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NEW DATA ON THE GEOLOGICAL STRUCTURE OF THE MEGHRI HPP HYDROTECHNICAL TUNNEL ROUTE TERRITORY (BASED ON GEOPHYSICAL INVESTIGATIONS)

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The article considers the results of complex geophysical studies performed in the south of the republic due to the planned construction of the Meghri HPP with the Iranian side. The main task was to obtain the necessary data for selecting the optimal route for the underground supply hydrotechnical tunnel. The accuracyand informativity of the geophysical investigations are important for such adifficult area, which is located near the Meghri pluton. The Meghri pluton is one of the main reasons in this area, that influencesthe structure of the rocks. The, about 18 *km* long, hydrotechnical tunnel, which is for transmitting water from thewater collecting dam to HPP, should avoid deep faults, fractured zones and underground water basins. The depth of its passage, depending on the surface, varies on average from 100 to 400 *m*. The necessary data on the thicknesses and depths ofintrusive andmodern sedimentary rocks and the presence of tectonic faults are obtained. These data will be used to select the direction of the optimal tunnel route. It is proposed to implement geophysical works in the remaining not-studied segments of the designed hydrotechnical tunnel, which will make the drilling – geological and geotechnical field works more effective.

Keywords: Meghri HPP, hydrotechnical tunnel, geophysical methods, geological survey.

Introduction. According to the Contract signed between the Governments of the Islamic Republic of Iran and Republic of Armenia, the construction of two hydro-power plants is planned on the boundary of the river Aras. The Armenian HPP, in particular, is designed in the area adjacent to town Meghri. For this purpose, construction of a dam is planned west from town Agarak, on the river Aras. The river water collected in the dam will be transmitted to the designed Meghri HPP through a tunnel (about 18 *km* long). For investigation of the tunnel route, implementation of geophysical studies was planned in the sites of "Agarak-Meghri".

This is a typical mountainous region, with its complex, cut relief. The southern slopes of the ridge (to the valley of the River Aras) represent plicate and deep canyons (200...700 *m* deep) divided from each other by mountain branches. They emerge from the Meghri mountain ridge and forming parallel canyon-like valleys, flow into the River Aras.

Characteristics of the study area and research objectives. From the geological point of view, the Agarak-Meghri mountain ridge, at the foot of which the site studied by us is located, is represented by granodiorites, granosyenites, syenites and granites, which form a joint intrusion. It is called Meghri Pluto, which is considered to be the biggest one in the whole Transcaucasia. According to the data of general geological survey (Aslanyan A.T., Movsesyan S.A., Adamyan A.I., et al), the intrusive formations of the Meghri mountain ridge, with some conditionality, are ranked to the Lower Mesozoic era [1,2]. The first complex by depth in the mentioned area, which is called Meghri pluton as mentioned above, stretches south-east from the River Voghji and about 40 *km* up to the River Aras (with an average length of 10 *km*). From here, it bends to the north-east and outcrops in Iranian Karadagh. Middle and Upper Devonian volcanogenic-sedimentary stratum rocks represent enclosing rocks here, consisting of porphyrites, shales, and partially limestones, quartzites and different tuffogenic rocks. The most widespread rocks among those of Meghri mountain ridge pluton are monzonites, syenite-diorites and gabbro-diorites, which are connected to each other by facial transitions and include thick porphyrites and other volcanogenic rocks (Fig. 1).

