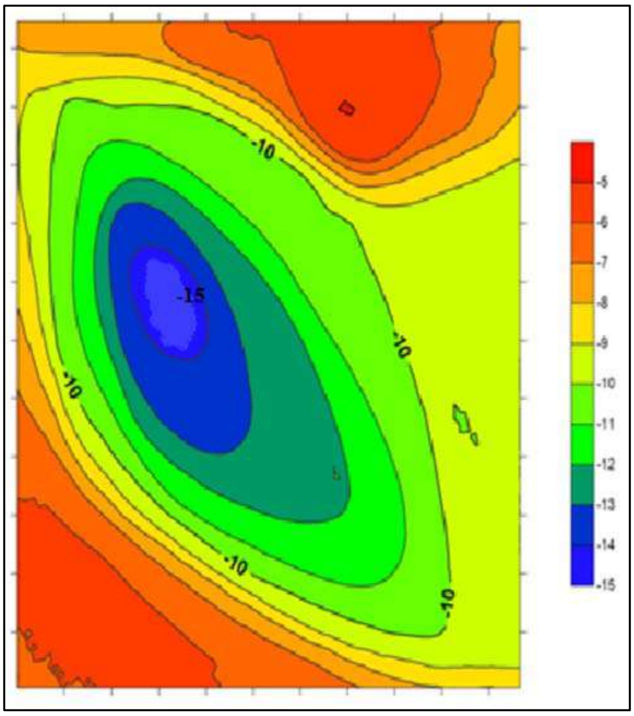

Fig.4. Structural map of the crystalline basement (in km) of the Yevlakh-Agjabadi basin developed using the SURFER program

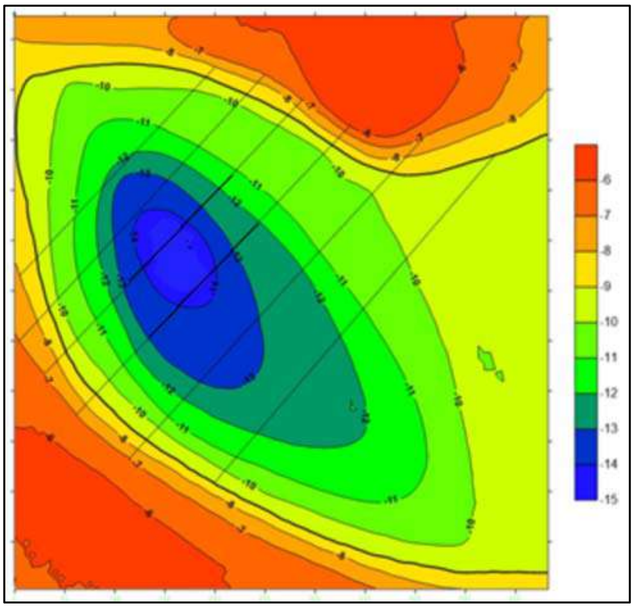

Fig. 5. Profiles crossing Yevlakh-Agjabadi Basin for computing Vz (2D variant)

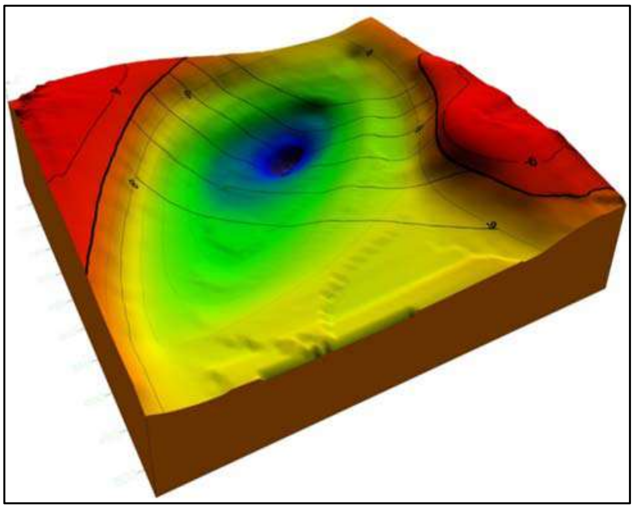

Fig. 6. Profiles crossing Yevlakh-Agjabadi Basin for computing Vz (first vertical derivative of gravity potential) (3D variant)

