UNDERGROUND MINING ENGINEERING 31 (2017) 45-66 UDK 62
UNIVERSITY OF BELGRADE - FACULTY OF MINING AND GEOLOGY ISSN 03542904

Review paper

NINETY YEARS OF MINING AND METALLURGY IN TREPČA – SEVER CONGLOMERATE (PART II)

Branislav Nikolić[1], Slobodan Trajković[2], Sanja Bajić[2], Vesna Vujačić

Received: September 18, 2017 **Accepted:** December 10, 2017

Abstract: Present company Trepča-Sever is formed by foreigners after the bombing of Serbia and Montenegro in 1999, and it is a part of former Trepča Conglomerate located in northern part of Kosovo and Metohija, namely in three municpalities: North Kosovska Mitrovica, Zvečan and Leposavić. Main office of Trepča Conglomerate was always in Zvečan, flotation of lead-zinc ore (in the period of 1930-1985), lead smelting and refining plants (founded in 1939), laboratory, Institute, electromechanical workshops and other ancillary services. In Leposavić flotation, ores of Kopaonik mines are processed, while financial and commercial services are located in the North Kosovska Mitrovica

Keywords: Trepča; ore; reserves; production; processing; smelting plant; lead;

1 INTRODUCTION

Trepča mines in Stari Trg, as well as Kopaonik mines were also active in the Pre-Christian era, during the reign of the Nemanjić dynasty this activity was intensified, but after the arrival of the Turks, this production declined and completely ceased after the migration of Serbs in 1690 and 1735.

In the new state: Yugoslavia, the Englishmen purchase concessions in 1926, and in 1927 they form the company Trepča Mines Limited, which under that name existed until the end of the Second World War. In addition to the mine in Stari Trg, mines in Kišnica, Ajvalija (1930), Novo Brdo (1933), Kopaonik (1937) were activated, and the flotation of lead-zinc ore was built in Zvečan, and started to work in 1930. The smelting plant and lead refinery in Zvečan began operating in 1939 and in the next thirty years, the existing and new mining and metallurgical capacities were reconstructed several times.

The construction of the new flotation in Badovac was completed in 1968 and in Leposavić in 1972. After 1960, the processing industry in Trepča was also developed. Production of mineral fertilizers in Kosovska Mitrovica started in 1961, the Factory of lead-acid batteries in 1967 in Kosovska Mitrovica, and later Peć, then the Hunting Ammunition Factory in Srbica, the processing of silver in Prizren, etc.

[1] Faculty of Technical Sciences in Kos. Mitrovica
[2] University of Belgrade – Faculty of Mining and Geology
[3] Institute for Technology of Nuclear and Other Mineral Raw Materials, Belgrade
Emails: slobodantra@mts.rs;

After the division in 1999, Trepča-North located in the industrial circle in Zvečan, flotation in Leposavić and Kopaonik mines, i.e. part of Trepča north of Ibar River, and the rest of the mines, flotations and plants are located in Trepča-South.

2 MINING IN THE PERIOD FROM 1945 TO 2017

After the Second World War, all the mines became the property of the state and the plans of the new Yugoslavia occupy one of the leading positions in the production and processing of lead, zinc, precious and rare metals. In this part, the mines Trepča-Stari Trg, Belo Brdo and Crnac will be processed.

Trepča – Stari Trg Mine is located about 9 km northeast from Kosovska Mitrovica. Trepča ore region was known and active as early as the time of the medieval Serbian state, and later, when this area was ruled by the Turks. In the period of Austro-Turkish war (1683-1689) the mine was destroyed, so that any serious mining activity was ceased. After the Balkan wars, Nikola Pašić got concession on Kopaonik and Trepča mines. By the beginning of World War I and during the war, in these concessions nothing serious was done.

Geological view – Trepča deposit with the wider environment belongs to the Vardar zone with the direction of north-northwest and south-southeast. The deposit belongs to the hydrothermal - metasomatic type of deposit. Hydrothermal minerals are represented by sulphides, carbonates and oxides. The most important sulphides are: galenite, sphalerite, pyrochthine, pyrite, arsenopyrite, plumosite and others. Quartz, calcite, dolomite, rhodochrozite and others appear as supporting elements. The most economically important minerals are: galenite, which is in addition to lead, the main carrier of silver and bismuth, then sphalerite, as zinc mineral, contains about 0.2% of cadmium.

In the horizontal section, the deposit has a shape of a horseshoe, where they differ: the central ore body and the ore bodies connected to the south and north wing. The central ore body is connected to contact limestone - breccia and its surface ranges from 2.000-10.000 m^2, while the ore bodies on the south and north wing are connected to contact limestone - shale and their surface is under 2.000 m^2. The decline of the central ore body is 40-45°, while in the south is 60-70°, and in the north 30-40°.

Mine Opening Structures - Depending on the configuration of the terrain, the level of research, as well as other factors, the Trepča mine in the Old Market has been opened in several stages. The higher parts of Trepča deposits (above the elevation of 760 m) are opened with adits at elevations of 865, 830, 795 and 760 m. Further research has shown that the deposits extend to the depth, which required the construction of an adit at the lowest elevation of 610 m (from Prvi Tunel settlement). For better ventilation and other needs from Prvi Tunel adit, at elevation of 610 m, a mine shaft was created to an elevation of 790 m.

Further exploratory depth borings were carried out from an adit at elevation of 610 m, with the finding that the ore body extends at least 300 m in depth. The opening of the lower parts of the deposit was done by the construction of four slopes, which were made inclined at 45°. By these slopes the horizons from I to VII were opened at elevations: 545, 485, 435, 375, 315 and 255 m. Over time, these slopes have become inadequate due to the proximity of some ore bodies, broken transport, and so on. For these reasons, in 1948, a new mine shaft for exporting at elevation of 772 m was constructed. In addition to the new window, there is also a blind shaft from V horizon to XI horizon. The blind shaft serves to deepen the new shaft for exporting as well as opening lower horizons.

Prvi tunel Adit – it is constructed at an elevation of + 610 m and represents the horizontal connection of the pit with its surface. The total length of the adit is 2,660 m. It was partially completed with a concrete support as well as with a metal arch. The free surface of the cross-section is 5.5 m^2. It serves for the dewatering of the pit, the entry of fresh wind current, the supply of materials, and since 1985 for transporting ore from the pit to the flotation in Prvi Tunel.

