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## ARTESIAN MINERAL WATER OF THE RAOTINCE SITE, TETOVO

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**A b s t r a c t:** A number of mineral springs occur on the west and east peripheral part of the Polog valley. Their appearance is connected with the Western Polog fault that stretches west to the brim of the valley NE–SW direction and east direction of Polog fault stretches in NW–SE. This paper presents the results of detailed hydrogeological investigations of mineral water at the site Raotince Tetovo. Based on data obtained on two operational investigative boreholes at the site in Raotince of the pleistocene limnic sediments at a depth of 38–67 m is founded artesian aquifer with low mineralized water.

**Key words:** artesian aquifer; mineral water; Raotince; Polog valley; limnic sediments

### INTRODUCTION

Raotince site is situated in the western part of Macedonia, 20 km north-east of Tetovo (Fig. 1). The occurrences of mineral and low mineral waters in this area appears in the left and the right banks of the river Vardar from the village Kopance to the village Raotince. In the immediate vicinity of the

site Raotince passes the river Vardar. Mineral waters from the wider environment Raotince were investigated by several authors: (Bajic, 1929, Kekic, 1973, 1986, Kotevski, 1980, 1987, Loncar 1996).



Fig. 1. Geographical position of the investigated area

## GEOLOGICAL COMPOSITION OF THE WIDER REGION

The geology of the region is made up of Paleozoic, Permian, Mesozoic, Tertiary and

Quaternary rocks (Petkovski, Karovic, 1977) (Fig. 2).

