Determining the Origin of Waters Flowing into the Senovo Mine by Hydrogeochemical and Isotopic Methods

By Miloš MARKIČ[1], Janko URBANC[2], Jože PEZDIČ[2] and Marijan MARIN[1]

[1]SP GZL - Institute of Geology, Geotechnics and Geophysics
YU - 61000 Ljubljana, Slovenia, Yugoslavia; Dimičeva 14

[2]Institute Jožef Stefan
YU - 61000 Ljubljana, Slovenia, Yugoslavia; Jamova 39

ABSTRACT

This paper studies the origin of waters emerging in underground mine workings of the Senovo Coal Mine. Chemical and isotopic characteristics of underground and surface waters were examined for this purpose, and the measurements of discharges of two streams embracing the mine were carried out as well.

It was found out that the major quantity of waters originates from the slopes of the Bohor massif north of the mine and not from the area south of the mine as considered before. The mean altitudes of recharge areas of individual waters in the mine were estimated. Although some water losses of the Dovce stream were detected, it is presumed that the majority of the total water input originates in the underground flows from the northern limestone-dolomite area.

INTRODUCTION

The Senovo Coal Mine is one of the smallest collieries in Slovenia with an annual production of 120.000 tones of bright brown coal. At present the exploitation is carried out from the stopes more than 400 metres below the surface, i.e. 80 m above sea level. The entrance into the mine is at +270 m a.s.l. Due to the deepening of the coal exploitation the total water input increases as well. At present it amounts to 45 l/sec and is pumped out mainly from the altitude +50 a.s.l. with the elevation difference of 220 metres. The origin of this water has been the aim of hydrogeological exploration. Mesozoic carbonate rocks, Miocene Lithothamnian limestones and the caved waste rock zone above the coal stopes are the most important aquifers of the area. The coal mine is embraced by two streams - the smaller Bela stream and the more significant Dovce stream.

The following questions have been raised on the real origin of the total water input:

1. Is the wide outcropping surface of the Lithothamnian limestone southward of the mine, providing the largest quantity of constantly emerging water into the underground mine workings, really the most important source of water as it has been considered up to the present[(1)]?

2. To what extent could the local streams influence the total water input?

3. What kind of hydrological connections are possible between different aquifers, mainly

between Mesozoic carbonate rocks and the Lithothamnian limestone?

We have tried to solve the problems stated above by using geological structural mapping, discharge masurements of the Dovce and the Bela stream, hydrogeochemical water analyses and in particular oxygen isotope water analyses.

Some relevant results already obtained in the course of the research are presented in this paper.

GENERAL DESCRIPTION OF THE STUDY AREA

Geology and Tectonics

The Senovo coal mine is situated in the eastern part of Slovenia (Fig.1). The main geological characteristics of the study area are shown in Fig. 2 and 3.

