Chapter 4 Current State and Tasks of Mining Activities

4.1 Activities of Large Mines owned by RTB Bor

RTB Bor is located in the Bor District which is about 230km by road to the southeast of Belgrade. RTB Bor consists of three mining complexes: the Bor Copper Mine (RBB), the Majdanpek Copper Mine (RBM) and the Copper Smelter (TIR). The RBM is located in Majdanpek City, but the other two complexes are in Bor City.

Mining at RTB Bor dates back well over a century. RTB Bor started as an underground mine and has expanded underground operations, but it has also developed open pit mines in Bor, Majdanpek, Veliki Krivelj and Cerovo. In 1991, RTB Bor recorded its highest production for one year, 26.5 million tons. But it closed the Bor open pit in 1993 and the Cerovo open pit in 2002, and currently produces ores from only 3 mines: the Bor underground mine, and the Majdanpek and Veliki Krivelj open pits. Fig. 4.1 shows production trends at RTB Bor for the last 20 years.

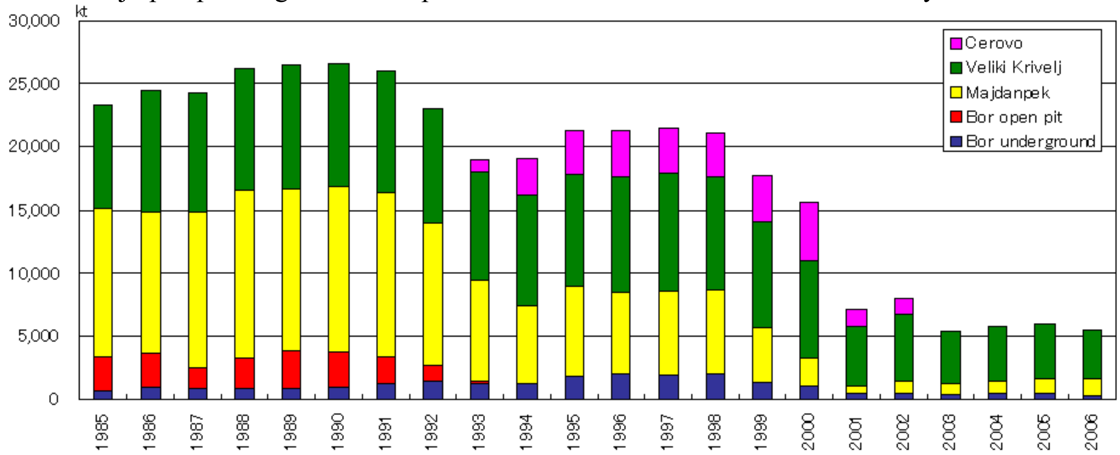


Fig.4.1 Production of the last 20 yrs at RTB Bor (source: RTB Bor)

Production dropped sharply in 1993 and 1999, as can be seen in Fig.3.18. It should be noted that Majdanpek used to account for the vast majority of production up to the early 1990s, but relinquished the lead to Veliki Krivelj in 1993. Production at Majdanpek began dropping sharply in 2001, and consequently total production of RTB Bor dropped dramatically, causing severe financial problems for the company. The state-owned mine RTB Bor has completed the procedure for full privatization, based on the restructuring and privatization strategy formulated in 2005. Official bidding was opened in 2006. The government negotiated with the top ranked bidder, Cuprom (Romania), but negotiations collapsed in May, 2007. The government is currently negotiating with the awarded Austrian company in the second tender.

Each mine is operated in three shifts/day, 365 days/year. The main mine facilities of RTB Bor in Bor City are shown in Fig.4.2. The organization chart of RBB is shown in Fig.4.3.

