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Geographo- Hydrological Arguments on Possible Expansion of the Tskaltubo Cave System

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ABSTRACT. The Tskaltubo Cave System is one of the most important speleological objects which is designed for effective tourist exploitation. Because of its complex geological setting the entire system and its unknown branches in particular have not been studied yet. On the basis of geographo-hydrological methods their provisional directions have been defined and new vectors of speleological research stated. *© 2007 Bull. Georg. Natl. Acad. Sci.*

Key words*: karst, theoretical and actual runoff, underground water circulation, topographic and underground basins.*

One of the most significant trends of hydrology is mountain hydrology. It is based on the basic regularity expressed by the vertical zonality of the elements of river runoff in mountainous areas. [2]. The mean height of the river basin index is taken for the most efficient and widely approved hypsometric characteristic. As a rule, there is a close and synonymous link between the mean height of river basins and elements of runoff. The larger is the territory under investigation the more probable is this link, which is of differential nature. Not only Georgia but the whole Caucasus is covered by such dependence curves. In case when azonal or anthropogenic impacts are registered in the area the mentioned regularity is disturbed and abstraction noted. The stronger is the influence of the outer factors upon the runoff the greater is abstraction. Thus we can theoretically define the volume and regime of the runoff of the rivers which are under the impact of azonal or anthropogenic factors, as well as determine the parameters when the rivers are not subject to any outer influence.

To determine one of the strongest azonal factors, i.e. to determine theoretical runoff under the conditions of karst expansion is very essential since we can determine the range of its effect by comparison of the indices of theoretical and actual runoff. On the basis of this procedure it is possible to estimate the effect of karst processes upon the local runoff in the process of the study of the Tskaltubo cave system and its vicinity. Besides, areas of inflow and outflow of underground karst water were identified, i.e. the mechanism and direction of water change /circulation/ were defined. Comprehensive research into underground water change is one of the major goals of karst hydrology. It will enable us to create the picture of not only the area of redistribution of runoff but to establish provisional offshoots of the speleological system, to outline the location of underground passages and their hitherto unknown branches.

Since the territory under study is maximum 800 m. above sea level and can be the main recharge source of karst water, we should take this hypsometric mark for determination of theoretical runoff. Heavily karsted territory to the north-south of Tskhunkuri settlement, on the right bank of the river Semi, attests to this. Its maximum height is 636 m. Let us call this 2.7 km^2 territory a potential inflow hearth of Tskhunkuri. Besides, a well defined possible inflow hearth is located to the right of

the Semi river, north-east of Melouri, with 1.5 km^2 area. Maximum hypsometric mark of the Okunela spot is 758m. We may as well call it a potential inflow hearth. It took its name from the village of Okunela, lately turned into ruins.

Both these territories are situated beyond the topographic, i.e. formal drainage basin limits of the Kumi river. But if we take karst hydrological principles for granted, topographic watershed loses its importance, if underground streams flow from one formal basin into another through karst passages or conduits. This is called underground water change, which can be positive or negative.

The basic principle of karst hydrology is especially important in the study of the Tskaltubo-Kumistavi speleological system, aimed at tracing unknown underground passages and their branches. This means that if the actual runoff of the Kumi river does not correspond to the amount of theoretical runoff of that height zone we should search for some other areas beyond the theoretical drainage system basin supplying the Kumi river with water through underground conduits. If this is confirmed, we should look for some new underground branches of the Tskaltubo cave system in the direction of inflow currents without fail.

It has been ascertained that the topographic or formal drainage system up to the village of Qvilishori on the Kumi river is 14 km^2. The underground river Ghliana receives its alimentation just from the same basin and it is not feasible to separate the surface basins of these two underground rivers on 1:50 000 scale topographic maps.

Now we have to determine the volume of water which is supplied by the 14 km^2 topographic basin and is considered to be the surface drainage system of the Kumi and Ghliana rivers.

If there exists a reliable zonal background of distribution of runoff, then it is possible to estimate those variations which are caused by azonal, anthropogenic and other local factors, including karstic. However, these estimations do not claim to be accurate, as only the zonal runoff of the territory by the river basin was considered and sometimes the data of hydrological stations located on quite vast territories.

Whenever we are interested in the zonal runoff of this or that uninvestigated river or the river beyond the impact of outer factors, whose basin is within the area of the curve, then it is desirable to posses at least some data on the river runoff which will help to make calculations of the runoff more precisely.

At the earliest stage of investigation of the Tskaltubo-Kumistavi cave system we requested the Hydrometeorological Service of Georgia to arrange hydrometeorological observation posts on the Kumi and Ghliana rivers in 1987. The annual cycle of observation was made up for everyday observation data. That year, the mean annual discharge on the Kumi river was 0.64m^3, on the river Ghliana it amounted to 0.16 m^3/sec. The total discharge of these two cave streams was formed within the limits of one common basin with the surface of 14 km^2 topographic area.

To determine the actual area of the drainage system of these underground rivers, the relation between the mean water discharge of 1987 and the mean perennial discharge should be defined.

It is more conclusive to estimate the rate of runoff per liquid atmospheric precipitation since the alimentation of the mentioned subsurface rivers is absolutely dependent on it.

For this purpose we have chosen the perennial data of the Kutaisi Meteorological Station, which is the most reliable and closest to the area under study. The annual rate of total sums of atmospheric precipitation was 1477 mm per observations of 1936-90, whereas the sum of precipitation of the same series in 1987 totalled 1718 mm. It means that the precipitation fall in Kutaisi in 1987 exceeded the perennial rate by 16 %. Consequently we may assume that the mean annual discharge of the Kumistavi and Ghliana rivers in 1987 must have also exceeded their joint perennial rate. Per simple mathematical calculations with Kutaisi atmospheric data taken as a basis the rate of the runoff of the Kumistavi and Ghliana rivers should total 0.688 m^3/sec.