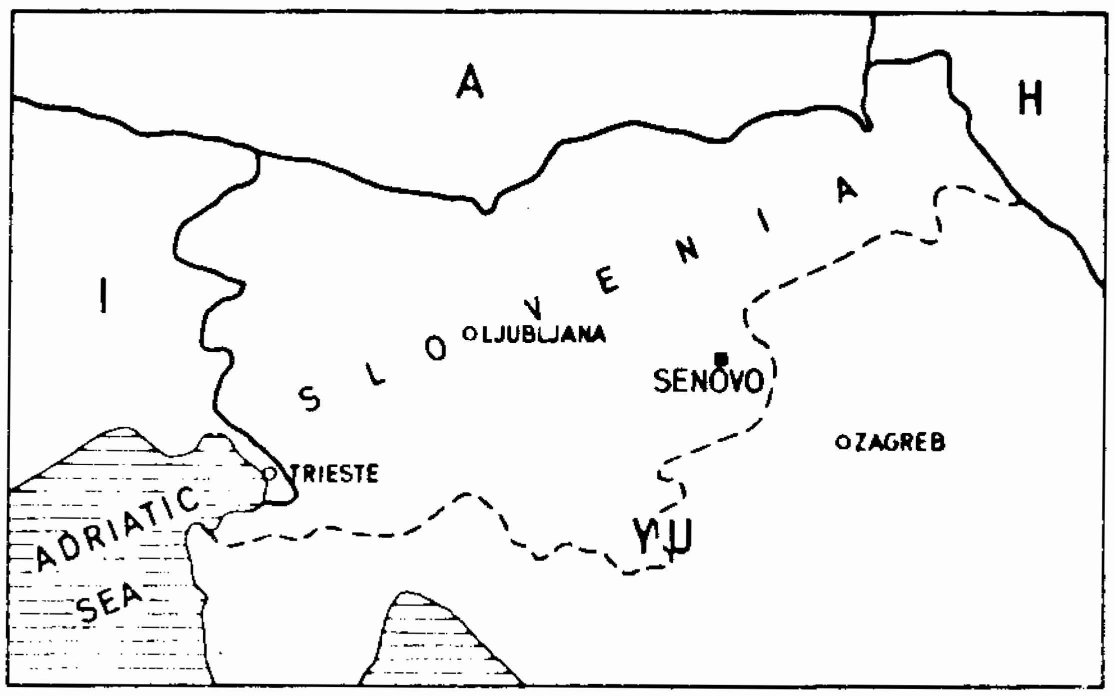
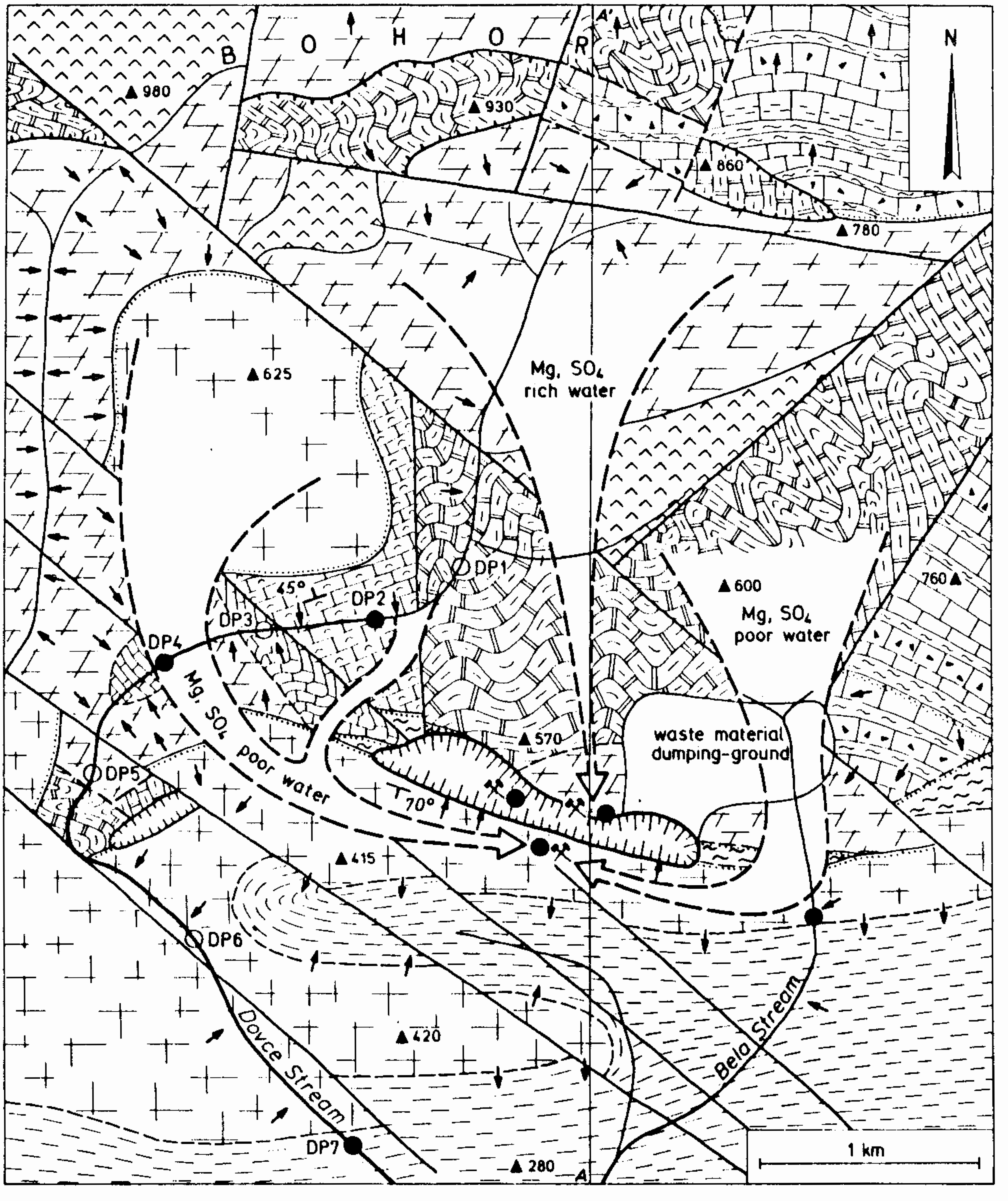