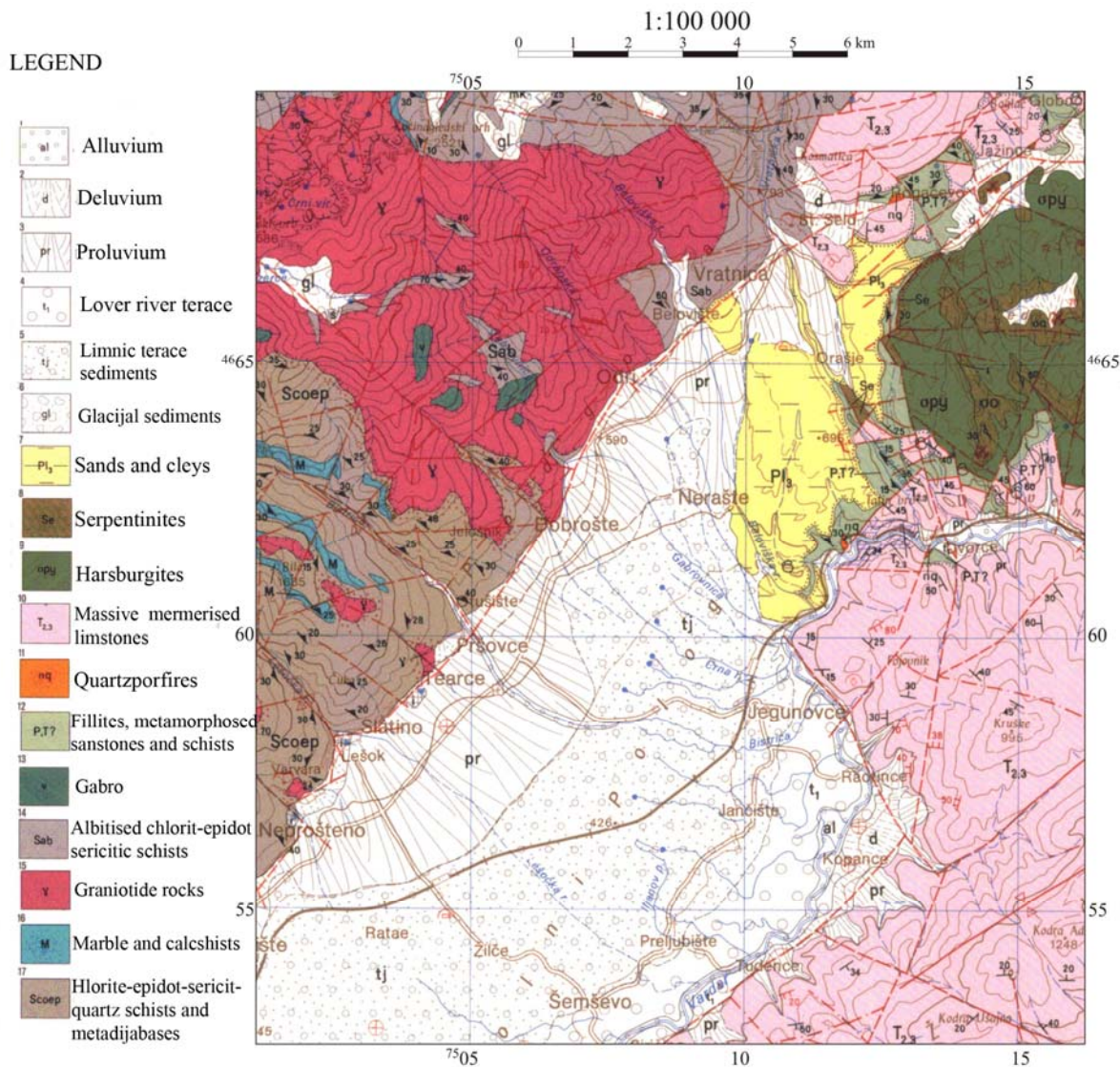


Fig. 2. Geological map of the investigated area. (Petkovski nad Karovic 1977)

The oldest rocks are represented of Paleozoic rocks present of: epidote – chlorite – sericite – quartz schist and metadijabases (Scoop), marbles and kalkshists (M), granite rocks ( $\gamma$ ), albitized – chlorite – epidiot – quartz schist, and gabbros (v). Permian rocks are represented by: fillices, metamorphosed cleystones, sandstones and schists (P, T) and quartz porphyry ( $\pi q$ ).

Mesozoic is present of Triassic massive marble (T 2.3), jurassic harsburgites ( $\sigma py$ ) and serpentinites (Se).

Tertiary is made up of only Pliocene sediments.

Quaternary rocks are represented of: moraine material (gl), limnic terrace sediments (tj), lower river terraces (t1), proluvial (pr), deluvial (d) and alluvial sediments (al).

The investigated area by geotectonic regional aspect belongs to the Western Macedonian zone (Arsovski, 1997).



### HYDROGEOLOGICAL INVESTIGATIONS

Two exploration drill holes with a depth of  $D_1 = 50$  m and  $D_3 = 70$  m. were made for the determination of the mineral water at the Raotince site .

With both boreholes artesian water were discovered bearing horizons with low mineral water. Based on data obtained by investigations drilling, was designed hydrogeological profile clearly presented lithological members (Fig. 3). From the hydrogeological profile it can be seen that the topmost parts of the site-built of alluvial terrace sediments which thickness ranges up to 10

meters. In the terrace alluvial sediments that are built of gravel and sand aquifer is formed by free level. Under the alluvial terrace sediments down to the final depth are determined limnic sediments, presents of gravels, sands and clays and a varieties of their mutual transition. After drilling and purification drill holles have been done galvanized perforated pipes with a diameter 3" have been filled. By measuring the yield of the drill holles artesian mineral water with capacity of:  $D1-Q = 8$  l/s  $D3 - Q = 2.6$  l/s is obtained.