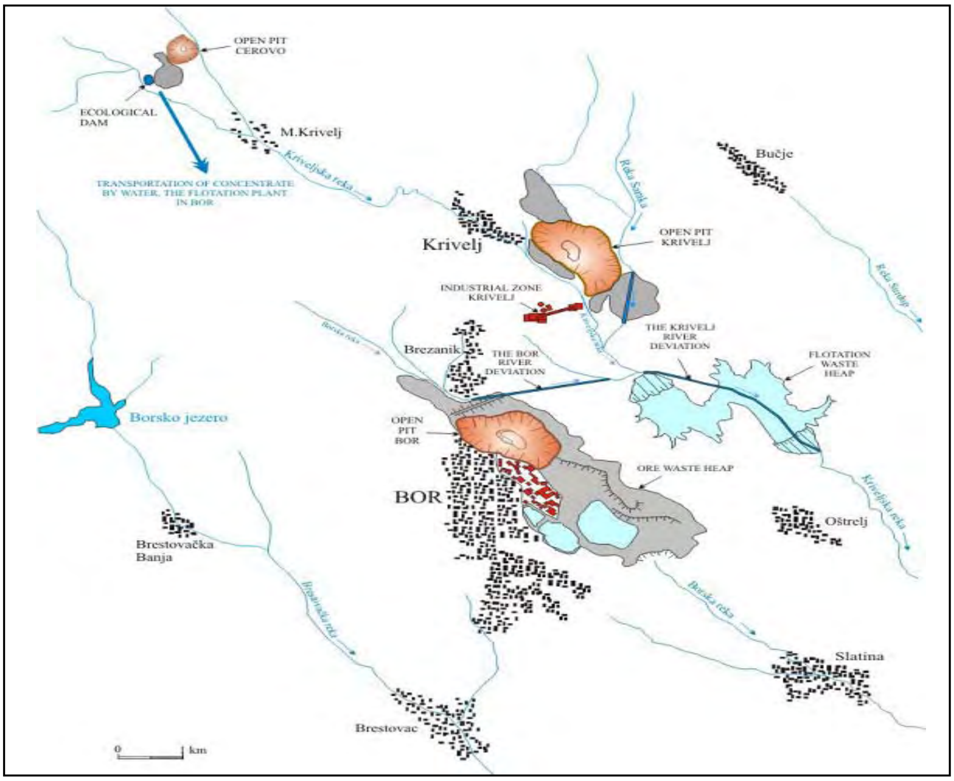


Fig.4.2 Layout of the Main Mine Facilities in Bor City (source: RTB Bor)

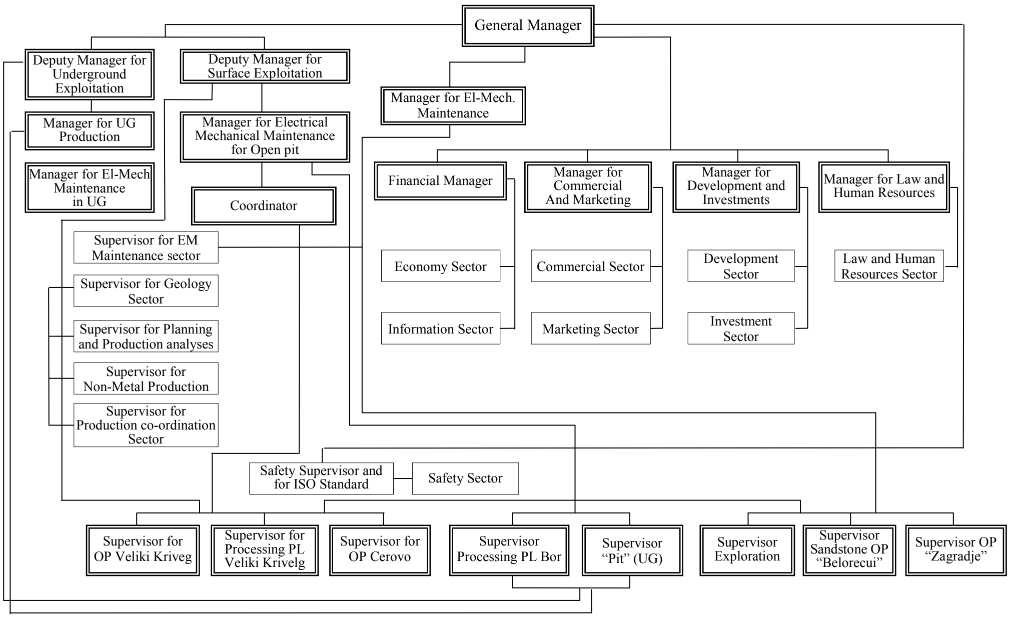


Fig.4.3 The Organization Chart of RBB (source: RTB Bor)