Fig. 1: Location map of the Senovo coal mine.

The main coal seam, having a lenticular shape of W-E direction, is on average 20 metres thick. Due to compressed syncline its dip amounts to 80°. The under wall consists of continuous 100 - 150 metres thick Oligocene clay bedset and it is always in direct contact with the coal. This clay bedset represents the aquiclude towards the Triassic limestone - dolomite groundrock. The upper contact significantly depends on the postoligocene tectonic activity: in the western part of the mine the coal is normally overlaid by Oligocene dark grey impermeable marls, while in its eastern part it is in tectonical contact with the Miocene karstified permeable Lithothamnian limestone and rarely with lenses of Miocene Govce sands and sandstones. The greatest thickness of dark grey marls reaches 200 metres and the thickness of the Lithothamnian limestone amounts to 300 metres. Sarmatian impermeable marls filling up the synclines above older Tertiary rocks are the youngest strata of the area.

The region's tectonics is of great importance in solving the hydrogeology of the mine and its surroundings. NW-SE faults are the youngest and the most distinctive faults in Triassic groundrock as well as in Tertiary strata. By underground geological mapping[2] W-E faults have been detected running between NW-SE dislocations but not intersecting them.



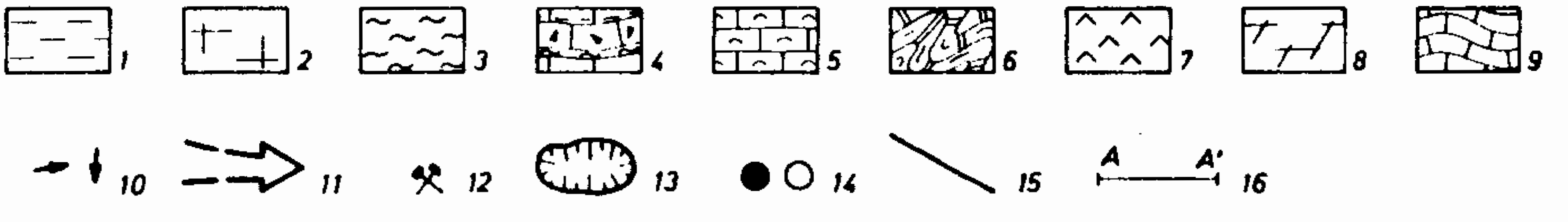


Fig. 2: Geological map of the study area (see the explanation of the legend on the next page).

