Faculty of Natural and Technical Sciences, University "Goce Delčev"-Štip, R. Macedonia with a grant from the CEI-ES Know How Programme organize

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1st INTERNATIONAL WORKSHOP ON THE PROJECT

Environmental Impact assessment of the Kozuf metallogenic district in southern Macedonia in relation to groundwater resources, surface waters, soils and socio-economic consequences (ENIGMA)

PROCEEDINGS

Edited by:
T. Serafimovski & B. Boev

Kavadarci, 10th October 2013

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Organizing Committee:

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Prof. D-r Todor Serafimovski, *President*
Faculty of Natural and Technical Sciences, University "Goce Delčev"-Štip, R. Macedonia

D-r Josef Šimek
GIS-GEOINDUSTRY, s.r.o. ("GISGEO"), Czech Republic

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Prof. D-r Orce Spasovski
Faculty of Natural and Technical Sciences, University "Goce Delčev"-Štip, R. Macedonia

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HYDROGEOLOGICAL ASPECTS OF GRAUND WATER SOURCES OF THE KOZUF AREA, WITH SPECIAL ATTENTION TO THE CARST SPRINGS LUKAR, R. MACEDONIA

Vojo Mirchovski[1], Tena Sijakova Ivanova[1], Gorgi Dimov[1]
[1] *Faculty of Natural and Technical Science, "Goce Delcev" University*

Abstract
The ground water resources of the Kozuf region are directly related with litological, hydrogeological and tectonic phenomena and processes which take place from paleozoik until recent geological past, which ends volcanic activity of Mount Kozuf. Based on the results of previous regional and detailed hydrogeological studies the investigated area by structural type of porosity that occurs in rocks that are present can be divided in: boundary type of aquifers, fracture type of aquifers, karst-fractured type of aquifers and conditional waterless terrain.
The ground water resources of the region is mostly associated with upper cretaceous limestone, characterized by fractured - cavernosal porosity. The upper cretaceous limestones of this region are affected by different level of karstification to the isolationist base represented by old Paleozoic shale (phylite, argiloshist and sandstone). Somewhere process of karstification to waterproof surface is completely finished (eg sources in the Valley Zharnica), and sometimes still is not finished.

Introduction

Geological and hydrogeological research in this area date back to the early mining activities in the mountain Kozuv. Basic geological and hydrogeological studies in this area carried out in the preparation of basic geological map of the R. Macedonia in measure 1: 100 000 (Rakichevic and Pendzherkovski 1963) and the preparation of regional hydrogeological map in measure 1: 200 000 (Gjuzelkovski and Koteski 1979).

Geological, mineralogical, geochemical, volcanological and metalogenetic research of Kozuv region performed: Boev (1988, 1990) Boev and Lepitkova (1991, 1992, 1994), Boev, Serafimovski and Lepitkova (1992), Boev, Stojanov, and Denkovski (1993), Boev, Serafimovski and Milosavljevic (1993), Boev and Kovacev (1994), Boev and Serafimovski (1996) and others.

Data for the hydrogeological and geological characteristics of the investigated area is given by Kekic, 1973, 1974, Kotevski, Kekic, Tanev, 1968, Kotevski 1971 Gjuzelkovski 1997 Petrov 2008 Stojanov and Petrovic 1957. All these studies are aimed at function on exploring of water potential of the Kozuf region primarily for water supply of populated areas Kavardaraci and Negotino with quality drinking water.

Geographic position on space Kozuf and sources Lukar

Investigated area is located in the southern part of the Republic of Macedonia in the border with Greece (Fig. 1). It is located about 45 km from the city Kavadarci. The links with the region are good because there exists asphalt road leading to the village Mrezicko and mine Rzanovo.

Fig.1 Geographical position of investigating area.

Geology of the wider region

According tectonic regionalization of Macedonia researched field belongs to the Vardar Zone Arsovski (1997).

The geological structure of the investigated field region Kozuf participate rocks from Old paleozoik, Triassic, Cretaceous, and Neogene Quarter (Rakichevic and Pendzherkovski 1963). The geological structure of the wider region of the investigated field is shown on the geological map 1: 100 000 (Appendix 1).

Old paleozoik is presented with the Horizon of phylite, argiloshist, sandstone and marble (FAr) Quartzporfires (Pz1), quartzite horizon (Q) and serpentite (Se).

Triassic rocks are represented with many color of sand shist, cherts and sandstone (T?) Keratophyre (η) and quartzkeratophyre (ηq).