4.1.1 Bor Underground Mine

The history of the RTB Bor underground mine dates back to 1897 when first exploration was done in the Tilva Ros area by a French investor. The first production took place in 1904. In 1907, a new copper smelter began operation with a capacity of 60,000t/year. At that time, mined ore was very high in grade (approx. 9%), and was sent to the smelter directly as concentrate without ore processing. In 1933, an ore processing plant was built, one year after mining of low-grade ore started. The high-grade ore deposits were mined intermittently after that until they were exhausted in 1991. A total of 9.12 million tons of high-grade ore was mined, with an average grade of 6.2%Cu.

In 1993, the Bor open pit stopped operation because mining targets (Tilva Ros and P2A) were too deep. Since then, these ore bodies have become the principal ore sources for the underground mine. Exploitation of the Brezanik ore body, which is slightly distant from these two ore bodies, was begun in 1980. Peak production of the underground mine was 1.93 million tons in 1996, and remained at a level near that for the next 3 years. However, production began dropping in 1999, and by 2001 it had fallen to 470,000t. This was due to a shortage of parts for underground machines caused by economic sanctions. Fig.4.4 shows production of the underground since 1985. Sharp production declines in 1999 and 2001 are easily recognized. All production data are attached in the Appendix.

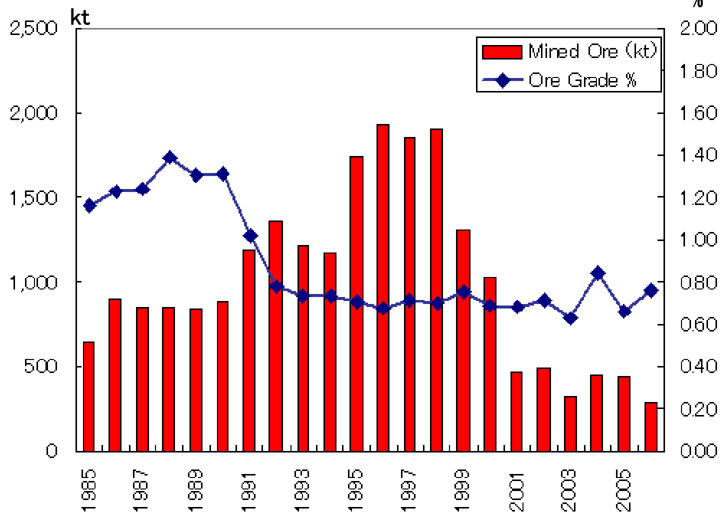


Fig.4.4 Production of the Bor Underground Mine

Fig.4.5 shows a schematic diagram of the current underground mine.