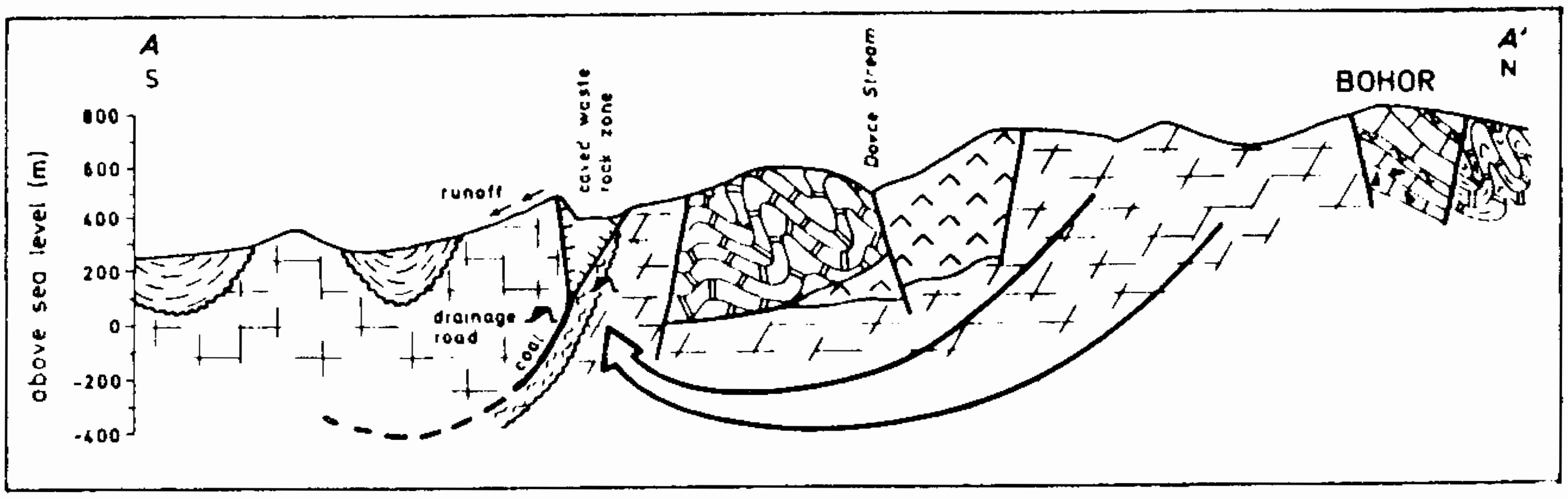


Fig. 3: Geological profile of the study area in N - S direction.

1-Sarmatian marl **2**-Miocene Lithothamnian limestone **3**-Oligocene clay bedset **4**-Cretaceous folded flysch sedimentary rocks **5**- Jurassic beded limestone **6**-Carnian beded limestone with marly interlayers **7**-Diabase **8**-Anisian dolomite **9**-Scythian rocks (limestones, carbonate siltstones, claystones) **10**-Surface drainage toward the streams **11**- Subsurface drainage toward the underground mine workings **12**-underground mine workings **13**-caved waste rock zone **14**-sample sites **15**-Fault.

The oldest faults are extended in N-S direction and most frequently they do not affect the Tertiary strata. Besides the main aquifers' permeability, they have also a significant influence on the more intensive hydrological connections between the surface and underground waters as well as between different aquifers. The unconformity between Mesozoic carbonate rocks and Lithothamnian limestone in the westward vicinity of the mine should be also taken into consideration.

Surface Hydrology and Total Water Input into the Mine

The local average precipitation is 1100 mm/a and the estimated evapotranspiration is about 50 % (Hydrometeorological Survey of Slovenia).

The coal mine is embraced by the smaller Bela stream and by the more significant Dovce stream. The discharge of the Dovce stream amounts to 50 l/sec in its upper flow and to about 90 l/sec in its lower flow, while the discharge of the Bela stream is about ten times smaller.

The total water input into the mine amounts to 45 l/sec. In the underground drainage system about 32 litres of water per second - i.e. more than 70 % - emerges from the Lithothamnian limestone. The most important contribution to this amount is a spring from the cavern in Lithothamnian limestone in the drainage road, at present only 30 metres below the active stopes. Discharges from the limestone are almost constant and it seems that they are not in a close correlation to the rainfall regime on the surface.

Another important aquifer is Triassic dolomite but its quantity of 10 l/sec represents only 22 % of the whole water input. It is interesting that such a huge area built up mostly of dolomite north of the mine (Fig. 2) provides such a small part of the total water input into the mine.

A contribution from the caved waste rock zone does not exceed 3 - 3.5 litres of water per second.

WATER LOSSES FROM THE DOVCE STREAM

On the basis of the discharge measurements carried out after longer dry weather periods a section of more considerable water loss has been detected between measuring sites DP-1 and DP-2 in the upper flow of the Dovce stream (Fig. 2). The water loss amounts to 5.7 l/sec.

Northward of the mine the Dovce stream passes various more or less permeable Mesozoic dolomites and limestones. Between the discharge measuring sites DP-1 and DP-2, a distinctive fault between Triassic and Jurassic limestone is extended in the N-S direction. It is presumed that this fault enables more intensive infiltration of the water directly from the stream into the mine.