The upper cretaceous is represented by rocks of turon and senon (?) In different faces including: plate and banck limestones (Turon) **(K_2^2)** and massive limestone (Senon) **(K_2^3).**

Neogene is represented by Pliocene sands, clays and conglomerates.

Quarter is built by Agglomeration-breccha tuff (lower floor) (1ωQ1), breccha tuff (ωQ1), Agglomeration-breccha tuff (upper floor) (2ωQ1) and Amphibole andesite (αamQ1).

Hydrogeologic features of the wider environment of region

Hydrogeological structure of the Kozuf region is represented of hydrogeological map at a scale of 1: 100 000 (Appendix 2). Within the studied area by structural type of porosity that occurs in rocks are the following types of aquifers:

- Boundary type of aquifers
- Fracture type of aquifers
- Karst-Fracture type of aquifers and
- Conditional waterless terrain

BOUNDARY TYPE OF AQUIFERS

Boundary type of aquifers are occurs in rocks of Pliocene age represented by sands, clays and conglomerates in which is present intergranular porosity.

FRACTURE TYPE OF AQUIFERS

This type of aquifers in wider environment of the investigated terrain has great spreading. It was developed in Amphibole andesite, Quartzporfires, quartzite horizon and on a smaller scale the horizons constructed of phylite, argiloshist, sandstone and marble. Amphibole andesite are cracked and tectonic damaged.

The existence of Fracture type of aquifers is identified with registration of sources in field mapping.

Fracture porosity is expressed differently, and allow the different hydrogeological characteristics of solid rock masses. For those parts of the field, where disintegration is more notable, there is an large number of cracks formed as a result of endogenous and exogenous factors. The parts of the field, where microtectonic activity was expressed more, are seen more cracks of endogenous nature. The same, with added exogenous agents are reactivated and expanded. This especially refers on the surface of the ground, where there is insight of atmospheric water and underground circulation of the same.

Fracture porosity not penetrating in greater depths, but it is limited to the surface of the ground. At greater depths atmospheric water will sink only through existing faults. This water comes up in the surface in the lower parts of the field, or in the natural drainage.

Water permeability of the the rocks from fracture aquifer

Rocks with fractured porosity have the highest spreading of studied terrain. According water permeability they are divided into:

- Well water permeable rocks
- Weak water permeable rocks
- Waterproof rocks

Well water permeable rocks are represented by:

- phylite, argiloshist, sandstone;
- marbleized limestone with phylite and other shist;
- hidrotermal altered andesite;

In marbleized limestone, mixed with philite and other shist, water permeability is especially so given that it is mostly rigid limestone massifs in which the cracks are not only longer but there are wider and with a certain degree of karstification.

Weak water permeable rocks
Weak water permeable rocks are represented by:
- Metamorphic quartzporfires;
- Amphibole andesite;

Waterproof rocks
Waterproof rocks are represented by;
- Agglomeration-breccha tuff;

Wateryield on the the rocks from fracture aquifer

Generally taken the rocks with fracture porosity is poor in water, and therefore the most parth of studied area is without water. So Agglomeration-breccha tuff, metamorphic quartzporfires, and in good part amphibole andesite are particularly dry. In these sources are very rare, and where their yield has rarely spends 0.05 l/sec. Only the top over Old River on the slopes of Dudica and Porta registered growing number of sources which yield mostly 0.1-1 l/sec. Therefore this part of the field, while the regionalization of fracture aquifers is constrained as poorly yield. As seen in hydrogeological map, in this part of the field are represented mainly Paleozoic philite, argiloshist and sandstone, and hidrotermal altered andesite and partly amphibole andesite. Considering that in the upper flow of the river Zharnica registered a number of sources, including those whose yield are greater than 0.1 l/sec. Therefore this part of the field on the attached map is marked as poorly yield terrain and near the source yield 1.1 l/sec, the area is marked as well yield. Other areas identified as weak yield in the studied terrain are: the slopes of Gladnica, right slope of Old River, after its exit from karst aquifer and among source Lukar 2. Displayed regionalization of the water permeability on hydrogeological map in any case should be accepted as orientation data, because they are not applied to some concrete research, with the exception of registering hydrogeological appeared in the summer 1970.

KARST-FRACTURED TYPE OF AQUIFERS

Karst-Fracture type of aquifers within the terrain which is the subject of our research is developed in cretaceous plate and banck limestones and massive limestone and having cavernosal - fracture porosity. According to the water permeable rocks this belong to the group of well water permeable. These rocks according to hydrogeological function were the collectors and conductors of fresh and mineral underground waters.