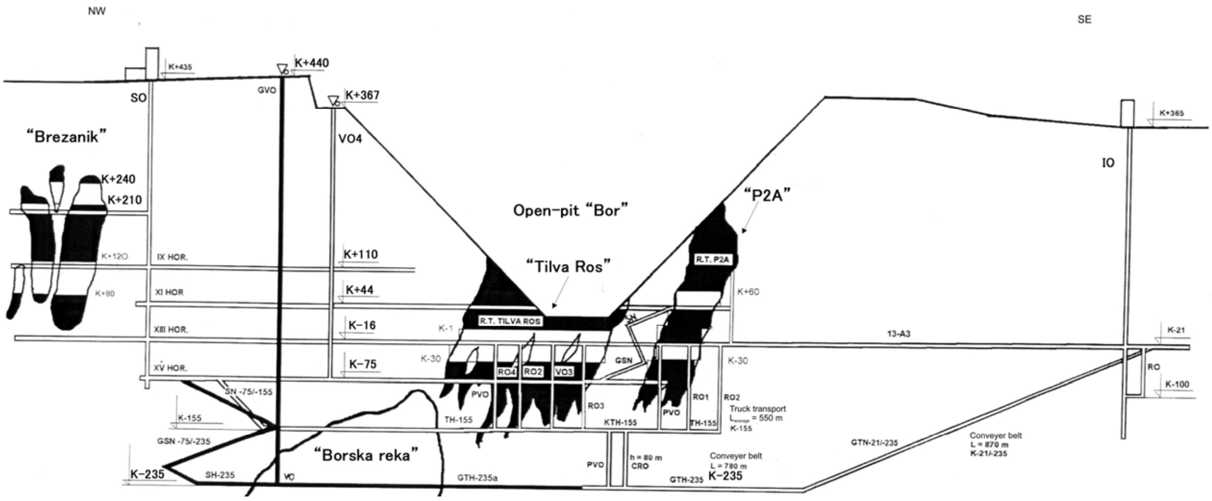


Fig.4.5 Schematic Diagram of the Bor Underground Mine (source: RTB Bor)

The main shaft (6.4m in diameter) runs between K+440mL and K-235mL, and a Koepe-type cage (capacity: 120 miners) runs between K+449mL to K-76mL (525m) to transport miners and materials in the underground. This shaft also provides lifelines such as ventilation, compressed air, electricity, water, etc.

The Bor underground mine introduced trackless system in 2003, when the underground tracks were removed. Regarding mining methods, sublevel caving is used at Tilva Ros and P2A, and cut and fill is used at Brezanik. The stope drift has a section of 4m (W)×3.5m (H), and haulage drift has a section of 5m (H)×3.5m (H). The main machines used underground are listed in Table 4.1.

Table 4.1 Main Machines used in the Bor Underground Mine (source: RTB Bor)

Type	Model	Manufacturer	Number	Year purchased	Note
Jumbo	MINIMATIK A 200M	TAMROK	1	1980	Compressed air
	MINIMATIK H207M	TAMROK	2	1984	Hydraulic
		MONOMATIK	1	1983	
	SIMBA H153	Atlas Copco	3	1990	
LHD	ST6C (9t)	Wagner	4	1990	For loading
	ST2DR (3t)	Wagner	2	1990	For service
Loader	CAVO320	Atlas Copco	2	1985	For loading
Truck	MT-420 (11m^3)	Wagner	2	2003	For transporting
	PK-6000	Normet	2	1983	

Underground machines are generally old. For example, some machines such as fans, feeders, belt conveyors, and pumps have been used for more than 30 years. Some heavy vehicles have been also used a long time; some drills for more than 20 years, LHDs for nearly 20 years. Such machines often break down due to mechanical troubles.

Ore in the P2A ore body is mined at the K0m Level and transported by ST6C to the R01 ore-pass, where it is dumped. Ore in the Tilva Ros ore body is mined at the K-30m Level and transported by ST6C and dumped in the R02 ore-pass. And ore in the Brezanik ore body is mined at the K+90m Level and transported and dumped by ST6C into the R03 ore-pass, and then removed at the K-13m Level to be transported and dumped by underground truck into the R04 ore-pass. Ores mined in these 3 ore bodies are extracted at the K-150m Level via several ore-passes to be transported and dumped by underground trucks into the underground ore-bin (capacity: 55m^3).

Ore is crushed mostly to under 150 mm by a primary crusher (Allis-Chalmers) installed in the K-150m Level. The crushed ore is then transported 755m horizontally by the belt conveyers at the K-235m Level, and then lifted 770m up to the K-16.5m Level by inclined belt conveyers to be crushed again to under 150 mm by another primary crusher (Allis-Chalmers type) made by Krupp, and sent to the ore bin. After the ore is weighed and loaded into the Koepe-type skip (capacity: 16t) installed at the K-100m Level, it is lifted about 500m up to the surface. The ore is then crushed to under 50mm by a secondary crusher (Symons) at the surface, and crushed to under 20mm by a tertiary crusher (Symons), after which it is sent to the processing plant by belt conveyers. The flow of ore from each stope is shown in Fig.4.6.