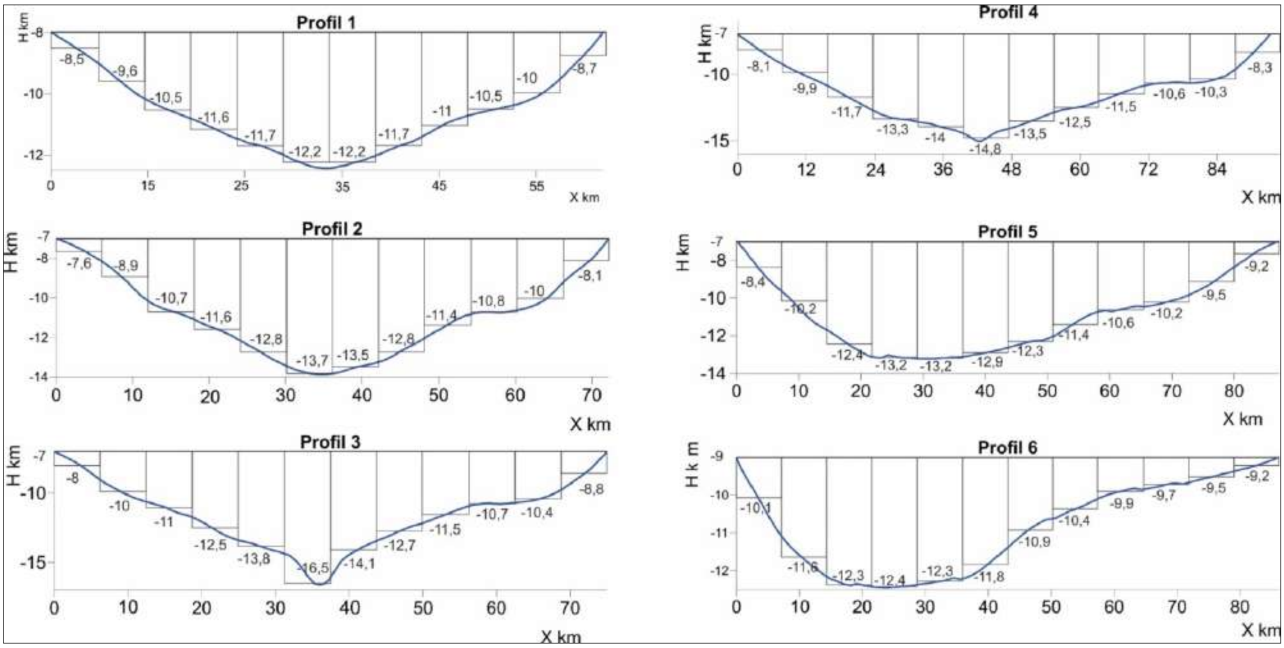

Fig. 7. The depths of the crystalline basement for profiles 1-6 (developed on the basis of the SURFER program)

Table 1

Initial data for the GTEOR program for profile No. 1

N	X1	X2	EMAX	DX	DX	DS	J
12	0	60	60	0	5	-0.3	50

Table 2

The depths of the crystalline basement computed for profile No. 1

H_1	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0
H_2	8.5	9.6	10.5	11.1	11.7	12.2	12.2	11.7	11.7	10.5	8.70	10.0

Table 3

Results of calculating the vertical component of the gravity force (in mGal) and magnetic component Z_A (in gamma) for profile No. 1 according to the GTEOR program

N	X	V_z	Z_A
1	0	-10.74	-7.81
2	5	-15.76	1.19
3	10	-21.29	11.64
4	15	-26.26	19.73
5	20	-30.16	25.63
6	25	-32.71	29.74
7	30	-33.63	31.23
8	35	-32.78	29.45
9	40	-30.34	25.12
10	45	-26.71	19.76
11	50	-22.15	13.42
12	55	-16.83	3.96

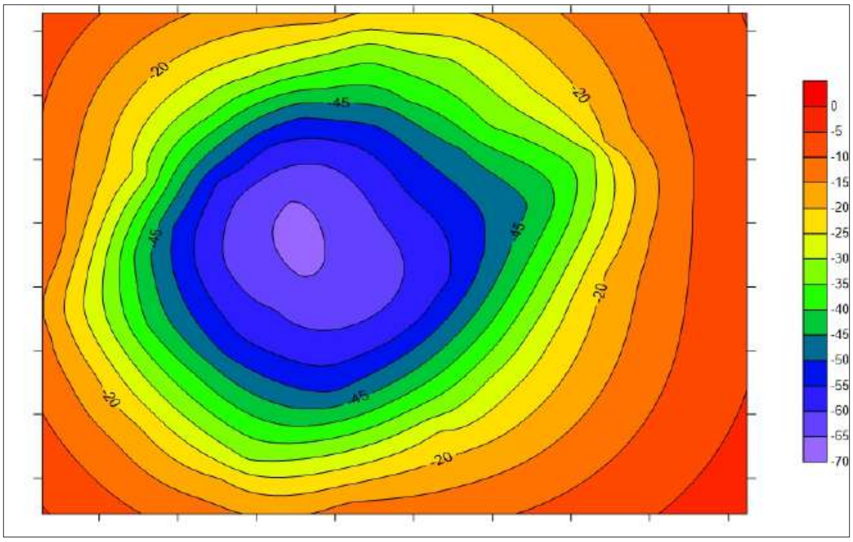

Fig. 8. Map of the vertical component of the gravity force (Vz) of the Yevlakh-Agjabadi Basin in milligals (2D variant)