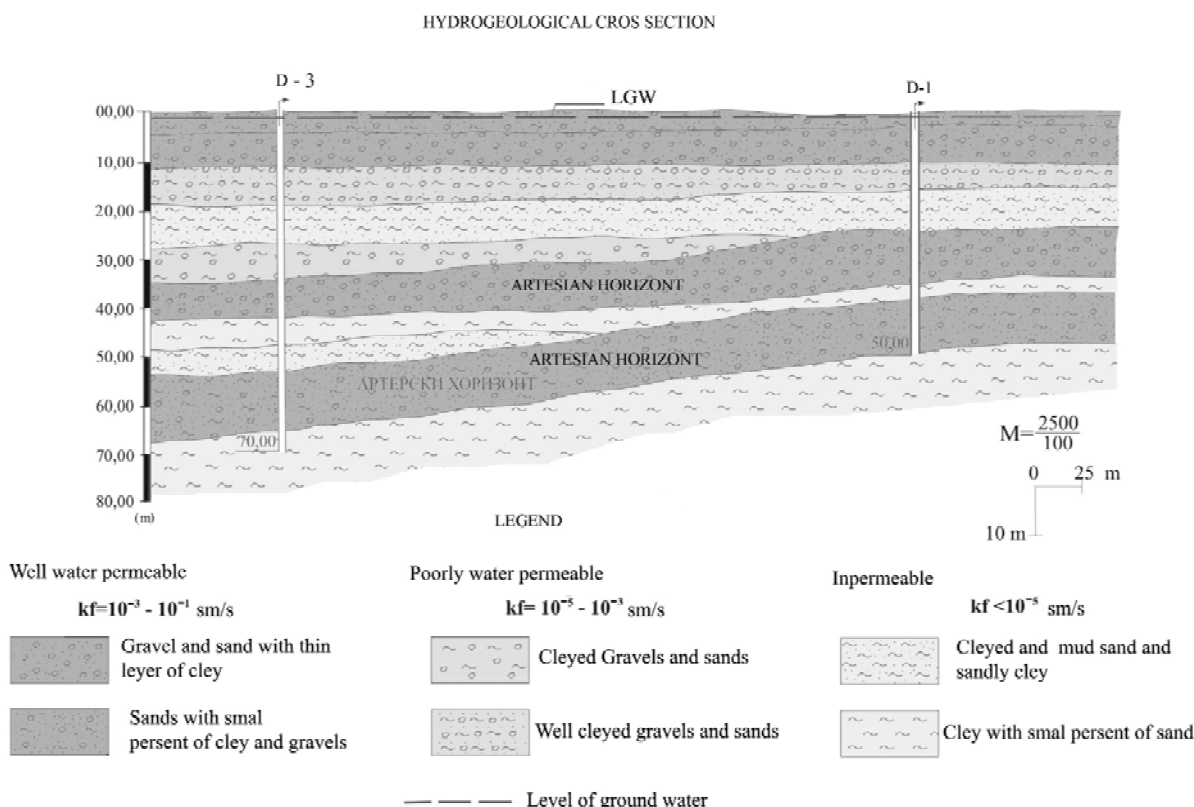


Fig. 3. Hydrogeological profile

On the bases of D1 drill hole there is greater yield in it so technical exploration is prepared for exploration as well (Fig. 4). The drill hole is located about 400 meters downstream of the bridge of river Vardar Raotince village.

Based on field observations on known data as a potential zone in which there is mineralisation water zone it is located on both sides of the river Vardar in NW–SE direction. The width of this zone ranges of 250–500 meters in length and can be traced right to the village Kopance



Fig. 4. Artesian drill hole of Raotince site

## CALCULATION OF THE HYDROGEOLOGICAL PARAMETERS

According to the data of the investigation work done a calculation has been made of the hydrogeological parameters of the water bearing environment:

$K$  – coefficient of filtration

$T$  – transmissivity coefficient

$Q$  – yield of drill hole

$N$  – hydrostatic pressure of aquifere

$l$  – thickness of water-bearing layer

*Filtration coefficient*

Filtration coefficient is determined based on determination of granulometric composition of samples from the artesian water-bearing layer which in the drill hole D1 is in the interval from 38.00 to 49.00 meters and the results obtained by the tests carried out on the well.

The results obtained from the granulometric analyses were used for calculation according to the formula of "USBR".

$$K_f = 0.36 \cdot d_{20}^{2.3}$$

Where is:  $K$  – coefficient of filtration,  $d_{20}$  – diameter of grains (mm), with representation from 20% to granulometric curve.

According to this formula the filtration coefficient was obtained by the following value:

$$K_f = 1.60 \times 10^{-1} \text{ sm/s, sm/s or 138 m/dey}$$

Static water level is located at + 4.5 m above the surface of the ground. The testing of the well obtained the following values of the capacity of the well  $Q$  and lowering the water level  $S$  in the well Table 1.

Table 1

*Data from the test well*

Height of LGW over field $H$ m	Capacity $Q$ l/s	Lower level $H_0 - H) = S$
$H_1 = 3.20$	$Q_1 = 2.40$	$S_1 = 1.30$
$H_2 = 1.80$	$Q_2 = 5.75$	$S_2 = 2.70$
$H_3 = 0.60$	$Q_3 = 8.05$	$S_3 = 3.90$

Based on the obtained parameters for  $Q$  and  $S$ , calculation of the filtration coefficient has been made according to Krasnopolski (1980), for conditions when artesian aquifer is away from

surface waters, there is not monitoring well and when the well radius ( $r$ ) is very small regarding the radius of its influence ( $R$ ).