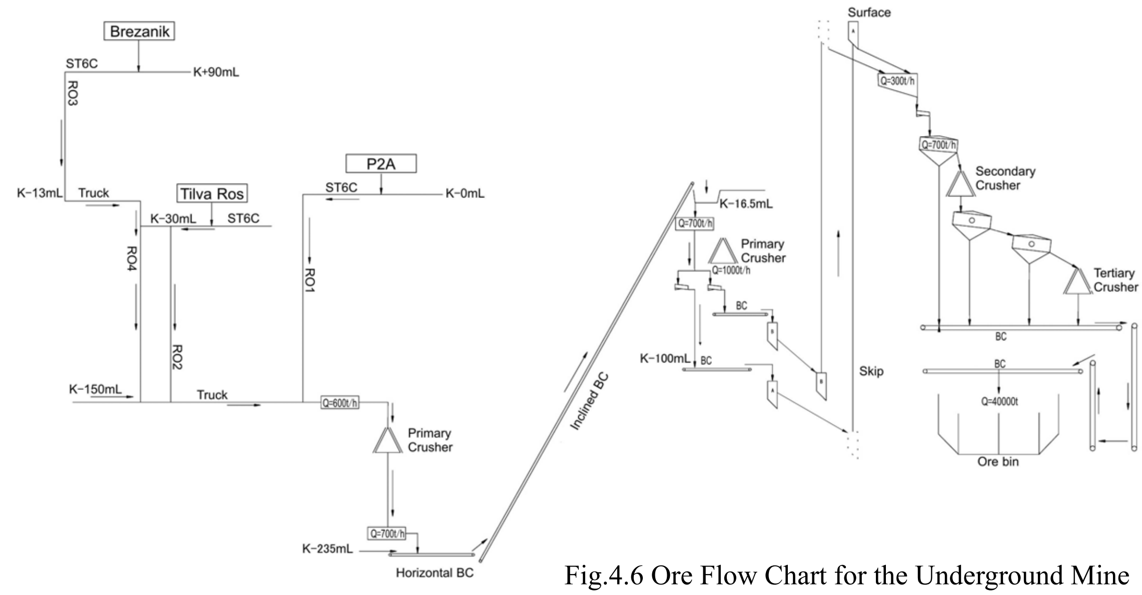


Fig.4.6 Ore Flow Chart for the Underground Mine

In Feb. 2007, an accident occurred in the Bor Underground Mine. The bottom broke due to heavy accumulated rain in the pit bottom of the former Bor Open Pit, and a large amount of water flowed into the Tilva Ros and P2A. A miner was killed and several miners were injured in the accident. Currently, neither mining area can produce ore because they are under water. Belgrade University is investigating the possibility of restoring the underground, however it seems it would be very difficult to reopen both mining areas.

Therefore, the Brezanik is presently the only underground mining area. The Brezanik mining area uses the Cut and Fill method with 3m slicing and filling as shown in Fig.4.7. The ore bodies are mined in two parts, leaving a horizontal safety pillar with a thickness of 10 m.

Fig. 4.7 shows schematic section of stopes in the Brezanik mining area.