Staro okno – it was made from an elevation of +790 m to an elevation of +610 m of total depth of 180.0 m. The shaft had a section of rectangular intersection, measuring 4,6 x 2,3 m with a timber support. By building other pit facilities, this shaft is used for ventilation and as a second exit.

Downcasts – since the Old Shaft has reached the floor limestone with its bottom portion, in order to open lower horizons, it was necessary to execute three downcasts starting from level + 610 m. Downcast I was used to extract the ore up to the first horizon on level + 610, downcast II was used for descent into the pit and for delivery of the materials, and finally downcast III was used for opening lower horizons and drainage. Downcast IV started from the horizon V (level + 375 m) and it was used for ventilation and removal of waste rock in the period when lower horizons were opened.

New Production Shaft – it was executed from level +772 m on the surface, to level +15 m on the horizon XI, in total depth of 757.0 m. The shaft has a circular section with the diameter of 5.5 m and concrete lining. The shaft has three compartments: a compartment with two two-level cages; a compartment with two skips and a manway. Aside from these compartments, the shaft also includes a space for pipeline and cables. Basic function of the new production shaft: transport of miners into the pit, extraction of ore, introduction of fresh air current and supplying the pit with material. Extraction of ore from the bunker on horizon IX up to the surface was performed by two skips, each with the capacity to carry 5.5 t of ore. Since 1985, the extraction is cut short and reaches the horizon I, i.e. adit Prvi Tunel, and from this point the ore is transported to the newly built flotation plant in the First Tunnel.

Up to horizon VII, the shaft was built from the surface downwards and by constructing downcasts. Additional deepening of the shaft was performed through a blind shaft. The

bland shaft was constructed from horizon V to horizon XIII. Construction of extraction shaft with the help of a blind shaft (for the depth of 120 m – two horizons) was performed by executing the excavation (chute) with the diameter of 2 m in the middle of the shaft first (from the bottom upwards) and then the widening of such excavation was performed from the top downwards until the full excavation profile had been achieved. Deepening of production shaft from horizon IX to horizon XI was performed in the period from 1977 to 1978 (Trajković et al, 2010)

Figure 1 shows the vertical section of the lead and zinc mine Trepča – Stari Trg mine pit.

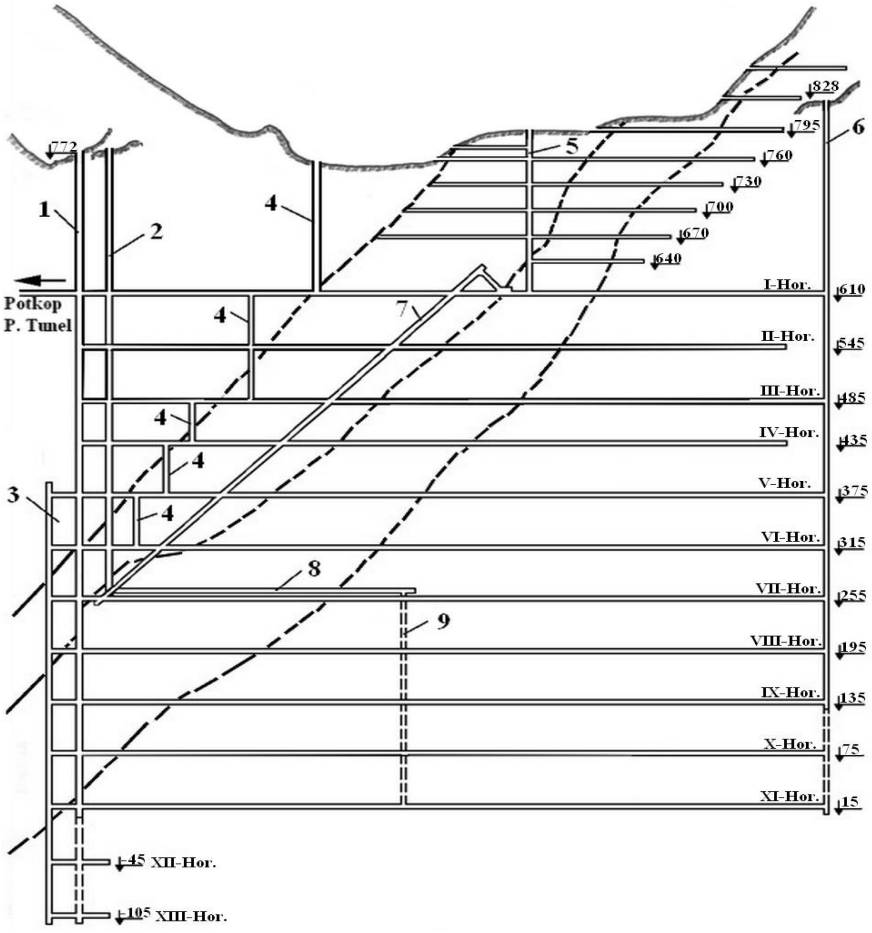

Figure 1 Vertical section of the lead and zinc mine Trepča – Stari Trg mine pit: 1- Main Extraction Shaft; 2- New Ventilation Shaft; 3- Blind Shaft; 4- Old Ventilation Shaft; 5- Old Extraction Shaft; 6- Service Shaft; 7- Downcasts No.1, 2, 3 and 4; 8- Ventilation Corridor; 9- Newly Designed Ventilation Shaft

Blind Shaft – It is constructed from level +375 m, horizon V, to level -105 m on horizon XIII. The shaft has a circular section with the diameter of 3.0 m and concrete lining. The shaft has a cage compartment, a compartment containing counterweight and a manway. On horizon V, the blind shaft has a room for extraction equipment and a clear height and depth of 15-20 m.

Northern Service Shaft – It is constructed from level +831.4 m to level 135.0 m on horizon IX. The shaft has a circular section with the diameter of 5.0 m and concrete lining 40 cm thick. The shaft has a two-level cage, counterweight and a manway. The shaft serves to: introduce the fresh air, provide a point for regular access of employees to the northern section of pit and provide a point for lowering and extracting material from the pit.

Based on bore pits the shaft passes through the following: from the surface level 831.4 down to level 505.0 it passes through slate; from level 505.0 to level 475.0 the shaft passes through limestone and then once more we encounter the slate which reaches the level of 285.0 m. From level 285.0 down to level 135.0, the shaft is constructed through a compact limestone of the Stari Trg's series (Dimić, 1975).