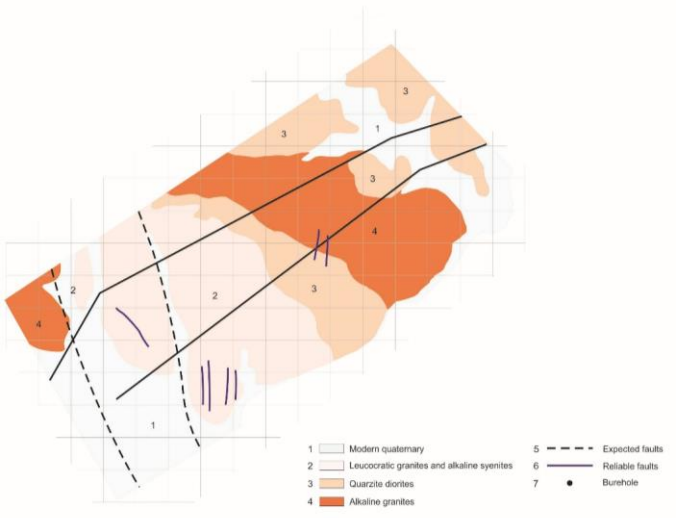

Fig.1. The geological map of the study area (Charazyan et al). Scale 1:50.000

The tectonic conditions of the area are understood as follows. In the direction of Zangezour ridge trend, Kajaran syncline is mapped with sub-meridional location. Its central part is represented by Meghri disruptive depressions, which are particularly developed in the right bank part of the River Meghri and rest upon Tashtun (Debaclin) deep faulting. In the direction of the faulting [3, 4], there are three depressions with more than 20 *km* of length, including the depression within the area of the town Agarak. They are represented by sediments that have a monoclonal dip in the south-west direction, i.e. they rest upon Tashtun fault.

East of the Tashtun fault, the narrow Meghri graben stretched in the meridional direction is located, which is probably divided from adjacent elevated areas by normal slips. Generalizing, it can be considered that in the interval of the two well-known main faults of Tashtun and Khustup-Giratagh limited by south-western and north-western zones, there is a whole complex of second-class north-west and near-transverse faults, which have divided the mentioned area into separate segments, making them of mosaic-block nature. In case of construction or other measures in the area under study, it should be taken into account that this area is considered an active seismic region. In order to justify the choice of the optimal route of the hydrotechnical tunnel, complex geophysical investigations were carried out.

Substantiation of the methodology and results of research. Based on thegeophysical works carried out the following tasks were implemented in the Agarak and Meghri sites:

1. Identification of recent rocks and determination of their total thickness.
2. Identification of weathered intrusive rock strata and determination of their thickness.
3. Determination of the depth of Sound intrusive rocks as well as the fault and fissured zones.
4. Determination of the velocity of the longitudinal waves in the study areas' strata.
5. Determination of groundwater table or distinguishing water-saturated (water-bearing) rock stratum.

Identification of recent rocks and determination of their total thickness. Recent sediments in the area are presented by alluvial, colluvial and other similar rocks. The electrometric method (vertical electrical and dipole-dipole electromagnetic sounding varieties), profile and surface survey and the seismometric refracted wave method were used for solving the problem. Taking into consideration that the thickness of the recent rocks was expected on the average of 80. . . 100 *m* Agarak area, first of all, vertical electric sounding VES method was applied here, and in case of relief limitations and difficulties, the dipole-dipole sounding method was applied. Characteristic examples of sounding curves for the given area are provided in figure 2. As the examples show, the area is characterized by themulti-layer geoelectrical structure. For

the purpose of clarifying the spatial location (by section and plan) of sedimentary rocks, mainly electrometric works by electrical sounding method (VES and SFS types) were carried out in the Meghri site with separate profiles and surface survey. The typical curves of theelectrical sounding method are shown in Fig. 2.