CHEMISTRY OF WATERS

During the last year period surface and mine waters in 12 sample sites were analysed for K^+, Na^+, Ca^{2+}, Mg^{2+}, Cl^-, HCO_3^- and SO_4^{2-} ion content in the Laboratory REK EK Trbovlje. It was found out that the most significant differences among the main types of waters exist especially in Ca^{2+}, Mg^{2+} HCO_3^- and SO_4^{2-} contents as shown in Table 1.

Table 1: Main geochemical characteristics of waters emerging in the underground mine workings and of the Dovce stream on the surface. Only mean values for the most significant ions are listed.

Concentration (mg/l)	Lithothamnian limestone	Triassic dolomite	Caved waste rock zone	Dovce stream
Ca^{2+}	89	113	170	63
Mg^{2+}	8	61	66	24
HCO_3^-	300	460	620	294
SO_4^{2-}	16	160	1012	31

Water percolating through the Lithothamnian limestone has distinctively lower Mg^{2+} and SO_4^{2-} ion contents in comparison with the "dolomite" water. Water emerging from the caved waste rock zone shows very high SO_4^{2-} content and also Ca^{2+} and HCO_3^- contents are significantly higher. Abundant SO_4^{2-} content could be explained by the oxidation of sulphide components from the coal or direct rock extraction(3). The higher Ca^{2+} and HCO_3^- contents are the product of the increased CO_2 concentrations due to the oxidation of coal in the caved waste rock zone.

ISOTOPIC COMPOSITION OF OXYGEN IN WATERS

Water input into the Senovo mine can originate from two different regions (Fig 4):

1. from the area south of the mine mostly with altitudes between 250 and 500 m above sea level, and
2. from the slopes of Bohor, extending north of the mine and having altitudes between 500 and 1000 m.