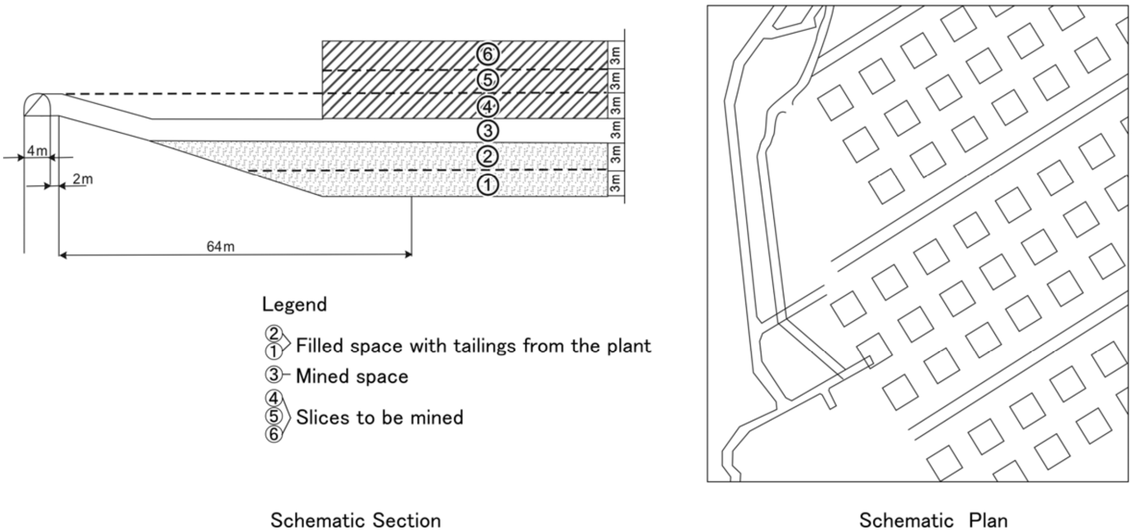


Fig.4.7 Cut and Fill Method in Brezanik

Several large fans provide ventilation that is required because of the diesel-powered machines used in the underground. Total inlet-volume is about 4,500m^3/min through the main inlet shafts (GVO and IO), and total exhaust volume is about 4,560m^3/min through the outlet shafts (VO4 and SO). A schematic diagram of the underground ventilation system is shown in Fig.4.8.

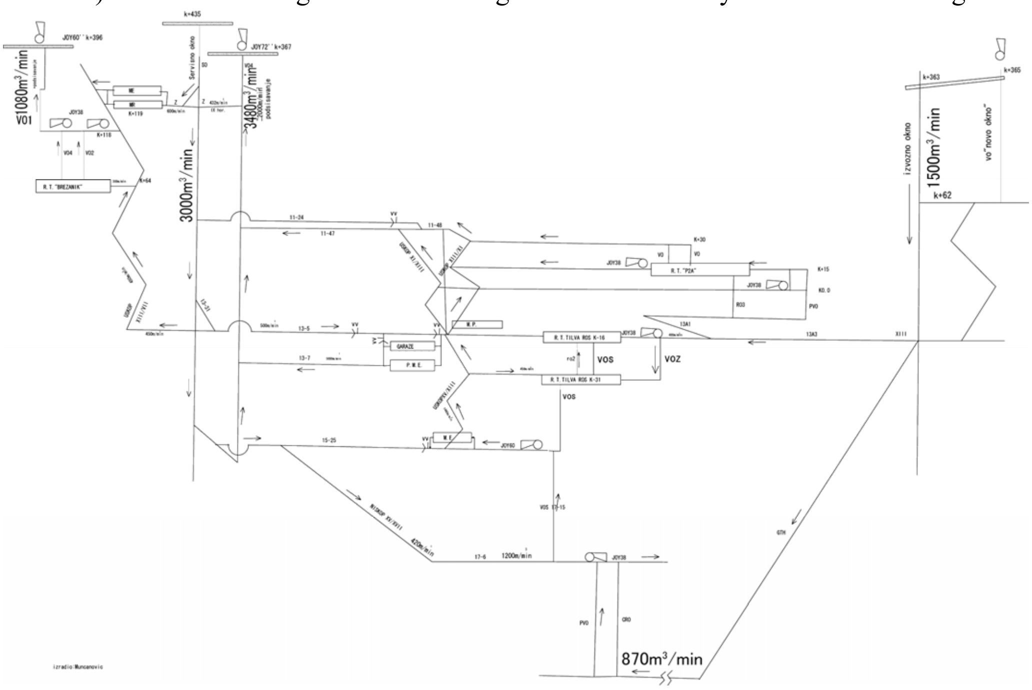


Fig.4.8 Schematic Diagram of Underground Ventilation

Underground operation is finely managed using various production and cost data, the same as in Western countries. Daily production information such as amounts of ore feeding to the plant, and amounts of ore transportation by skip and by underground tracks, is provided to the mining department for production and budget management. Weekly meetings are held in the mining department to determine countermeasures when the budget is not met. However, the leading cause of budget shortfalls is the low workability of superannuated machines, so there is no specific penalty for them. Table 4.2 shows a comparison of operation efficiency between 1996 (year of production peak) and 2003 (year of significantly reduced production).