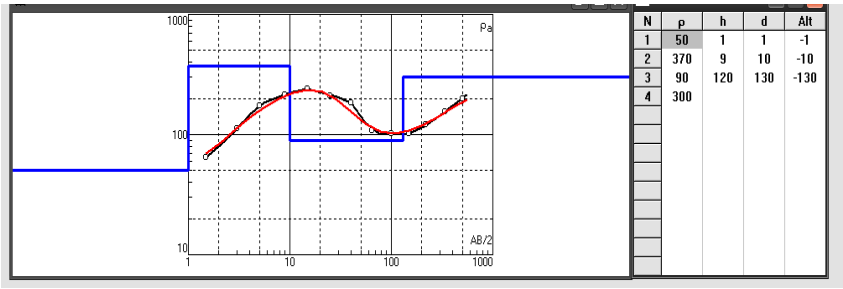

Fig. 2. The typical curves of applied Vertical Electrical Sounding method (Area Meghri, VES-83)

Geoelectrical section 1-1 (Fig. 3). The recent sediments have small thicknesses in the Meghri site and are different also by their lithological composition. In the considered section, in the part of soundings no. 37 and 88 (the left part of the drawing), the thickness of the recent sediments is about 30...40 *m*. It significantly increases in the right part of the section, according to the data of soundings no. 79. Here the average thickness is equal to 100...120 *m.* The electric resistivities of rocks for the given sediments vary in the range of 100...350 *Ohm.m.* The right segment of the section - the 79...82 area of soundings, is an exception. Here, near surface rocks have 600...900 *Ohm.m.* resistivity and are represented, likely, by their large-fragmented and relatively “dry” diversities.

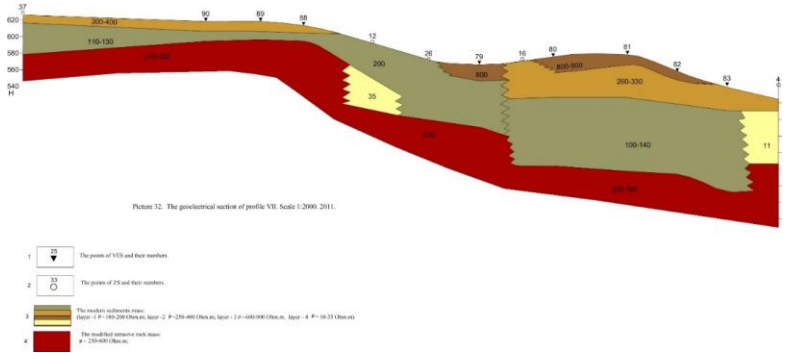

Fig. 3. The geoelectrical section of profile 1-1, Area Meghri. Scale 1:2000

For clarification of the spatial structure of the sedimentary rocks by depth in the studied Meghri site, the isoline maps of the variation ρ_{ap} of the sediment resistivityby depth are presented compiled for H= 25, 50 and 75 *m* deep sections. The analysis shows that sediments of relatively low resistivity in these sections (blue colour on the map) occur in the north-western part of the site. Such sedimentary rocks also occur at depths of 50 *m* and particularly 75 *m* in the south-western part of the site.

Determination of the depth of Sound intrusive rocks. The given task for the sites of Agarak and Meghri was solved in parallel with the above-mentioned clarification of the spatial structure of sedimentary rocks. The complex of the applied geophysical methods (electro-seismometry) and for the approaches of data processing are the same but, of course, the interpretation results are different. Theidentification of the weathered intrusive rock is located directly under the recent sedimentary rocks. According to the general geological survey data, we rank these rocks to intrusive, but unsound (weathered, fissured) rocks.

Fig. 4. The map of the intrusive bedrock surface. Area Meghri, Scale 1:5000

In general, in the area of the considered geoelectrical sections, the thickness of the unsound (weathered, fissured) intrusive rocks exceeds 80...100 *m*. For the solution of this task, mainly, the electromagnetic dipole-dipole (SFS) method was used, which also allowed to have vertical electrical sounding (VES) data on the recent relief. Based on the data, separate geoelectrical sections and general maps of thesound intrusive rock relief structure were compiled for the studied area. In determining the depths of the sound intrusive rocks and clarification of their relief structure, corresponding maps and map-diagrams were compiled, which are provided in the Meghri site. The depths of intrusive bedrocks determined here (Fig.4) vary on average from 130 *m* in the western part of the site and up to 230 *m* in its eastern part. The drawn up maps show the variation of electrical resistivity of the sound intrusive rocks with depth for the H=200 *m*, 300 *m* and 400 *m* sections. According to the analysis of the obtained data, the electrical resistivities of the intrusive rocks in the Meghri site, beginning from the depths of 200 *m* up to 400 *m* (and probably more) are mainly higher and do not vary. Consequently, the structural nature and lithological composition of those rocks are the same from the geoelectrical point of view. To understand the spatial location of the weathered (and fissured) rocks by thedepth and the changes in their thickness, maps of the Agarak and Meghri sites.