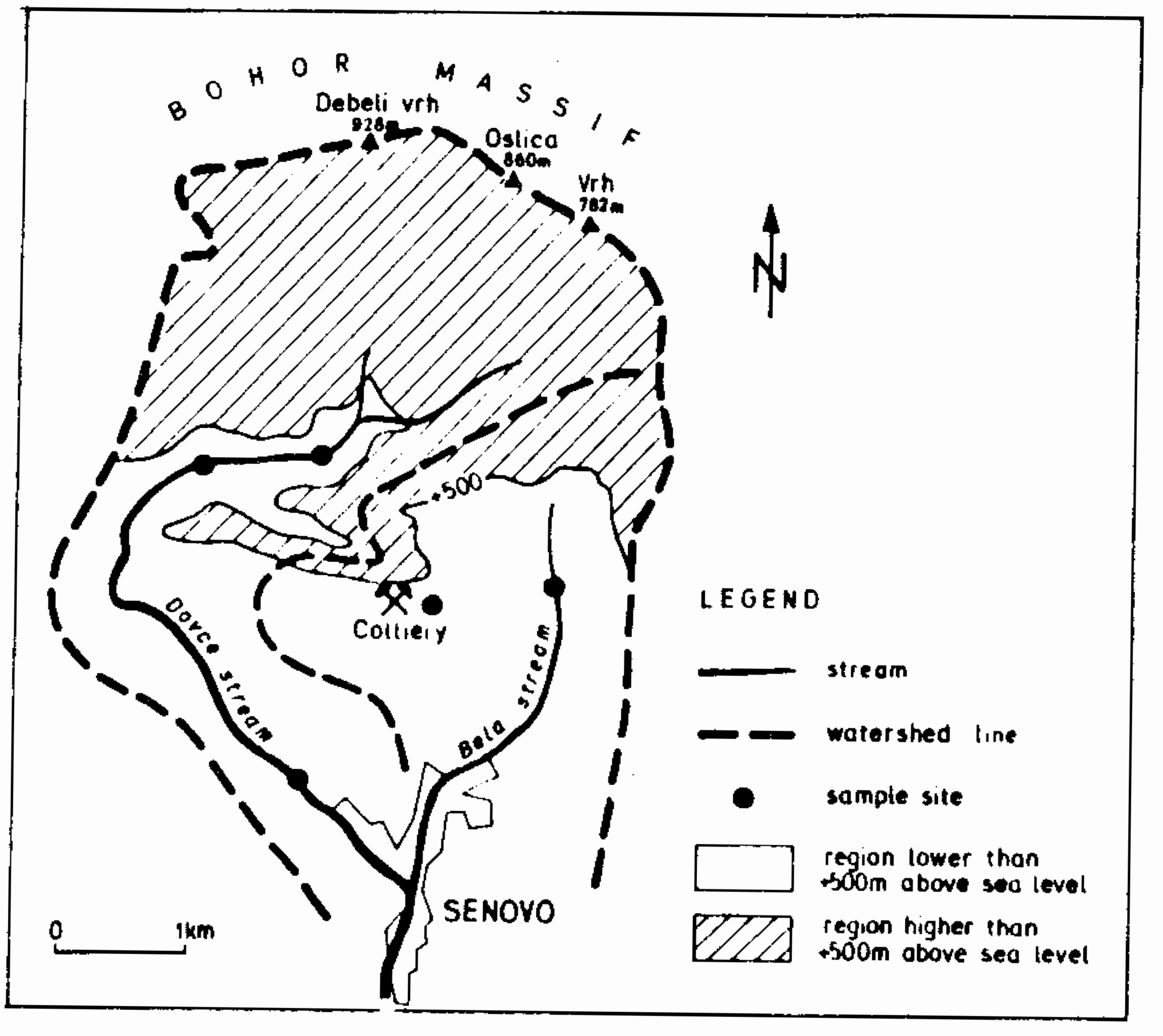


Fig. 4: Two regions with different altitudes around the Senovo mine.

Due to the altitude isotopic effect on precipitation, $\delta^{18}O$ values of precipitation in the mine's vicinity are expected to be more positive than those measured on the slopes of Bohor. Our aim was to use these differences, which are of course further reflected in surface and ground waters, to determine the origin of waters in the Senovo mine.

In the mine, we measured the isotopic composition of waters from Triassic dolomite, from Lithothamnian limestone and from the caved waste rock zone above the coal stopes. We measured also the isotopic composition of oxygen in water in the upper, middle and lower flow of the Dovce stream and in the middle flow of the Bela stream. Sampling was carried out only after a few days' periods of no precipitation, in order to ensure the prevailance of base flow waters.

The isotopic composition of oxygen in water was determined by equilibrating water with CO_2 [(4)]. The analyses were carried out on the Varian Mat 250 mass spectrometer at the Jožef Stefan Institute in Ljubljana.

Yearly fluctuations of isotopic composition of oxygen in the base flows of observed waters were found to be very small; the amplitude in streams was 0.5 $^{o}/_{oo}$, while it didn't even reach 0.3 $^{o}/_{oo}$ in the mine waters. Figure 5 illustrates the average isotopic composition of oxygen in observed waters, calculated on the basis of 6 samples taken from May 1990 to March 1991. We can see that the lowest mean $\delta^{18}O$ values were measured in the water taken from Triassic dolomite in the mine, its value being -10.3 $^{o}/_{oo}$. By taking into account the altitude effect on the isotopic composition of oxygen in precipitation, it can be concluded that the catchment area of this water lies at the highest altitudes.