The feeding of groundwater from aquifers of this type is the account of rainfall and drainage of the same place in the zones of faults and fractures.
According to hidrodinamical characteristics groundwaters are characterized by a free level.

Characteristic of karst represented in the Kozuf region is that upper cretaceous limestone under the influence of tectonic and eruptive effusion be developed into smaller or larger masses, or covered with agglomeration-breccha tuffs and andesite effusion. The largest mass of these limestones are preserved in the central part of the studied field (in the smaller part on the left side of Old River, and significantly more on the right side of the areaChardak -Gladnica). Limestone rocks on this part of the field is characterized by fracture-cavernosal porosity, less spongy or even speaking with karst porosity. Because of its specificity compared to fractured porous rocks that was discussed earlier, they are set aside as a special type of aquifer, ie as karst aquifer. In a variety of geological, geomorphological and hydrological processes of karst formation undoubtedly the greatest significance have litogenetic characteristics of carbonate rocks themselves, then the nature and degree of their impairment tectonic, hidrometrical and spatial position in the relief of the terrain, and especially to their solubility under the effect of surface and groundwater. From the surface karst forms are detected 4 sink holes, located on the ridge between Gladnica and Bara. Sink holes are in the form of a shallow dish, one slightly larger than the other three, all are filled with residium and overgrown with grass. Other phenomena observed on surface karst caves are three, one in the valley of Zharnica of 2 - 3 m. above the river level, then on the Old River valley about 30 m height on the left site and one on the eastern slopes of Gladnica near the contact of limestone and upper cretaceous Paleozoic limestones with philite and other shist at their floor. In some places on the slopes of Stara Reka been observed phenomena of clints in the form of parallel and deeper grooves with open cavities of 10-20 cm width. Similar karst phenomena are found on the limestone along the river Zharnica or along the left source branch on the Old River (near the border with Greece). Taking into account this development on the karst and its cracking, in general no doubt that the water permeable in upper cretaceous limestone is highly expressed. That these rocks are highly water permeable can be seen from the absence of surface flows in the upper parts of the ground and during most of of the year, and larger flows such as the left branch of the source of the Old River immediately diving after the release of upper cretaceous limestone or partial descent of the river Zharnica as part of his stream will be found in karsted upper cretaceous limestone. Taking all that in mind, these rocks are placed in the category of highly water permeable rocks with fracture-cavernosal porosity.

As an example of the development of the karstifiication in upper cretaceous limestone to waterproof base represented by old Paleozoic schists (phylite, argiloshist, and sandstone) can see on schematic hydrogeological profiles of the position of the sources in the river valley Zharnica (Fig. 2 and Fig. 3).

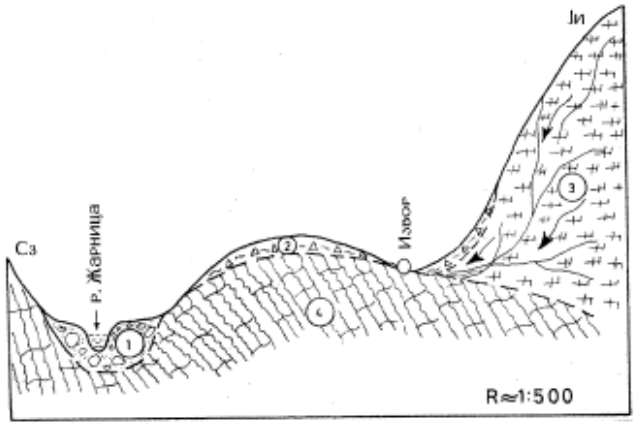

Fig 2. *Schematic hydrogeological profile with display the waterproof base in terms of karstifiication in upper cretaceous limestone, whose contact occurs source, in the right side of Old River .1 - river sediment, 2 - deluvial slope sediment, 3 - upper cretaceous limestone, 4 - old paleozoic schists (phylite, argiloshist, sandstone).*