Determination of probable fault zones. The solution of this task requires joint analysis of various geophysical data. However, in some cases, it is of probabilistic nature. First, let us consider the materials of electrical sounding that comprises a large volume of the study. Based on these data geoelectrical contacts are plotted in the sections and on the plan that could be conditioned by fault, including altered, fissured zones. In this case, abrupt “deviations, distortions” of the sounding curves as compared with the curves characteristic for horizontal layered sections, as well as variations of strata thicknesses in the sections served a basis. Examples of characteristic “distorted” VES curves (Fig. 5), where it can be seen that beginning from the AB/2=25...65 *m* spacing and after, the values of apparent electrical resistivity of the rocks vary corresponding to not characteristic horizontal layered sections. Taking into account these soundings, as well as, in particular, the variation of rock thicknesses with depth observed in some geoelectrical sections, the revealed geoelectrical contacts are shown by a special conditional mark (dashed line) on the actual data maps of the studies. They are mainly to be considered as probable fault zones, because of which the geological structure of the sites must be considered by separate blocks.

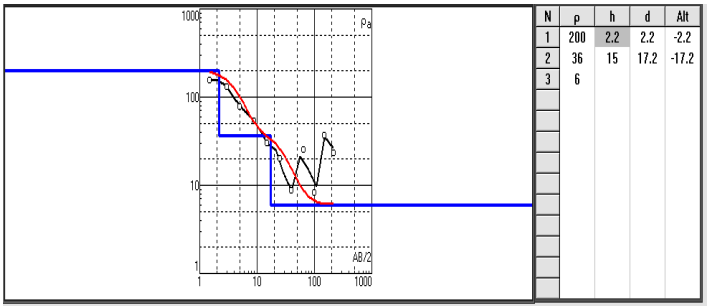

Fig. 5. The typical curve of the applied Vertical Electrical Sounding method (VES-48)

From ageological point of view, their nature is different; some of them are conditioned by faults of tectonic nature; others are conditioned by lithologically altered (weathered fissured) rocks or by the same lithological rocks altered (weathered fissured) to different degrees. The direction of contacts on the sections is of conditional nature. In this case, it is explained in some cases by non-accuracy of the measured points (here the scale of the studies, and in some cases relief conditions of the area and man-made factors have had an impact). In case of the final selection of the tunnel route, thespatial specification of contacts (particularly tectonic contacts) is possible based on field works of not very big volume.

Taking into account the general hydro-geological understanding of the studied area, the altered types of intrusive rocks have been considered as possible aquifers or strata. We consider that the structure of the relief of the mentioned horizon shows the possible spatial distribution of groundwater. Taking into account the mentioned above, we prepared appropriate maps, where the results of electric sounding, as well as seismometric materials for some sites, were used.

Conclusions. As a result of geophysical investigations implemented in the Agarak and Meghri HPP hydrotechnical tunnel route area, the following conclusions were drawn:

- **Identification of recent rocks and determination of their total thickness:**

  Based on the geophysical data, characteristic sections and general maps were compiled for the studied Agarak and Meghri sites. The sections and maps show the variations of the lithology and thicknesses of recent sediments by depth and plan.