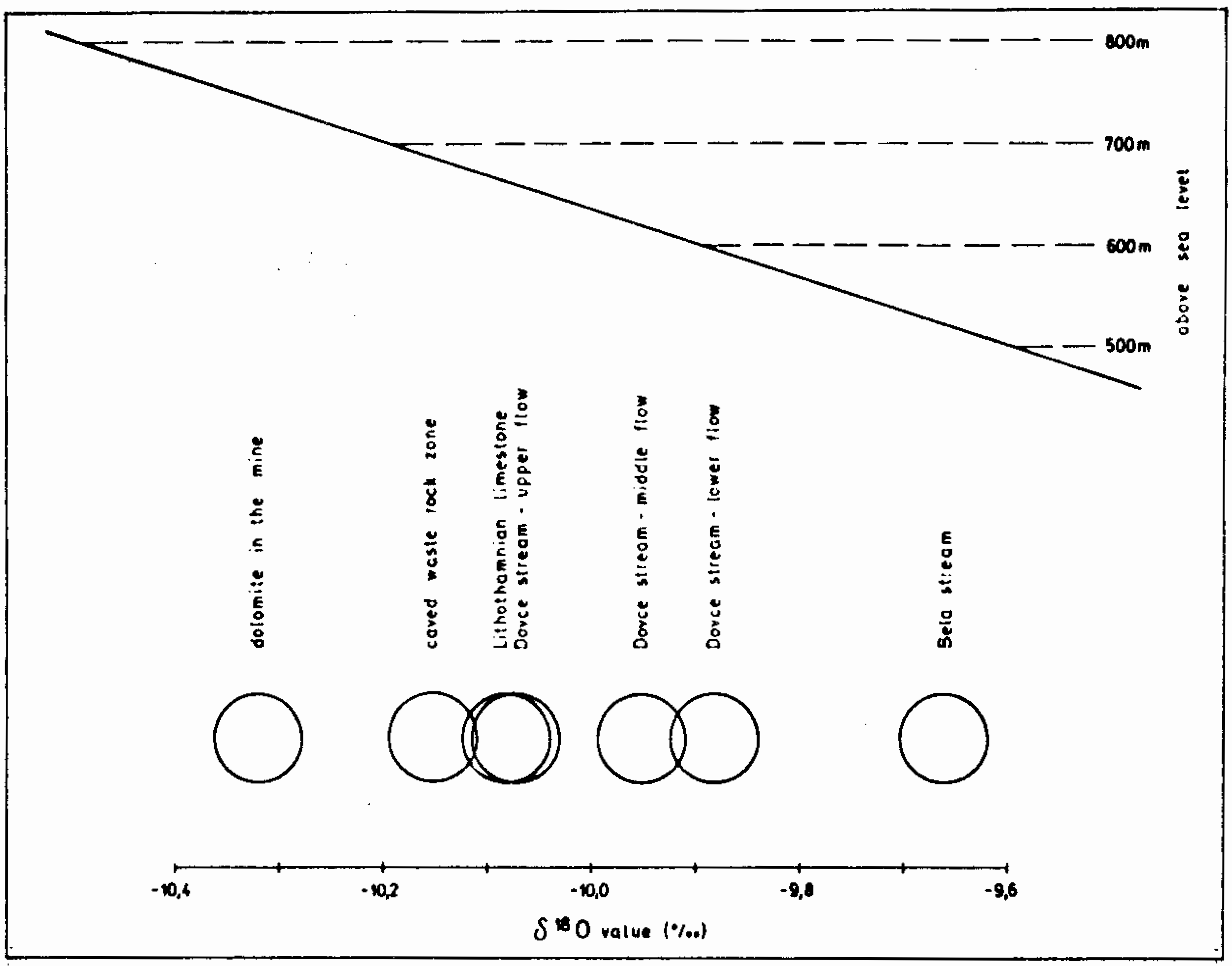


Fig. 5: $\delta^{18}O$ values of waters in the investigated area with calculated approximate mean altitudes of their catchment areas.

Values around -10.1 ‰ were measured even at three sampling sites, namely in the water from the upper flow of the Dovce stream, in the water from Lithothamnian limestone and in the water from the caved waste rock zone in the mine.

In the Dovce stream, more and more positive $\delta^{18}O$ values were measured in samples further down the stream, reflecting the influence of local waters, which have their catchment area in areas with low altitude precipitation, and are thus enriched in ^{18}O. The influence of low altitude precipitation is most evident in the Bela stream which has a mean $\delta^{18}O$ value of -9.6 ‰ .

For a better illustration we calculated approximate mean altitudes of catchment areas of the waters discussed. The mean altitudes of their catchment areas were determined on the basis of analogy with the Bela stream catchment area, where we relatively well know the mean $\delta^{18}O$ value of its base flow as well as the mean altitude of its catchment area. As we do not know the exact value of the oxygen isotope altitude gradient in this area, we adopted from literature(5) the value 0.3 ‰ per 100 m as the mean observed gradient. The altitudes calculated are given in Table 2.

Table 2: Calculated approximate mean altitudes of catchment areas of waters in the mine and streams above the mine.