$$K = \frac{0,16 \cdot Q}{m \sqrt{r \cdot S}}$$

Input parameters are:

$Q = 8.05$  l/s – Well capacity

$S_3 = 3.90$  m – Lowering the water level

$m = 11$  m – Thickness of water-bearing layer

$r = 3''$  – Radius of well pipe

$$K = 8.35 \times 10^{-2} \text{ cm/s} = 72 \text{ m/dey}$$

$$m = 11 \text{ m}$$

$$T = 72 \times 11 = 792 \text{ m}^2/\text{dey}$$

*Transmissivity coefficient*

Transmissivity coefficient ( $T$ ) was calculated according to the formula for the non stationary conditions of streams in the water-bearing artesian layer:

$$T = K \times m$$

$K$  – coefficient of filtration

$m$  – thickness of the water-bearing layer

$$K = 72 \text{ m/dey}$$

$$m = 11 \text{ m}$$

$$T = 792 \text{ m}^2/\text{dey}.$$

*Capacity of the drill hole*

After the drill hole has been technically equipped, testing of its capacity has been made.

The measurement was conducted for a period of 13.5 months and the results are shown in Table 2.

A granulated gravel has been placed around the drill hole and over it until the surface of the clay court built as a buffer layer which acts to isolate the mineral waters from the penetration of water from upper layers. The mouth of the drill hole was equipped and protected by concrete manhole and plate.

This equipped drill hole was washed with water and measuring of the capacity was conducted for a period of 10.22.1995 to 05.04.1996.



Table 2

*Capacity of the artesian drill hole*

Date of measurement	Capacity Q l/s	Temperature °C
22.10.1995	10.22	12.4
12.11.1995	10.06	12.3
05.04.1996	12.0	12.0
11.01.1996	9.70	12.0
10.02.1996	10.28	11.8
15.03.1996	9.55	12.0
14.12.1996	10.00	12.1

After the results of the capacity of the drill hole is concluded to be stable hydrogeological conditions. Based on measurements data the exploitation yield for the drill hole is

$$Q_{\text{exp.}} = 10.0 \text{ l/s.}$$

However yield over time will decrease because of the dynamic discharge aquifer and reducing the permeability of the filter tubes over time this will be monitored and analyzed.

*Hydrostatic pressures in the aquifere*

Hydrostatic pressures in the aquifere was measured at the outlet pipe, thus obtained values ranging from 1.6 – 2.2 bar.

## QUALITY OF THE WATER

Quality of the mineral water was analyzed by the National Institute for Health Protection in Skopje have been made two chemical analysis.

According to the chemical composition the water belongs to the group of hydrocarbonate, calcic- magnesian water.

It is characterized by a pleasant tartness, no smell and has increased mineralization ranging from 708–895 mg / l, according to which it belongs to the group of low mineralized water.

According to the pH value (pH = 6.32) water belongs to the group of weakly acidic waters.

## CONCLUSION

In the area of Raotince which was covered by detailed hydrogeological investigations in the pleistocene limnic sediments at a depth of 38 – 67 m, was founded aquifer of two artesian horizons with low mineralized water.

Exploitation drill hole D1 works in stable hydrogeological conditions with capacity of

$$Q_{\text{exp}} = 10.0 \text{ l/s}$$

According to the chemical composition water belongs to the group of hydrocarbonate, calcic-magnesian water.

According to the mineralization ranging from 708–895 mg / l water belongs to the group of low mineralized waters.

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## Резиме

## АРТЕСКА МИНЕРАЛНА ВОДА ОД ЛОКАЛИТЕТОТ РАОТИНЦЕ, ТЕТОВО

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**Клучни зборови:** артески водоносник; минерална вода; Раотинце; Полошка котлина; езерски седименти

Поголем број на појави и минерални извори се појавуваат по западниот и источниот ободен дел на Полошката котлина. Нивното појавување е поврзано со западно Полошкиот расед кој се протега по западниот обод на котлината со правец СИ-ЈЗ и со источно Полошкиот расед со правец на протегање СЗ-ЈИ. Во овој труд се прикажани резултатите од деталните хидрогеолошки истра-

жувања за минерална вода на локалитетот Раотинце Тетовско. Врз основа на податоците кои се добиени со две истражно експлоатациони дупнатини на локалитетот Раотинце во плеистоценските езерски седименти на длабочина од 38 – 67 m е констатиран артески водоносник со слабо минерализирана вода.