To define the area of the drainage system basin of the given runoff the zonal rate of the runoff was used again, which within the range of 500-1000 m altitude totaled 50 l/sec.km^2 at the Tskhenistskali-Rioni interfluve. Due to appropriate estimation, it was found that the rate of the Kumistavi -Ghliana runoff was accumulated from 13.76 km^2 area. This shows that the area of the territory of 14 km^2 drainage system basin, depicted by us on the map, absolutely coincides with the area estimated according to calculations based on the runoff data. Such coincidence is good on the one hand, and points to the preciseness of estimation of theoretical runoff but on the other hand, doubts still arise since there exists an objective reason that the Kumistavi-Ghliana actual underground drainage system does not coincide with the surface of the formal basin on the map. The Above-mentioned 2.7 km^2 potential inflow hearth of Tskhunkuri and 1.5 km^2 Okunela hearth belong to such territories. Besides, in the southern part

of the territory under study there exist some undefined sites from where the recharge of underground karst water is possible. First of all to such sites belongs the Qvilishori potential inflow zone situated in the vicinity of Qvilishori settlement at the north edge of the town of Tskaltubo.

One of the spots of underground water discharge may prove to be the outfall of the Tskaltubo river, which deserves more attention than it was paid until now.

Let us go back to the issue of atmospheric precipitation and say that besides the observations and estimations of the runoff carried out in 1987, special work on precipitation gauging was accomplished in the area above the underground Tskaltubo-Kumistavi system and its vicinity. As a result of observations very high indices were registered at the three observation posts organized by the Hydrometeorological Service of Georgia at our request. For instance the precipitation gauge at Melouri at 450 m above sea level registered an annual precipitation sum of 2331 mm, the second precipitation gauge at 250 m situated by the Kumistavi village, near our research station and at Opitcho funnel of discharge registered 2184 mm. At the exit of Kumistavi cave at 127 m altitude 2155 mm precipitation was registered, whereas the Tskaltubo meteorological station recorded 2060 mm at 150 m. In the city of Kutaisi the amount of precipitation reached 1718 mm. All this shows that in the area of Kumistavi cave and its vicinity in the low and piedmont zones of the Rioni-Tskhenistskali interfluve significant gradient changes were observed in the sums of atmospheric precipitation within the range of 350-400 m altitude.

In order to carry out a through investigation of the Tskaltubo-Kumistavi cave system and its profound karstic and hydrological study it is necessary to restore the special permanent hydrometeorological observation network, without which it will not be possible to widen the subsurface research of the cave and ensure its safe and reliable operation for tourist recreational purposes in future.

The Tskaltubo river, whose outfall is in the very territory of the town of Tskaltubo is doubless recharged by karst water. Permanent observations of its runoff were carried out from 1936 to 1940.

Three full annual cycles of observations and gauging were accomplished (1936,1938, 1940). The mean annual discharge totalled 1.72m^3/sec. The mean monthly discharge was also included in these calculations., which were obtained during the years of unsystematic observations (1937, 1940).

The area of the drainage system basin (i.e. topographic basin) up to the water gauging station is 25 km, as registered in the official reference book.

As observations of the Tskaltubo river runoff were very rare, it became necessary to evaluate it on the basis of atmospheric precipitation. Again the most reliable data turned out to be of the Kutaisi Meteorological station which were used in calculating the mean perennial discharge of the Tskaltubo river 1.49 m^3/sec. near the town of Tskaltubo.

The runoff module calculated according to this discharge was 59.6 l km^2/sec. which considerably exceeded the zonal index characteristic of the part of the Rioni river basin where the Tskaltubo flows. This zonal index is 35 l/sec. km^2. The area of the topographical basin of this river cannot provide the amount of the runoff which is available under the existing hydrometeorological conditions. It became necessary to define topographical boundaries of the actual drainage system where the Tskaltubo receives alimentation. The area from where this river could get its alimentation is 49.1 km^2 . All kinds of negative forms of relief which might be considered as surface water consuming hearths have been estimated.

On the basis of methodological geographic-hydrological study it has been found that the height of the layer of the zonal runoff is 1100mm in the basin of the river Tskaltubo and nearby, whereas per the data of actual observations it is 960 mm. We took zonal indices of the runoff to calculate the area of the basin which totaled 42.6 km^2. It can be viewed as a great coincidence (difference is 6.5 km^2) and means that we may proceed with the search for underground channels and streams flowing through them within the limits of the topographic drainage system basin defined by us, where the Tskaltubo gets its alimentation.

It should be noted that at this stage of research the results of study should not be viewed as absolutely authentic, but we have outlined the direction of our further investigations and identified well-founded boundaries of water tracing required for carrying out experiments.

ფიზიკური გეოგრაფია

წყალტუბოს მღვიმური სისტემის შესაძლო გავრცელების გეოგრაფიულ-ჰიდროლოგიური არგუმენტები

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წყალტუბოს მღვიმური სისტემა უმნიშვნელოვანესი სპელეოლოგიური ობიექტია და იგეგმება მისი გამოყენება მასობრივი ტურიზმისათვის. დიდი სირთულის გამო, იგი ბოლომდე არ არის გამოკვლეული. დასადგენია მისი დღემდე უცნობი განშტოებები. კვლევის გეოგრაფიულ-ჰიდროლოგიური მეთოდიკის საფუძველზე განისაზღვრა მღვიმური სისტემის შესაძლო გავრცელების მიმართულებები და სპელეოლოგიური ძიების ახალი ვექტორები.

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