Location of water	Mean $\delta^{18}O$ (‰)	Calculated altitude a.s.l. (m)
Triassic dolomite in mine	-10.32	740
Lithothamn.limestone in mine	-10.08	660
Caved waste rock zone	-10.15	680
Dovce stream - upper flow	-10.07	655
Dovce stream - middle flow	-9.95	615
Dovce stream - lower flow	-9.88	590
Bela stream - middle flow	-9.66	520

Another important conclusion which can be drawn from data on the isotopic composition of waters is that the aquifers in Lithothamnian limestone and in caved waste rock zone in the mine do not recharge in the area where they crop out, but have their recharge areas higher up on the slopes of Bohor. If these two aquifers recharged in their outcrop zones, where the altitudes lie between 250 and 500 m a.s.l., their mean $\delta^{18}O$ value ought to be around -9.2 ‰. This supposition is based on data from sampling of precipitation around the mine and on an analogy with the precipitation in Zagreb.

In any case the mean $\delta^{18}O$ value of these waters should be more positive than the mean isotopic composition of the Bela stream (-9.6 ‰), as its catchment area lies partly at lower and partly at higher altitudes.

Thus the isotopic composition of oxygen in waters from Lithothamnian limestone and the caved waste rock zone can be explained in two ways, the first being the inflow of waters into the mine from the slopes of Bohor through subterranean channels, and the second the infiltration of waters into the mine from the upper flow of the Dovce stream. We think that a combination of both explanations is possible, although on the basis of Ca^{2+} and Mg^{2+} content in streams and mine waters we believe that the underground inflow from Bohor plays the main role. We expect that with further investigations it will be possible to locate the catchment area of the mine waters more precisely.

In previous researches it was supposed that also the Bela stream water could infiltrate into the mine(1). Since the $\delta^{18}O$ values measured in the mine waters are not as positive as those of the Bela stream, we suppose that this does not happen to a large extent.

CONCLUSIONS

The multidisciplinary researches carried out in the last two years revealed new points of view on the general hydrogeology of the Senovo coal mine and its surroundings.

The topic's results are the following:

1. The main recharge area of waters emerging in the underground mine workings are the high altitude slopes of the Bohor massif north of the mine and not the regions south of the mine as considered before.

2. Calculated approximate mean altitudes of recharge areas of waters draining into the mine are:

- Triassic dolomite	740 m
- Lithothamnian limestone	660 m
- Caved waste rock zone	680 m

3. By discharge measurements of the Dovce stream the water loss in its upper flow was detected. The isotope water analyses of $\delta^{18}O$ content do not exclude the possibility of water connection between the Dovce stream water and the underground water in the mine, although the chemical data indicate that this influence could not be very intensive.

4. The Bela stream has no significant influence on the mine waters.

5. Water from the caved waste rock zone is enriched in Ca^{2+}, HCO_3^- and SO_4^{2-} ion contents. The Ca^{2+} and HCO_3^- enrichment is caused by the increased CO_2 concentration in this zone as a result of coal oxidation while the SO_4^{2-} enrichment results from the sulphides oxidation or direct rock extraction.

REFERENCES

1. Kuščer D. Raziskava in izdelava študije preprečevanja vdorov vode in blata v Rudniku rjavega premoga Senovo. Študija No. 814/85. Univerza v Ljubljani - Montanistika. Ljubljana, pp. 1-20 (1985).

2. Uhan J. Strukturne raziskave na območju med Kališovcem in Senovim. Študija No. 612-1/86. Geološki zavod Ljubljana. Ljubljana, pp. 1-23 (1986).

3. Dolenec T., Pezdič J., Herlec U., Kuščer D. and Mitrevski G. Ugotavljanje izvora vode v premogovnikih s pomočjo naravnih izotopov in drugih geokemičnih parametrov. Rudarsko - metalurški zbornik. Vol.36, pp. 521-546 (1989).

4. Epstein S. and Mayeda T.K. Variations of 18O contents of water from natural sources. Geochim. Cosmochim. Acta. Vol.4, pp.213-224 (1953).

5. Gat, J.R. The isotopes of hydrogen and oxygen in precipitation. Handbook of Environmental Isotope Geochemistry (Fritz, Fontes editors), pp. 21-47, Elsevier, Amsterdam (1980).