Ventilation Shaft – following the concept of the mine development, the shaft was constructed in a broken line and contains three parts: top shaft section, bottom shaft section and ventilation – connection corridors.

I. Top Shaft Section – it has the following levels: on surface z_1 = 774.79 m; on horizon VII z_2= 259.70 m. Top Shaft Section is connected to pit premises through connection links made on: horizon I level 601.63 m and horizon IV level 432.50 m.

II. Bottom Shaft Section – it's located on horizon VII with the level: z_1 =+271.85 m and horizon XIII with the level z_2 = -105.0 m. Bottom Shaft Section is connected to pit premises through connection links: on horizon VII level + 252.93 m, horizon X level + 75.0 m and horizon XIII level – 105.0 m.

III. Ventilation Connection Corridors – they connect the top and bottom shaft sections on the level of horizon VII. The corridors are one above the other at a distance of 5.0 m, with the length of 2 x 328.3 = 656.6 m.

Such ventilation shaft concept is implemented only down to horizon IX.

Based on the samples taken from the bore pits and during the excavation works, it's evident that the shaft from the surface level +774.79 to level +605.0 m passes through soft phylites and slates. Between the horizon III and IV, the shaft passes through a tectonic zone manifested as breccia with the average coefficient of strength according to Protodyakonov's scale of 3.8. This tectonic zone stretches from the NW towards SE with the fall towards the NE at an angle of 70º. Starting from the level +428.0, very soft slates can be seen and the depth of this layer is 113.0 m. The last layer is made of very weak

limestone and slate (with the coefficient of strength between 5 and 7) and its thickness is 60.0 m.

Ventilation Shaft serves exclusively for removing the stale air from the pit. Its dimensions are sufficient for 250 m^3/s of air. The shaft has a circular section with the diameter of 6.0 m and concrete lining [4].

Mining Methods – In Trepča mine the following mining methods are applied:

- Square-set stoping in horizontal slices with stowing and leaving the safety pillars;
- Roof stoping in horizontal slices with stowing and leaving the safety pillars; and
- Sublevel caving method with roof caving.

The first method was used mainly for higher horizons (from horizon I-IV), the second one for lower horizons, while the third method was experimented with and was not approved. Roof stoping in horizontal slices with stowing and leaving the safety pillars is widely accepted especially when the safety concrete slab is not constructed in the phase of deposits undercutting. All mining from horizon VII downwards is performed without safety concrete slab.

Number of active excavations for each year varied depending on: applied plant and equipment, lack of spare parts, defects and structure of mining surfaces, contents of metals, subjective weaknesses and accidents and discrepancy between excavation and backfill, etc.

Overview of ore production in the period from 1945 – 1998, with the content of metal in the ore for mine Trepča– Stari Trg is given in Table 1 (Savić, 1999).

Table 1 Overview of ore production for mine Trepča – Stari Trg in the period from 1945 – 1998

No.	Year	Ore Qty(t)	Content of metal in the ore		No.	Year	Ore Qty(t)	Content of metal in the ore	
			Lead (%)	Zinc (%)				Lead (%)	Zinc (%)
1.	1945	119,457	7.9	9.0	28.	1972	599,236	5.3	3.8
2.	1946	430,377	6.8	9.4	29.	1973	609,256	5.1	3.5
3.	1947	486,635	6.9	5.0	30.	1974	631,111	4.8	3.1
4.	1948	533,573	7.2	5.5	31.	1975	636,937	4.7	3.2
5.	1949	694,266	6.6	4.9	32.	1976	658,437	4.4	3.3
6.	1950	665,201	6.5	4.7	33.	1977	671,758	4.3	3.2
7.	1951	625,785	7.3	4.3	34.	1978	601,805	4.5	3.9
8.	1952	574,831	6.9	4.3	35.	1979	674,801	4.5	2.8
9.	1953	537,566	6.8	4.2	36.	1980	688,418	3.8	2.7
10.	1954	510,539	6.9	3.0	37.	1981	695,047	3.8	2.3
11.	1955	558,598	6.8	3.7	38.	1982	628,237	3.6	2.3
12.	1956	576,233	7.6	4.2	39.	1983	664,366	3.4	2.3
13.	1957	561,727	7.0	4.0	40.	1984	702,718	2.97	1.92
14.	1958	573,152	6.9	4.0	41.	1985	686,770	3.05	1.86
15.	1959	593,397	7.0	4.1	42.	1986	647,078	2.75	1.77
16.	1960	602,162	6.7	3.6	43.	1987	636,935	3.24	2.19
17.	1961	605,594	6.5	3.9	44.	1988	571,618	3.18	1.89
18.	1962	623,934	6.5	3.8	45.	1989	368,573	3.27	2.09
19.	1963	621,817	6.4	4.1	46.	1990	204,570	3.44	1.92
20.	1964	629,503	6.3	3.8	47.	1991	206,489	3.55	2.27
21.	1965	571,766	6.1	4.1	48.	1992	134,946	3.09	2.11
22.	1966	545,727	5.7	3.9	49.	1993	48,612	2.69	2.10
23.	1967	596,103	5.6	3.6	50.	1994	32,475	2.28	2.57
24.	1968	584,670	5.6	4.0	51.	1995	125,761	2.66	2.77
25.	1969	607,162	5.4	3.8	52.	1996	181,009	2.95	3.77
26.	1970	610,403	5.3	3.9	53.	1997	257,888	2.71	3.27
27.	1971	602,564	5.3	3.9	54.	1998	311,315	3.10	3.07

2.1 Mines in the scope of Trepča – North

In the scope of Mining-metallurgy and chemical combine Trepča, in the year 1960, a new plant was established under the name: Mines of Kopaonik and Rogozna with Flotation in Leposavić. Flotation plant was constructed in Leposavić and in its vicinity four deposits of lead and zinc ore can be found: deposit Belo Brdo in the north, Žuta Prlina and Koporić in the northeast and deposit Crnac in the southeast.

Mines Belo Brdo, Žuta Prlina and Koporić are located on the south slopes of mountain Kopaonik and Crnac is on the east slopes of mountain Rogozna.