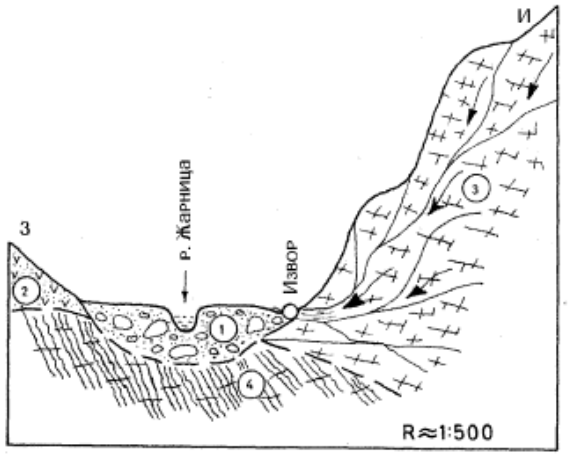

Fig 3. *Schematic hydrogeological profile for source with number 24 in the same locality and nearby to the source with number 23. 1 - river sediment, 2 - andesite, 3 - old paleozoic schists (phylite, argiloshist, sandstone) 4 - upper cretaceous limestone.*

Process karstification to the waterproof base (Paleozoic shale) is not fully completed as you can see in the Old River canyon, where on the length of 1200 m before joining the river in Paleozoic shale on both sides within the limestones occur more number of sources of 1-15 m height above the riverbed (Fig. 4,5, and 6).

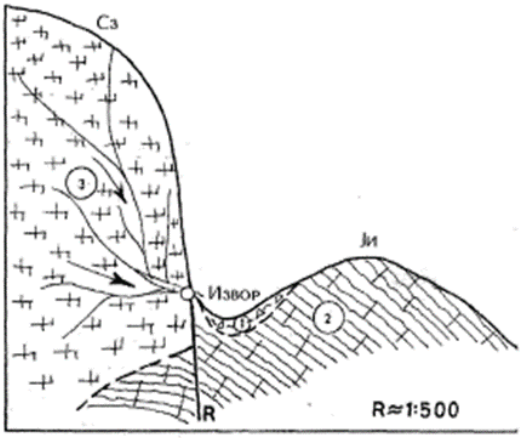

Fig. 4 Schematic hydrogeological profile for the source with number 8 (left side on the Old River) .1 - deluvial slope sediment, 2 - upper cretaceous limestone, 3 - old paleozoic schists (phylite, argiloshist, sandstone).

The appearance of the spring on the left side of Old River, is very specific. As seen from Fig. 4 the source occur at the contact along the fault between karstifiicate upper cretaceous limestone and waterproof base represented by old Paleozoic shist, but about 5-6 m above waterproof ground, which is also represented by Paleozoic shale. Therefore, it is a source that appears in something more complex hydrogeological conditions than previous examples.

CONDITIONAL WATERLESS TERRAIN

As a conditional waterless terrains are separate those parts which are constructed from many color of sand shist, cherts and sandstone, vulcanogene sediments constructed from different types of tuffs, cherts and sandstone. In these rocks is developed fracture porosity and they are waterproof or characterized by very low permeability. Most of the cracks are filled with products of decomposition so that are no conditions for the accumulation of significant quantities of ground water in them.

Karstic sources Lukar-1 and Lukar-2

Sources Lukar 1 and Lukar 2 are the largest karst springs in the investigated area through which groundwater is drainage from karst aquifer (Fig. 5 and 6). These sources are captured and they are performed water supply to cities Kavardaraci and Negotino. As seen from the Fig. 5 source Lukar 1 is part of the smashed karst aquifer, who leak of water manifests itself through 5 smaller and larger sources. But, as can be seen at field, the water from the source springs out under some pressure, not from contact with waterproof ground, but by something greater depth within the limestone, which means that karstification in this part of the field is deeper.

At the same time in this part of the field on contact with schist are seen more cavities in the limestone rock, which means that this karstification is a affected all waterproof surface.

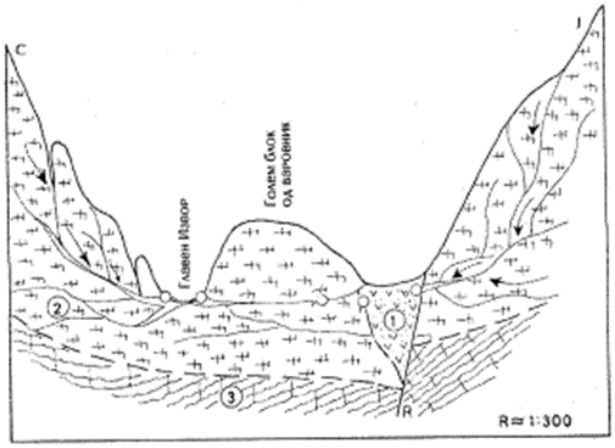

Fig. 5 *Schematic hydrogeological profile of the source Lukar 1, made during the execution of the construction works of the catchment on the source. 1 - andesite, 2 - upper cretaceous limestone, 3 - old paleozoic schists (phylite, argiloshist, sandstone)*

The sources Lukar 1 and 2 are part of the same karstic aquifer, only with difference that through the source Lukar 1 running significantly more water than the Lukar 2. It is quite logical if we take into account that Lukar 1 is 1-2 m lower than Lukar 2, located in the peripheral part on karst aquifer.