  Meghri site- the thicknesses of the recent sediments here are relatively small. The following data were obtained: the electrical resistivities are equal to 400...500 *Ohm.m* for the upper stratum of the section, and 100...300 *Ohm.m* for the lower stratum of the section. The average thicknesses of sediments are equal to about 60…70 *m*.

- **Identification of unsound - weathered, fissured intrusive rock strata and determination of their thickness:**

  Agarak-Meghri site - average electrical resistivities of the rocks vary in the range of 100...120 to 150...200 *Ohm.m.*, the average thicknesses are equal to 60...80 *m*, in some cases up to 100 *m*.

- **Determination of the depth of Sound intrusive rocks:**

  For the solution of the task, the data of geoelectrical, in some cases also seismometric studies were used. The map of the structure of Sound intrusive rock relief of the site was compiled. In general, the Sound rocks are characterized by high electrical resistivity, in particular exceeding 400...500 *Ohm.m.* The depths of the studied rocks in the Agarak and Meghri site are equal to 130 *m* in the western part of the site and reach up to 230 *m* in its eastern part.

  The analysis of the compiled map-diagrams and maps shows that in the Agarak-Meghri sites, in the sections of H=200, 300 and 400 *m* depths, the resistivity of the rocks is mainly high and they are not subject to significant structural or lithological changes from the geoelectrical point of view.

- **Determination of probable fault zones:**

Based on the joint analysis of geophysical data, there are likely to be fault zones or separate geological (lithological and unsound rocks') contacts.

On the Agarak and Meghri site, the obtained results of the geophysical studies for the routes of the main and additional hydro-technical tunnels are as follows. In the segments of Meghri, options of the planned tunnel geological contacts have been revealed, which are probably of tectonic nature. From aspatial point of view, they have a north-west – south-east direction. From ahydrogeological point of view, underground water strata are expected for the two options on average at 70...100 *m* depths. Water-repellent intrusive rocks are located on average at 120...130 *m* depths for both options. According to the geological-hydrotechnicalsection,the depth of the main tunnel in the Agarak and Meghri site is designed about 100 *m*.

Consequently, here the fact of thepossible impact of underground water shall be taken into account during the design (construction) works.

Summing up the analysis of the geophysical results, it is to be noted that in spite of the complicated relief conditions and the artificial difficulties made as a result of the anthropogenic activity, application of geophysical methods is mainly efficient for the solution of such engineering-geological and hydrogeological tasks.

Therefore, it is proposed to implement geophysical works in the remaining not-studied segments of the designed hydrotechnical tunnel, which will make the drilling – geological and geotechnical field works more effective.

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ՆՈՐ ՏՎՅԱԼՆԵՐ ՄԵՂՐԻ ՀԷԿ-ի ՀԻԴՐՈՏԵԽՆԻԿԱԿԱՆ ԹՈՒՆԵԼԻ ՈՒՂԵԳԾԻ ՏԱՐԱԾՔԻ ԵՐԿՐԱԲԱՆԱԿԱՆ ՍՏՐՈՒԿՏՈՒՐԱՅԻ ՄԱՍԻՆ
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Ս.Ս. Մանուկյան, Հ.Ա. Իգիթյան, Ռ.Ա. Քարամյան, Ռ.Ս. Մինասյան