Table 4.2 Comparison of Underground Operations in the Bor Mine in 1996 and 2003 (source: Bor)

Item		1996			2003		
		operation	workers	efficiency	operation	Workers	Efficiency
Mining	Brezanik	260,098t	22,896	11.36t/miner	29,111t	4,315	6.75t/miner
	Tilva & P2A	1,672,977t	18,960	88.24t/miner	294,674t	9,221	31.96t/miner
	total	1,933,075t	41,856	46.18t/miner	323,785t	13,536	23.92t/miner
Drifting		6,058m	12,900	0.47m/miner	1,464m	7,484	0.20m/miner
Investment		1,544m	9,694	0.16m/miner	1,559m	8,587	0.18m/miner
Transporting & crushing		1,933,075t	12,6446	152.88t/miner	323,785t	12,644	25.61t/miner
Grand total		1,933,075t	75,987	25.44t/miner	323,785t	42,251	7.66t/miner

According to this table, production in 2003 was only about one sixth of the 1996 level. This dramatic decrease was mainly due to the embargo on mining machine parts. Operation efficiency decreased in all areas, because of disruptions caused by inadequate machines. Painful situation of the mine operation can be easily understood. The amount of drifting also dropped, falling to one fourth because only a few machines could be used for production. Therefore, subsequent mining could be more difficult owing to the lack of mining preparation and exploration.

It should be noted that total mining efficiency of the Bor operations in 1996 was 36% lower than that of the Kamioka Mine, which was the most mechanized mine in Japan. Mining efficiency cannot be compared easily because mining conditions are not the same. However, it is likely to be one reason for the Bor to have not been depleted as much as Japanese mines. In underground operations, there is not a precise understanding of ore distribution.

4.1.2 Development of the Borska Reka Ore body

The Borska Reka is a gigantic ore body located near the Bor underground and Veliki Krivelj open pit, but it lies beneath the Bor underground mining levels. A plan for mining the ore body was formulated at Belgrade University in 1999, and a mining consultant contracted by the World Bank reviewed and analyzed the contents of the plan in 2005, with the following conclusions:

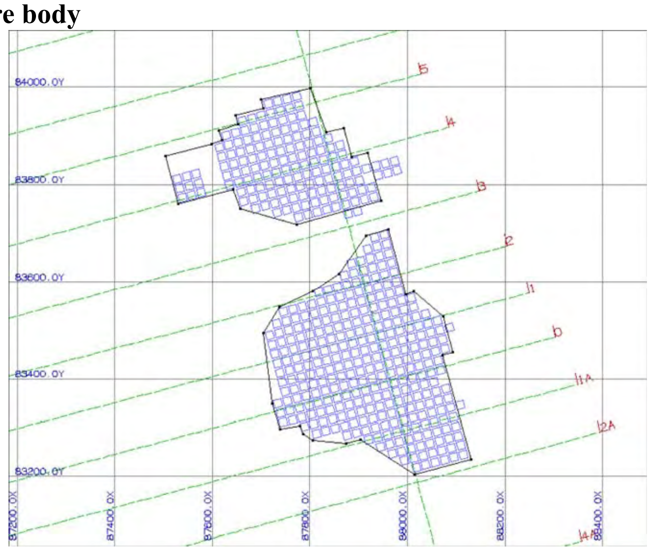


Fig.4.9 UCL Plan at -450mL Depicted by Gemcom

- ♦ It may be technically possible to mine some areas of the Borska Reka in a profitable way.
- ♦ Due to the geometry and characteristics of the ore body, block caving would be the preferable mining method, if not the only one.
- ♦ Due to the quantity and quality of the resource, a low investment scenario is recommended as a strategic approach to the project's analysis. Based on this, a scenario that uses the Veliki Krivelj flotation plant, conditioned for a 23,000t/day processing capacity (8.4 million t/year), has been developed.
- ♦ The mining reserves for this project are 131 million t (0.56% Cu and 0.23g/t Au). The relatively low-grade ores are quite sensitive to copper prices.
- ♦ The start-up period, including production ramp-up to over 3 years, is estimated to take 7 years to reach full production capacity.
- ♦ The potential profitability of the analyzed scenario has not been estimated, as it depends

strongly on some strategic decisions that are yet to be made by the RTB. Nevertheless, the project can be marginally profitable at a TC/RC of copper of around US$0.30.