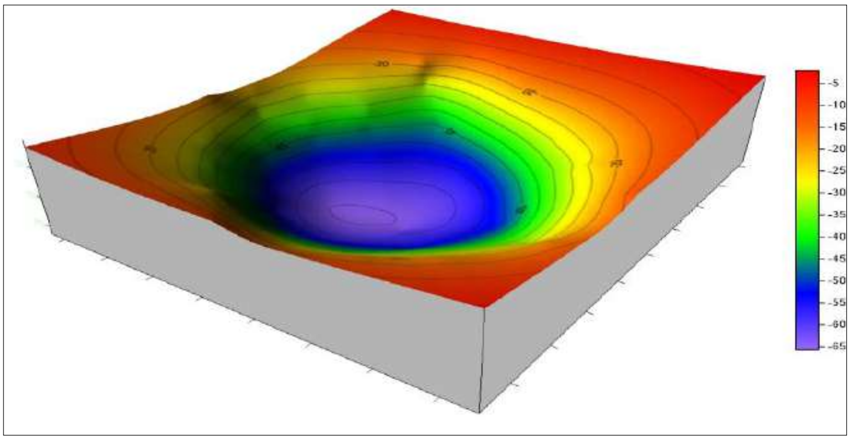

Fig. 9. Map of the vertical component of the gravity force (Vz) of the Yevlakh-Agjabadi deflection in milligals (3D variant)

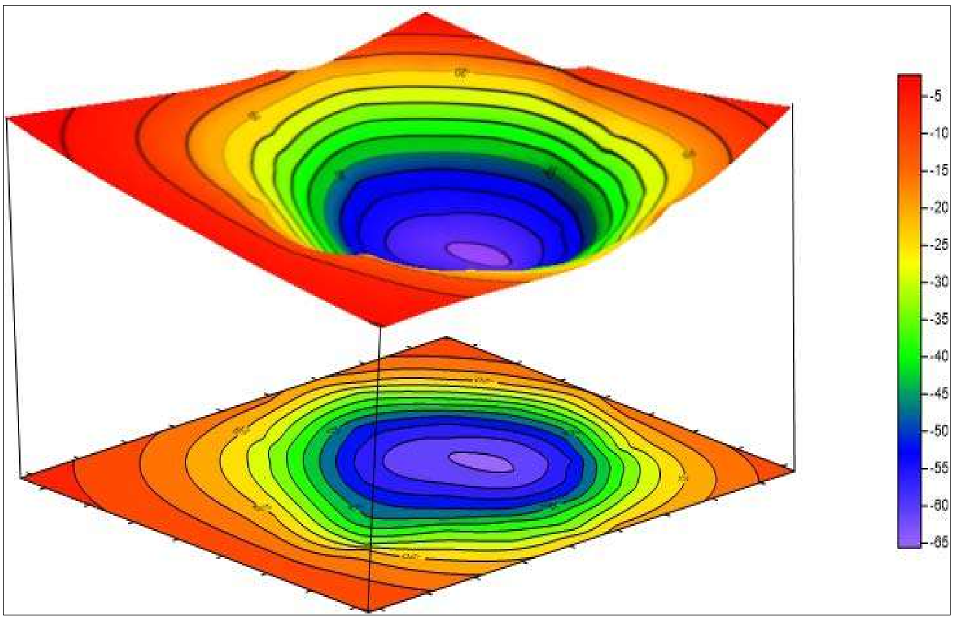

Fig. 10. Combination of 2D and 3D maps of the vertical component of the gravity force (Vz) of the Yevlakh-Agjabadi Basin (in milligals)

Conclusions:

1. The block diagram of our GTEOR algorithm for calculating the theoretical values of the gravity anomaly in the profile version is presented. The GTEOR program is implemented using the FORCE FORTRAN compiler in the WINDOWS system.

2. Using the SURFER program, digital modeling of the structural map of the depths of the Yevlakh-Agjabadi deflection in three dimensions was performed.

3. Using the GTEOR program, the values of the gravity field of the Yevlakh-Agjabadi Basin were calculated, and the SURFER program was used to gravitational field digitization, which can be applied to estimate the gravitational effects of the sedimentary rock formations.