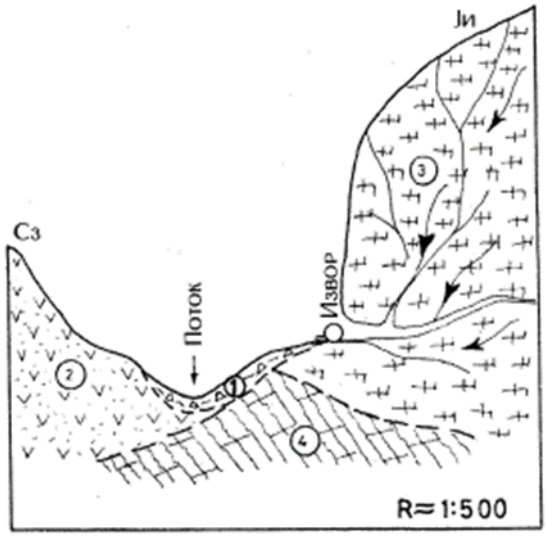

Fig. 6 Schematic hydrogeological profile of the source Lukar - 2, which is also made in the execution on construction works on the catchments. 1 - decomposed material, 2 - agglomeration-breccha tuff, 3 - upper cretaceous limestone.

From all registered hydrogeological phenomena within the karst aquifer,the most yield source is Lukar 1. In the period 1971 - 1972 hydrometeorological Institute - Skopje performed measurement, according to which yield amounted:

17.12.1971	166 l/sec
16.03.1972	225 l/sec
22.06.1972	239 l/sec
30.08.1972	253 l/sec
09.11.1972	223 l/sec
12.12.1972	236 l/sec
Average 223,66 l/sec	

Yield of source Lukar 2 in the same period was:

17.12.1971	44 l/sec
16.03.1972	33 l/sec
22.06.1972	38 l/sec
30.08.1972	47 l/sec
09.11.1972	44 l/sec
12.12.1972	51 l/sec
Average 43 l/sec	

The data obtained by measurements made on 17.11.2000, are the following:

- Lukar 1 with yield of 105 l / sec
- Lukar 2 with yield of 22 l / sec

When we compare data for measurements on these two sources, on first glance noticed some differences in the growth or lowering of yieldi of source Lukar 1 in terms of source Lukar 2. For example in 12.17.1971 was recorded lowest yield of the source Lukar 1 while for the source Lukar 2 that is registered on 16.03.1972 when yield of Lukar 1 increased significantly compared to the previous measurement. Maximum yield on spring Lukar 1 is registered on 30.08.1972, and Lukar 2 on 12.12.1973 g. Consequently it is clear that the feeding on these sources and generally speaking their regime are not identical, even though belonging to the same karstic aquifer and separated by a distance of about 250 m. Also these two sources are quite different in hemistry of water. For example, the source of water is 1 Lukar hydrocarbons, sulphate-chloride-calcite, and the source Lukar 2 hydrocarbons calcite.

From the measurements can be seen that on karst springs yield of Lukar 1 and 2 is highly variable throughout the year.

Conclusion

Within the studied area by structural type of porosity that occurs in rocks are the following types of aquifers:

- Boundary type of aquifers
- Fracture type of aquifers
- Karst-Fracture type of aquifers and
- Conditional waterless terrain

The greatest amount of groundwater in on Kozuf region is accumulated in karst-Fracture type on aquifers which was formed in upper cretaceous limestone. These limestones, lying on transgression with old paleozoic rocks. Due to intense cracking and karstification the limestone are collectors and all significant aquifers in the region genetically linked precisely with these rocks.

The most important karst springs by which drains the largest amount of water in karst aquifer are sources Lukar 1 and 2.

These sources drained same karstic aquifer, only with the difference that the through source Lukar 1 running significantly more water than the Lukar 2. Yield of the source Lukar-1 is on ranges from 105 to 253 l/s, and the source Lukar-2 it is 22-47 l/s.

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