Mines Belo Brdo and Crnac were exploited even before the flotation in Leposavić was put into operation and their ore was processed in flotation in Zvečan. After flotation in Leposavić was constructed (1971/72), the exploitation of deposits Žuta Prlina and Koporić started.

2.1.1 Ore deposits on Rogozna and Kopaonik

Several significant deposits of lead-zinc ore was detected on mountain Rogozna such as: Crnac, Plakaonica, Lipovica, Kukavica, Brekinja, Leskova Glava, etc.

Mining activity in this region was recorded as early as in Middle Ages, as evidenced by many old works (adits, shafts, cuts) as well as the fortress of Old Ras city Galič in Sočanica.

During the Turkish occupation mining activity in this region suddenly stalled, only to be taken up again in the early 19 th century. In the period from 1927 to 1934, an English stock company „SELECTION TRUST LTD" once more initiated exploratory works and performed detailed geological mapping of the narrow areas of Crnac–Plakaonica and Belo Brdo. In the Plakaonica deposit, an old adit was opened and expanded, a shaft 90m deep was constructed and so was the adit beneath Zminjak in the north-south direction in the length of 20m.

Since 1957, geology department of Mining-metallurgy and chemical combine Trepča starts with more elaborate exploratory works on Rogozna. Narrow area of Crnac – Plakaonica was thoroughly surveyed and a geological map was made at ascale of 1:2500 (Rudarsko-metalurško-hemijski kombinat olova i cinka Trepča, 1974).

On southern slopes of Kopaonik mountain lead-zinc ore is extracted from the following deposits: Belo Brdo, Žuta Prlina and Koporić.

Detailed geological explorations of deposit Belo Brdo were performed around 1950 and the exploitation begun in 1962.

For deposit Žuta Prlina, geological explorations started in 1960 and the exploitation in 1970. In the immediate vicinity there's also deposit Koporić which was first exploited after the flotation in Leposavić was constructed.

Mineralogical and chemical composition of ore – is based on performed explorations which should be processed in flotation plant in Leposavić (Štrbić, 1975).

Mineral composition – mineralogical and microscopic analysis confirm that the basic ore material for each deposit site is as follows:

Deposit Žuta Prlina – pyrite, sphalerite, galena- primary; smithsonite and cerussite - secondary minerals;
Deposit Belo Brdo – pyrite, pyrrhotite, sphalerite, galena and arsenopyrite - as primary minerals;
Deposit Crnac – pyrite, sphalerite, ad galena - as primary minerals;
Deposit Koporić – galena, sphalerite, pyrite and marcasite - as primary; limonite, cerussite, anglesite and samsonite - as secondary.

Chemical composition – ores from deposit (exploration data from 1970) Žuta Prlina, Belo Brdo, Crnac and Koporić are given in Table 2.

Table 2 Chemical composition of ore from deposits Ž.Prlina, B.Brdo, Crnac and Koporić

Mine	Chemical composition, (%)									
	Pb	Zn	Fe	S	Cu	SiO_2	Al_2O_3	MgO	CaO	As
Ž.Prlina	6.68	4.65	19.90	16.10	0.03	29.48	2.74	4.00	0.02	-
B.Brdo	4.34	3.42	27.20	21.00	0.10	19.58	4.31	1.27	5.65	0.70
Crnac	7.50	5.28	14.50	13.54	0.02	31.55	9.20	2.80	7.42	-
Koporić	3.32	1.73	14.73	2.12	0.07	45.45	7.32	6.55	2.07	-

- The following is characteristic for ores from these mines:
- Žuta Prlina contains a significant portion of oxidation minerals of lead and zinc (0.95 – 1.12 %);
- Belo Brdo contains high proportion of iron and arsenic;
- Mine Crnac has elevated content of Al_2O_3 and CaO,
- Koporić contains high portion of oxidation minerals of lead and zinc and a high content of SiO_2,
- All four mines also contain significant amount of silver (approximately 60 – 80 g/t).

Mine „Belo Brdo“ – it is located in the central region of mountain Kopaonik, in the area beneath the mountain top Vojetin (level 1561 m), 3.5 km southeast from Suvo Rudište (level 2017 m). Deposit and mine Belo Brdo is in use ever since 1937, with occasional shorter or longer interruptions.

From Belo Brdo where loading and unloading stations, workshop and other mining facilities are located, the ore is transported to Lešak using 11.5 m long cableway. From Lešak to flotation in Leposavić the ore is transported by trucks. Belo Brdo is connected to Lešak by 20 km long asphalt road.

Hydrogeological and climatic conditions – Geomorphological area of central Kopaonik has all the characteristics of a high mountainous area with a very dramatic relief and steep valley sides. From the central Kopaonik area, streams and rivers dive towards the

western side as tributaries of the Ibar River, and on the eastern and northern sides towards the South and West Morava. The climate is mountainous with harsh and long winters.

Geology of Deposits – The geological structure of the deposits is characterized by rocks which differ by composition, structure and genesis, namely: *floor series of deposits, serpentine peridotites, sedimentation of Upper Cretaceous and volcanic rock.*

Belo Brdo ore deposit belongs to a group of Kopaonik lead-zinc deposits that are genetically and spatially related to tectonic and magmatic processes of tertiary age. These deposits are characterized by more or less the same mineralogical composition (FeS, FeS_2, PbS, ZnS, etc.), and differ in size, quality, structural and morphological types of ore bodies and lithological structure. Among the secondary minerals the following are found: chalcocite, covellite, argentite, pyrite, marcasite, cerussite, limonite and others. The most common is limonite, which is very often deposited in the clayey faults and cracks.

Mine Opening Structures–The mining activities start from several adits, namely: adit Belo Brdo at level +1000 m; adit Zaplanina at level +1235 m; adit no. 2 at level +1334 m; adit no. 3 at level +1379 and adit at level +1425 m. Adit Bećirovac at level +1105 m is made for opening the site Bićerovac.

From adit at level +1000 (horizon) to adit at level+1235 m, two blind shafts have been constructed, i.e. shaft no. 14 and 15. Blind shaft no. 14 is at a distance of 2,500 m from the entrance into the adit at level +1000 m and serves for occasional transport of man and materials, while the shaft no.15 is used for regular transport of people and material.

Both shafts have timber supports and are equipped with a cage and a counterweight. There were two skips for lowering the ore in the shaft no. 15, but after the central ore chute was constructed they were removed from the pit, thus increasing the capability of the shaft to introduce larger quantities of air.