Դիտարկված են երկրաֆիզիկական համալիր ուսումնասիրությունների արդյունքները, որոնք իրականացված են հանրապետության հարավում (Մեղրու շրջան), որտեղ, իրանական կողմի հետ համատեղ, նախատեսվում է Մեղրի ՀԷԿ-ի կառուցումը: Մեղրի ՀԷԿ-ի հզորությունը կկազմի 130 *ՄՎտ*, որը տարեկան կարտադրի 793 *մլնկՎտժ* էլեկտրաէներգիա: ՀԷԿ-ի հզորությունը վերահաշվարկվել է (100 *ՄՎտ*)՝ Արաքս գետի հոսքի նվազման պատճառով: Դրված հիմնական խնդիրը նպատակաուղղված է՝ ստանալու անհրաժեշտ հետազոտական տվյալներ ՀԷԿ-ին մոտեցող հիդրոտեխնիկական թունելի օպտիմալ մայրուղու ընտրման համար: Երկրաֆիզիկական հետազոտությունների ճշգրտությունը և տեղեկատվությունը կարևոր են այնպիսի բարդ տարածքի համար, որը գտնվում է Մեղրու պլուտոնին մոտ: Այս տարածքում Մեղրու պլուտոնը հիմնական գործոններից մեկն է, որն ազդում է ապարների ստրուկտուրայի վրա: Ջրամբարից դեպի ՀԷԿ ջուր տեղափոխելու համար, մոտ 18 *կմ*

երկարությամբ հիդրոտեխնիկական թունելի կառուցման ընթացքում, հնարավորինս պետք է խուսափել խորքային ապարների խախտումներից, ճեղքվածքային գոտիներից և ստորգետնյա ջրավազաններից: Կախված ժամանակակից ռելիեֆի բացարձակ նիշերից՝ թունելի ուղեգծի խորությունը սպասվում է միջինը 100...400 մ: Ուսումնասիրությունների արդյունքում ստացված են անհրաժեշտ տվյալներ տեղամասի ժամանակակից նստվածքների, փոփոխված և արմատական ինտրուզիվ ապարների հզորությունների ու դրանց խորությունների վերաբերյալ, ինչպես նաև տեկտոնական հնարավոր խզվածքների առկայության մասին: Ստացված հետազոտական արդյունքները և նյութերն օգտագործվելու են ՀԷԿ-ին մոտեցող թունելի օպտիմալ մայրուղու նախագծման համար:

Առանցքային բառեր. Մեղրի ՀԷԿ, հիդրոտեխնիկական թունել, երկրաֆիզիկական մեթոդներ, երկրաբանական հանույթ:

НОВЫЕ ДАННЫЕ О ГЕОЛОГИЧЕСКОЙ СТРУКТУРЕ ТЕРРИТОРИИ ТРАССЫ ГИДРОТЕХНИЧЕСКОГО ТОННЕЛЯ МЕГРИНСКОЙ ГЭС (ИЗ ГЕОФИЗИЧЕСКИХ ИЗЫСКАНИЙ)

С.С. Манукян, А.А. Игитян, Р.А. Карамян, Р.С. Минасян

Рассмотрены результаты комплексных геофизических исследований, выполненных на юге Республики Армения (Мегринский район) в связи с намечаемым здесь совместно с иранской стороной строительством Мегринской ГЭС. Предполагаемая мощность Мегринской ГЭС составит 130 *МВт*, что позволит производить 793 млн *кВтч* электроэнергии в год. Позже мощность ГЭС была перерассчитана (100 *МВт*) из-за уменьшения потока реки Аракс. Основная цель исследований заключалась в получении необходимых данных для выбора оптимальной трассы подводящего гидротехнического тоннеля. При этом для такой сложной области, какая расположена рядом с Мегринским плутоном, важное значение имеют точность и информативность геофизических исследований. В этой области Мегринский плутон является одной из основных причин, влияющих на структуру горных пород. Гидротехнический тоннель протяженностью около 18 *км*, предназначенный для передачи воды из водосборной плотины в ГЭС, должен избегать глубоких разломов, трещин и подземных водоемов. Глубина его прохождения в зависимости от абсолютных отметок дневной поверхности изменяется в среднем от 100 до 400 *м*. Получены необходимые изыскательские данные о мощностях и глубинах залегания современных образований, измененных и коренных интрузивных породах, а также о наличии здесь тектонических нарушений. Эти данные могут быть использованы при выборе оптимальной трассы тоннеля.

Ключевые слова: Мегринская ГЭС, гидротехнический тоннель, геофизические методы, геологическое съемка.