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ЦИФРОВАЯ ОЦЕНКА ГРАВИТАЦИОННОГО ВЛИЯНИЯ КРИСТАЛЛИЧЕСКОГО ФУНДАМЕНТА ЕВЛАХ-АГДЖАБЕДИНСКОГО БАССЕЙНА (СРЕДНЕКУРИНСКАЯ ВПАДИНА, АЗЕРБАЙДЖАН)

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Резюме. Статья посвящена оценке гравитационного влияния кристаллического фундамента Евлах-Агджабединского прогиба Средне-Куринской впадины Азербайджана. Как известно, для Евлах-Агджабединского прогиба характерна мощная толща осадочных отложений мезозойского и кайнозойского возраста, залегающих на кристаллическом фундаменте. По данным глубинного сейсмического зондирования была построена структурная карта поверхности кристаллического фундамента. Сам прогиб ориентирован в кавказском направлении. На этой площади известны месторождения нефти и газа Мурадханлы и Джафарлы. Кристаллический фундамент, а также мезокайнозойские отложения обладают избыточной плотностью и поэтому хорошо отображаются в гравитационном поле в виде локальных аномалий силы тяжести. Можно сказать, большинство площадей Азербайджана, в том числе и территория Евлах-Агджабединского прогиба, покрыто общей и детальной гравимагнитной съемкой. По этим результатам здесь, а также на площадях Мурадханлы и Джафарлы выделен целый ряд локальных аномалий. В настоящее время проводятся высокоточные гравиметрические и магнитометрические съемки с использованием цифровых гравиметров и магнитометров, что открывает большие возможности перед гравимагниторазведкой при исследовании этого региона. Кроме того, на кафедре «Геофизика» Азербайджанского государственного университета нефти и промышленности разработано программное обеспечение для различных трансформаций гравимагнитных полей, а также решены прямая и обратная задачи грави- и магниторазведки. С помощью программы SURFER было выполнено цифровое моделирование структурной карты глубин прогиба Евлах-Агджабединского в трёх измерениях. С помощью программы GTEOR рассчитывались значения гравитационного поля Евлах-Агджабединского бассейна, а для оцифровки гравитационного поля использовалась программа SURFER, которая может применяться для оценки гравитационных воздействий осадочных пород.

Ключевые слова: *алгоритм, блок-схема, гравитационная аномалия, структурная карта, оценка гравитационного эффекта, гравитационная модель, цифровое моделирование*

YEVLAX-AĞCABƏDİ HÖVZƏSİNİN KRİSTAL TƏMƏLİNİN QRAVİTASİYA TƏSİRİNİN RƏQƏMSAL QİYMƏTLƏNDİRİLMƏSİ (ORTA KÜR ÇÖKƏKLİYİ, AZƏRBAYCAN)

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Xülasə. Məqalə Azərbaycanın Orta Kür çökəkliyinin Yevlax-Ağcabədi çökəkliyinin kristallik bünövrəsinin qravitasiya təsirinin qiymətləndirilməsinə həsr edilmişdir. Məlum olduğu kimi, Yevlax-Ağcabədi çökəkliyi kristallik bünövrə üzərində yatan mezozoy və kaynozoy yaşlı çöküntülərinin qalın təbəqəsi ilə xarakterizə olunur. Dərin seysmik zondlama məlumatlarına əsasən, kristallik bünövrənin səthinə görə struktur xəritəsi qurulmuşdur. Çökəklik özü Qafqaz istiqamətində yönəldilmişdir. Bu ərazidə Muradxanlı və Cəfərli neft-qaz yataqları mövcuddur. Kristallik bünövrə, eləcə də Mezo-Kaynozoy çöküntüləri izafi sıxlığa malikdir və buna görə də qravitasiya sahəsində ağırlıq qüvvəsinin lokal anomaliyalar şəklində yaxşı əks olunur. Demək olar ki, Azərbaycanın əksər əraziləri, o cümlədən Yevlax-Ağcabədi çökəkliyi ərazisi ümumi və mükəmməl qravimaqnit planalmalar ilə əhatə olunub. Bu nəticələr əsasında burada, o cümlədən Muradxanlı və Cəfərli ərazilərində bir sıra lokal anomaliyalar müəyyən edilib. Hazırda bu sahədə rəqəmsal qravimetir və maqnitometrlərdən istifadə etməklə yüksək dəqiqlikli qravimetrik və maqnitometrik planalmalar aparılır ki, bu da bu regionun öyrənilməsində qravimetrik və maqnitometrik kəşfiyyatlar üçün böyük imkanlar açır. Bundan əlavə, ADNSU-nun "Geofizika" kafedrasında qravimaqnit sahələrinin müxtəlif çevrilmələri, eləcə də qravi və maqnit kəşfiyyatının düz və tərs məsələlərinin həlli üçün proqram təminatı hazırlanıb. Buna görə də, rəqəmsal modelləşdirmədən istifadə edərək qravitasiya məlumatlarına görə bu çökəkliyin öyrənilməsi çox aktual bir məsələdir.

Açar sözlər: *alqoritm, blok-sxem, qravitasiya anomaliyası, struktur xəritəsi, qravitasiya təsirinin qiymətləndirilməsi, qravitasiya modeli, rəqəmsal modelləşdirilmə*