The height of the pit is divided into horizons spaced at 50.0m, so that within the mining area of shaft no. 15 the following horizons are developed: horizon I at level k+1000 m; horizon II at level+1055 m; horizon III at level +1105 m; horizon IV at level +1155 m; horizon V at level +1195 m; horizon VI at level +1235 m; horizon VII at level +1285 m; horizon VIII at level +1334 m; horizon IX at level +1379 m; horizon X at level +1425 m.

The pit is divided into two mining areas, namely: upper and lower one. The upper area includes the works above the level of adit Zaplanina at level +1235m, while the lower mining area includes the works from extraction adit B.Brdo at level +1000 m up to the level of adit Zaplanina at +1235 m (Trifunović, 1977)

The Figure 2 shows the vertical section of Belo Brdo lead and zinc mine.

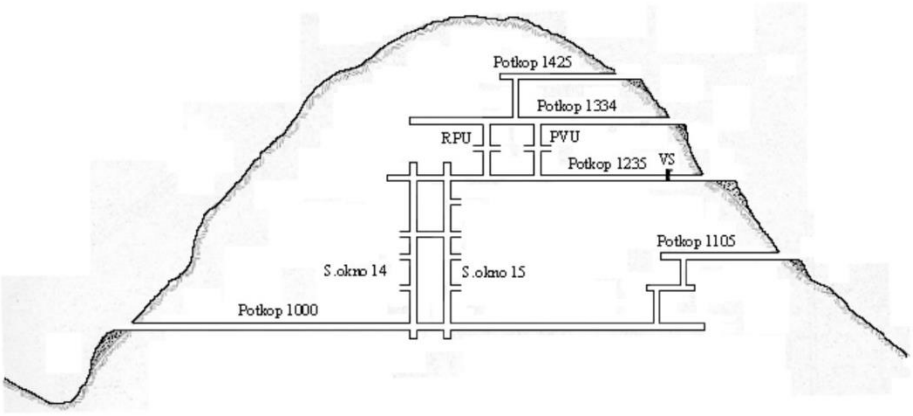

Figure 2 Vertical section of Belo Brdo lead and zinc mine

Mining Method – In B.Brdo mine the following mining methods are used:

- Horizontal roof undercutting from the bottom upwards with stowing of excavated areas and
- Transverse stoping method with stowing.

The first method is used in environments with favourable conditions, where adjoining rocks and ore are solid and compact. The second method is used for ore bodies where during excavation higher pressures are encountered and in environments where the ore is prone to caving, the overburden is cracked and clayey and when excavating the last levels below the adit of the higher horizon.

The Table 3 gives the overview of ore production, preparatory and exploratory corridors and raises for the period between 1966 and 1977 (Trifunović, 1977)

Table 3 Overview of ore production, preparatory and exploratory corridors and raises in B.Brdo mine

No.	Year	Ore Qty (t)	Preparatory and Exploratory		No.	Year	Ore Qty (t)	Preparatory and Exploratory	
			corridors (m)	Raises (m)				corridors (m)	Raises (m)
1.	1966	90,523	1,153	208	7.	1972	94,522	2,133	129
2.	1967	91,396	1,206	311	8.	1973	102,771	1,583	469
3.	1968	94,000	1,204	266	9.	1974	102,912	679	275
4.	1969	95,788	1,009	357	10.	1975	96,989	1,234	386
5.	1970	88,958	1,181	294	11.	1976	99,989	1,014	346
6.	1971	87,614	1,485	126	12.	1977	111,054	982	268

Crnac Mine – It is located in central region of mountain Rogozna approximately 15 km from Leposavić. It is situated in the valley of Crnačka reka, left tributary of River Ibar. The altitude of the Mine Crnac is relatively small, from 600 to 900 m.

Mine Opening Structures – In 1957, geology department of mine Trepča initiated more comprehensive exploratory works in this region, especially on sites Crnac and Plakaonica. Exploratory boring and mining explorations were performed. With the established reserves of 743,079 tons of ore, activities on the exploitation of Crnac deposit started. Opening of Crnac Mine was performed in two phases. The first phase covers the period from 1957 to 1968, with the level above 862.0 m, and the second phase covers the period from 1968 to 1980 from level 610.0 m – Gnježdanski adit (Milentijević et al., 2015).

Above the level 862.0 m Crnac deposit was opened by an adit system, which simultaneously represented the horizon levels, namely: horizon 0 at level 1.062.0 m; horizon I at level 996.2 m; horizon II at level 944.7 m; horizon III at level 902.0 m and horizon IV at level 862.0 m.

Opening of deposit beneath the level 862.0 m was executed by constructing Gnježdanski adit at the level 610.0 m, 3,781 m long. A blind shaft was constructed from Gnježdanski adit up to the level 862.0 m and five horizons were made from it: horizon V at level 818.0 m; horizon VI at level 768.0 m; horizon VII at level 718.0 m; horizon VIII at level 668.0 m and horizon IX at level 609.89 m (Milentijević et al., 2015).

Mining Method – In mine Crnac, the following mining methods are applied:

- Horizontal roof undercutting from the bottom upwards with stowing of excavated areas;
- Variant of horizontal roof stoping with spontaneous stowing
- Sublevel stoping method in open pit.

The production of the mine was constantly growing, so in 1987 it reached 68,047 t containing 5.05% of lead and 2.82% of zinc. In the coming years, production varied and ranged from 80,000 to 90,000 tonnes, with a slight drop in the ore metal content. In the period from 1979 to 1991, the exploitation was also carried out at the site Kaluđer, where approximately 160,000 t of ore was extracted with the lead and zinc content of approximately 4%.

Table 4 gives an overview of lead and zinc ore production for mines Kopaonik – Leposavić for period between 1988 and 1999 (Trajković et al., 2010).

Table 4 Overview of lead and zinc ore production for mine Kopaonik – Leposavić

Year	Ore Qty (t)	Metal content in ore			Year	Ore Qty (t)	Metal content in ore		
		Pb (%)	Zn (%)	Ag (g/t)			Pb (%)	Zn (%)	Ag (g/t)
1988	265,031	3.37	2.24	44.0	1994	13,663	3.96	2.54	56.0
1989	237,028	3.22	2.27	38.0	1995	86,000	-	-	-
1990	217,755	3.30	2.04	43.0	1996	111,000	-	-	-
1991	105,322	4.53	3.15	53.0	1997	139,000	-	-	-
1992	64,983	3.30	2.12	44.0	1998	178,000	-	-	-
1993	26,437	4.48	2.77	59.0	1999	106,000	-	-	-

The extracted ore in mines Trepča – North, production was as follows for each year:

2006 ..... 82,000 t 2011 ..... 180,000 t

2012 ..... 160,000 t 2013 ..... 198,000 t

2014 ..... 205,000 t 2015 ..... 135,000 t.

More complete data for the period after the year 2000, for the mines Trepčas-North, were not available to us, so for these reasons we are not able to show them.

3 FLOTATION PLANTS

In the scope of Mining-metallurgy and chemical combine Trepča, the organization was conceived in such a manner so that each mine or a group of mines has an appropriate flotation plant. Such an organization (starting from 1974 onwards) constituted the following production and processing units: OOUR (Basic Organization of Associated Labour) Mine and Flotation Trepča – Stari Trg; OOUR Mine and Flotation Kišnica and Novo Brdo – Priština; OOUR Mine and Flotation Kopaonik – Leposavić; OOUR Mine and Flotation Lece – Medveđa; OOUR Mine Rudnik – G.Milanovac and OOUR Mine and Flotation Blagodat – Vranje (Rudarsko-metalurško-hemijski kombinat olova i cinka Trepča, 1974).

Flotation Plant Zvečan – It is located in the industrial complex of the combine Trepča-Zvečan. The trial production of the concentrate in the flotation plant in Zvečan began on August 17, 1930 with a capacity of 500 t/day. The plant was used for processing the ore from the mine Trepča – Stari Trg, which was transported to plant by a 6.350 m long cableway.

The capacity of the plant in Zvečan was continuously growing, so in the 80's of the 20th century tha capacity was 3,500 t/day.

As other mines were opened (Belo Brdo, Novo Brdo, Ajavalija, Kišnica, Crnac and others), the ore was transported and processed in Zvečan flotation. By 1973, Zvečan flotation processed 24,000,000 tons of ore, with an average content of Pb + Zn of 11.9%.

In Zvečan Flotation Plant, the following concentration methods were applied:

- selective flotation of lead, zinc and pyrite minerals;
- magnetic separation of pyrrhotite.

Facility for magnetic concentration of pyrrhotite was constructed in 1963 with the capacity of 1,500 t/day.

Flotation of lead minerals is performed according to Sheridan-Griswold method in basic environment at pH = 8.5 – 8.8. The flotation process is carried out in Denver-Fahrenwald mechanical flotation machines with 16 cells, each cell with a volume of 1.08 m^3.

In recent years, the lead concentrate obtained in Zvečan Flotation contained 70-75% Pb, and before 1945, it contained 75-80% of Pb, because as the time went by the percentage of metals in the ore decreased.

Flotation of zinc minerals is carried out in the basic environment, at pulp value of pH = 10-11. The flotation process is performed in Denver-Fahrenwald mechanical flotation machines with 16 cells.

After construction of the flotation plant in the First Tunnel in 1985, Zvečan flotation was closed. The area where Zvečan flotation used to be located was cleaned and prepared for the expansion of metallurgical and other capacities. The cable car for ore supply Stari Trg - Zvečan was dismantled in 1996.

Flotation tailings were deposited in two locations along the Ibar River:

- Tailing Gornje Polje is located between Topionica and Kosovska Mitrovica on the right bank of river Ibar. It was active in the period from 1932 to 1962 with the surface area of 50 acres and the quantity of $12x10^6$ t of tailing;
- Tailing Žitkovac is located on the left bank of river Ibar at a distance of approx. 1.5 km from flotation Zvečan. It was active from 1962 to 1974, with the surface area of 26 acres and a quantity of $8,5x10^6$ tonnes of tailing.

These tailings contain: 14-25 % Fe; 8-12 % S; 18-30% SiO_2; 0,3-0,4 % Pb, approx. 0,3 % Zn,etc.

Aside from the abovementioned, there's a third tailing Žarkov potok. It was formed for depositing tailing from the newly built flotation in the First Tunnel (1985). The tailing is situated at approx. 1.0 km from the tailing Gornje Polje. For the receipt of the tailings

from the flotation in the First Tunnel, an 87 m high dam was built creating a space for receiving 8.200.000 m^3 of tailing. A portion of the tailing is used for backfilling (hydro-filling) of the cut in mine pit Trepča – StariTrg [10].

Transport of tailing from flotation in the First Tunnel to location Žarkov potok is performed through two pipelines (one active and one backup) with the diameter of 125.0 mm, placed in the tunnel 1,676.0 m long. The tunnel has a clear width of 2.16 m and a height of 2.2 m, with a height of arch radius R_1= 1.495 m and R_2 = 0.566 m. Along the entire length of the tunnel, 600 wide tracks are placed using 22,12 kg/m' rails and the fall of 2,5 ‰.

After revitalization and landscaping, these tailings can be used for many structures with light constructions: sports fields, garages, warehouses, workshops, etc.

Flotation Plant Leposavić – It is located in Leposavić, 30 km north of Zvečan, next to the main road Kosovska Mitrovica – Raška. In the immediate vicinity of the flotation plant there are four mines of lead-zinc ore: in the north deposit B.Brdo (26 km); in the norteast deposit Žuta Prlina (18 km) and Koporić (12 km); and in the southeast deposit Crnac (12 km).

Before the flotation plant in Leposavić was put into operation, the ore from Belo Brdo and Crnac mines was processed in flotation Zvečan. Activities in mines Žuta Prlina and Koporić started when the flotation in Leposavić was constructed (1971/72), so the ore from these four mines was processed in flotation in Leposavić.

Basic purpose of constructing the flotation plant in Leposavić is to shorten the transport distance of the ore from the surrounding mines to flotation plant in Zvečan by some 30 km, as well as to achieve the highest possible utilization of ore from these deposits, through the use of technologically advanced flotation plant.

Within the scope of flotation plant, a semi-industrial facility has been built which enables better determination and continuous control of the parameters of the technological process. For flotation of lead and zinc minerals, flotation cells with air insufflation have been installed; the cell type is PPM-GMO-1.6, they were built in Russia and were used in our country for this type of ore for the first time. In some phases of the technological process, automatic control and regulation was introduced.

Primary crushing of ore from the mines Žuta Prlina, Koporić and Belo Brdo is performed in separate plants built within the mines, while the ore from the mine Crnac is primarily crushed in plants that were built as part of flotation plant Leposavić. Secondary crushing is carried out in joint plants, for each ore separately.

According to the design documentation, the daily processing capacity of the flotation plant is 1,300 t/day or 490,000 t/year.

In 1974, in the flotation Leposavić, the results achieved in the processing of ore are shown for Crnac mine in Table 5. and for Belo Brdo mine in Table 6 (Štrbić, 1975)

Table 5 Achieved results in processing of ore from mine Crnac in Flotation Leposavić

Product	T (%)	Pb (%)	Zn (%)	Ag (g/t)	Cd (g/t)	I Pb (%)	I Zn (%)	I Ag (%)	I Cd (%)
Ore	100.0	5.61	2.42	66	119	100.0	100.0	100.0	100.0
K/Pb	7.63	66.05	3.47	729	-	92.23	11.22	86.72	-
Pb Flow off	92.17	0.47	2.33	9	-	7.77	88.78	13.28	-
K/Zn	3.90	2.36	46.58	47	2667	1.64	74.99	2.82	87.12
Tailing	88.27	0.39	0.38	8	-	6.13	13.79	10.46	-

Table 6 Achieved results in processing of ore from mine Belo Brdo in Flotation Leposavić

Product	T (%)	Pb (%)	Zn (%)	Ag (g/t)	Cd (g/t)	I Pb (%)	I Zn (%)	I Ag (%)	I Cd (%)
Ore	100.0	4.22	3.06	70	185	100.0	100.0	100.0	100.0
K/Pb	5.40	63.22	3.22	896	-	80.84	5.68	68.66	-
Pb Flow off	94.60	0.85	3.05	23	-	19.16	94.32	31.34	-
K/Zn	5.01	2.94	46.03	47	2891	3.48	75.38	3.35	78.46
Tailing	89.59	0.74	0.65	22	-	15.68	18.94	27.99	-

In Leposavić flotation, 235,000 tons of Kopaonik ores were processed in 2015, and 205,000 tons in 2014. Tailings from the flotation are deposited in the bay on the right bank of the river Ibar, using a hydrocycolone. The hydrocyclone sand is used to upgrade the initial embankment of the tailing dam.

4 METALURGY OF LEAD AND SILVER (1945 - 1977)

In the first post-war years, since the recovery and development of domestic mines was evident, the further expansion of metallurgical capacities in Trepča - Zvečan has begun.

Three new tank furnaces were put into operation in 1949, and three more in 1950, so there were a total of 12 tank furnaces. Additionally, mechanical (bag) filters were increased from four to nine chambers (Author group, 1979).

Reduction of lead content in ore, even in concentrates, further complicated already strenuous work on producing the lead using tank furnaces. This called for processing the ore using the shaft furnaces, so in 1950, a kiln with an active surface of 1.5 x 15.0 = 22.5 m^2 and a rectangular type shaft furnace (later called "C") with the diameter in the zone of the tuyere of 1,3 x 1,4 = 5,8 m^2 were commissioned (Author group, 1979). Also, another shaft furnace was erected with the dia. of 0.09 m^2 as an addition to the existing one. The covered warehouse of raw materials was extended from 90 m to 180 m, the number of bunkers for batching increased to 16, and an *electrostatic precipitator* for roasting gases with the capacity of 20 Nm^3/s was erected (Author group, 1979).

In the refinery in 1949, three more boilers with a capacity of 280 t were made, and after the hall was expanded in 1950, four more boilers were installed which gives the total of 12, and the so-called „threeton" boilers are used to this day. For bismuth refining, 30, 15 and 5 t boilers were installed in 1950 and for silver refining, in 1951, a zinc distillation furnace Celje and another cupellation furnace were built (Rudarsko-metalurško-hemijski kombinat olova i cinka Trepča, 1974). This distillation furnace was replaced around 1960 by six retorted Faber du Four furnaces that still work.

The plant for*electrolysis of silver according* to a *Moebius*-type *process*was erected in 1954 and was put into operation in 1955, which significantly increased the production of silver and gold (Nikolić, 1999).

From 1947 to 1953, eight Zenica type (lignite powered) gas generators were manufactured, which meant that from that moment on the boilers were heated by generator gas instead of coal burning (Nikolić, 1999). The present lead refining procedure uses these gas generators, as well as silver electrolysis completed in 1955, and the first reverberatory furnace for processing of copper drosses was put into operation in 1947. Two chlorine tanks for bismuth refining were installed in 1955/56 (Nikolić, 1999). The chlorination of Pb-Bi alloys and bismuth products is significantly facilitated by the use of chlorine tanks, instead of chlorine barrels.

With the construction of these plants the annual capacity has grown to:

- 92.000 t of raw lead and 78.000 of refined lead, while
- Lead smelter and refinery had about 1,000 workers.

This capacity of the Refinery was mainly achieved before the major reconstruction in 1967, and asides from the refined lead, the following commercial products were obtained: various lead alloys, electrolytically refined silver, refined gold and bismuth, copper-lead matte and speiss.

In the period from 1965 to 1967, lead smelter has been reconstructed, modernized and significantly increased its capacity, and most important is the following (Author group, 1979; Nikolić, 1999).

- two small shaft furnaces were removed (each with 0,9 m^2) as well as tank furnaces;
- aside from the furnace C (5,8 m^2), two new shaft furnaces were erected, Port Piri type, with the capacity of 260 t of raw lead in 24 h;
- new agglomeration plant was built with the active surface of 2.5 x 32 = 80 m^2,
- new electrostatic *precipitator*for roasting gases rich in SO2 and five chamber bag filters;
- a plant for production of sulphuric acid from rich roasting gases has been built, 60.000 Nm^3/h with 5% SO_2.

With this increase in capacity, the annual projected capacity of the Smelter Plant was increased to 170,000 tons of raw lead, but this projected capacity of shaft furnaces was not reached until the end of 1974.

This was a triple increase in capacity and a reconstruction carried out simultaneously with the increase in production of raw lead: about 7,000 t per month, and in 1969 as much as 97,707 t.

The Trepča team that took over the production as well as Lurgi company experts failed to reach the projected capacity of the shaft furnaces and to put the sulphuric acid plant into continuous operation, and instead the roasting gases were released into the atmosphere, which is unacceptable from an environmental point of view due to the presence of sulphur dioxide.

The designed capacity of new shaft furnaces (one furnace 260 t/raw lead/24 h) was only achieved, and further maintained in day to day operation in the second half of 1974 and 1975, when the production was at its highest level in all those 60 years:

- 115,000 t of raw lead;
- 89,138 t of refined lead, 111.4 t of silver and 55.2 t of bismuth.

One of the main reasons for this increase in production is the change in the furnace batch with the view of changing the composition of shaft furnaces slag (the content of FeO is reduced). This new composition of slag (32-34% FeO, 18-20% CaO, 21-23% SiO2) was subsequently applied as well.

During this period, mining and metallurgical capacities were developed and production increased and it was decided to develop the manufacturing industry: battery factories were built in Kosovska Mitrovica and Peć, hunting ammunition factory in Srbica, expansion of silver processing plant in Prizren and similar. It was also decided to build a new lead refinery with complete processing of intermediate products, a new shaft furnace, waste batteries treatment plant, a new chimney (300 m) and the necessary supporting facilities, all for an annual capacity of 170,000 t of refined lead. The construction of these investment facilities began to intensify in 1977, after all funding was secured, even though investment programs were completed as early as in 1975.

5 METALLURGY OF LEAD (1977 - 2000)

Basic flaw of the old Lead Refinery was insufficient and incomplete processing of lead products, which is the main reason for the construction of a new Refinery with associated plants for the production of silver, gold, bismuth, S_b-P_b alloys and P_b-C_u matte.

In the new Refinery many modern technological operations are foreseen: supply of liquid lead, softening with air, vacuum dezincing, electrothermal processing of silver foam and copper drosses, electrolysis of P_b-B_i alloys instead of existing chlorine process and construction of filters for metallurgical gases. For this new Refinery probably over 80% of works are finished, but for many reasons it has not been completed yet.

The political events and disintegration of Yugoslavia prevented the completion of these investments, but the main facilities were built: a new shaft furnace, a 305-meter chimney, a new lead refinery, a waste batteries treatment plant. In 1985, the flotation plant in Zvečan was dismantled providing the space for the expansion of lead metallurgy.

The production of refined lead rapidly decreased starting from 1989, and was reduced to a mere 4,458 t in 1994 (Đokić, 1977). In the last eight years (1992-1999) only 125,785 t of refined lead was produced, while in the previous eight years (1984-1991) 548.770 t of refined and 658.2 t of electrolytically refined lead were produced.

After the end of the bombing of Serbia in 1999 and the arrival of international forces in Kosovo and Metohija, the head of UMNIK, Kouchner, passed the Decree on July 25, 1999, by which UMNIK „has jurisdiction over movable and immovable assets which are the property or are registered to FR of Yugoslavia or Republic of Serbia, on the territory of Kosovo“. Based on this Decree, the occupation of Trepča was carried out in August of 2000 and the operation of the Lead Smelter Plant was suspended and has not been restored until the present day.

Aside from certain intermediate products, lead deposited near the Smelting Plant and Refinery in Zvečan, on the old landfill of Gornje Polje flotation tailing, there's a stock of approximately 2.5 x 10^6 t of slag from the shaft furnaces containing 30-35% of Fe, cca. 12% of ZnO, 20-22 % of SiO_2, cca. 1,5 % of Pb, which can be processed („fuming“) or sold and treated as a secondary raw material.

The slag and the ash from the thermal power plant and other waste materials were deposited across the road from the thermal power plant on the hill in the village of Rudare. This is a problem because it endangers the main road and Ibar River.

Figure 3 provides a photograph of the industrial grounds in Zvečan after 1990.

Figure 3 Industrial grounds in Zvečan after the year 1990

6 PERIOD OF UNMIK JURISDICTION (2000 – 2017)

Metallurgy of lead Trepča (kiln, shaft furnaces, refinery of lead) ceased its operations in August 2000, and as described by Biljana Marinović in the daily newspaper „Politika" on April 28, 2011: Trepča was occupied on August 14, 2000, when in the early morning hours, approximately 900 KFOR soldiers surrounded and then blocked the operation of this complex in Zvečan, under the pretext that Trepča in its work did not comply with „ecological standards". British, French, Danish and Pakistani soldiers of KFOR participated in the occupation. First the lead smelter was invaded where mainly Serbs were employed, and then about 150 soldiers of the English royal regiment stormed the hotel Zvečan. Following the take-over of the industrial grounds, Trepča's administrative building was invaded. Bernard Kouchner, former head of UNMIK, made sure that this occupation is perceived as a completely legal act by passing his Decree in July 1999.

Kiln and shaft furnaces still do not work, and in the Refinery in the past fifteen years, only 1,000 to 1,500 tons of waste is refined per year, pieces of raw lead picked up from the industrial grounds. Over the past 17 years, only about 20,000 tons of lead have been refined.

It's paradoxical that doctor Kouchner didn't note the trafficking of human organs in Priština hospital he visited, yet he noticed that there is a risk of air pollution caused by

lead metallurgy plants with the most modern (electrostatic and sleeve Flakt) filters which further lead the metallurgical gases through a new 305 m high chimney before the purified gases are released into the atmosphere. The current facilities are depreciated due to age and idleness (idle time), the technologies progressed, so there's the dilemma of alternative solutions for the future work of the Lead Metallurgy Trepča.

7 CONCLUSION

In the first fifty years of operation (1945-1990), the lead and zinc ore mines, Flotation, Smelter and Refinery Trepča in Zvečan were among the leading Yugoslav production organizations and largely contributed to the economic and social development of the country. In the next ten years, the break-up of Yugoslavia, transition, subjective weaknesses, external influences and other factors negatively influenced the operation of these plants of combine Trepča. The foreign occupation which started in 1999 and the prohibition of the operation of these plants (other than active mines), which are closed for 17 years, led to a dilemma about the future work of these very important, strategic production organizations.

The foreign factor that contributed to the current situation should contribute to bringing the metallurgical production of lead, silver and other accompanying commercial products in Zvečan to a normal working state.

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