- The mine manpower requirement is estimated to be approximately 350 workers. If other areas are included, the complete project may require 700 to 1,000 direct employees, plus another 700 to 1,000 contractors doing associated work.
- There are some areas in which the current information is weak, particularly regarding geo-mechanical conditions and hydro-geological characteristics at depth.
- Information about the project is not properly organized at this stage and may not be available for potential buyers.

The following recommendations have been derived from a World Bank study from the perspective of the privatization process:

- There are many tasks that can be undertaken, at low cost, with the current amount of information available, like:
    - Developing an RQD model from existing borehole values, based on interpretations of sections or plans of the available data.
    - Improving the quality of the analysis and documentation related with geotechnical characteristics of the deposit.
    - Developing a block model with a resource coding that follows Western standards.
    - Completing the block model validation as started in the report and improving the reliability of the figures.
    - Documenting precisely the block modeling process carried out by the RTB. This should be done following international standards.
    - Documenting the QA/QC procedures used in the sample preparation and assaying processes, including the analytical results. A part of this task, sample rejects should be systematically stored so that any potential buyer can access the rejects for internal validation.
    - Reviewing the flotation plant potential, from the perspective of a business plan oriented toward the selling of copper concentrate. This means analyzing the options to increase the concentrate grade to values close to 30%.
- The introduction of the deeper ore in the analysis may add interest to the project for some types of investors. From this perspective, it is recommended to bring the mine project to the next step, that is, analyzing in more detail the potential effect of mining the deeper ore, below -450mL. This will require the refining of the present project and the extension of it to the next UCL level, including the development of a rough mine plan.

4.1.3 Bor Open Pit Mine

The Bor Open Pit Mine was started in 1923, but stripping data did not exist until 1928. The grade of ore was somewhat higher, 7 to 4 %Cu, in those years. However, the grade gradually decreased, and has been less than 2%Cu since 1955. But, it appears that the Bor Open Pit had kept its grade somewhat higher than other open pits. The pit bottom reached the deep part of both deposits, P2A and Tilva Ros, in 1993, so the open pit was stopped due to the expansion of the stripping ratio, and both deposits began to be mined by the underground "Sublevel Caving" method. Production data for 1985 to 1993 are shown in Fig.4.10. All operational data are listed in the Appendix.

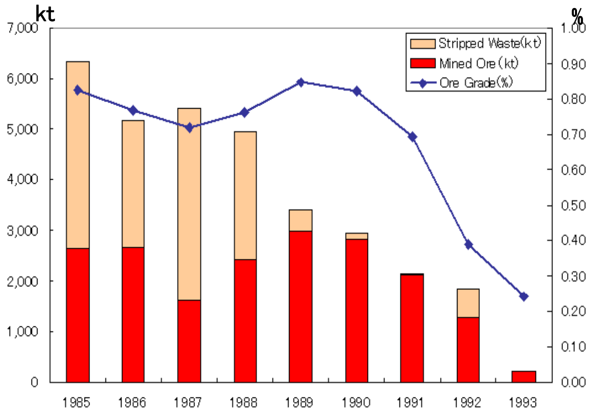


Fig.4.10 Operation Result of the Bor Open Pit

The total exploited rock mass from mine opening to closing was as follows:

Total ore 95,799,627t (Cu 1.4%) Total waste 171,176,926t (stripping ratio: 1.40)

4.1.4 Veliki Krivelj Open Pit Mine


Fig.4.11 Geological Section of the Veliki Krivelj

The first waste stripping in this mine was started in 1979, and the first ore production was begun as the 4th mine of RTB Bor in 1983. Annual production reached 9.6 million t in the 4th year after first production, and had been maintained at nearly the same level until 1998, when the economic sanctions began. Since 1999, mine production has decreased; in 2006, it was less than 4 million tons, which was about 40% of the peak. Ore grade was 0.5% Cu at the beginning, but it had decreased over time to 0.28% Cu in 2006. However, today it plays the lead role in production, accounting for 70% of the ore

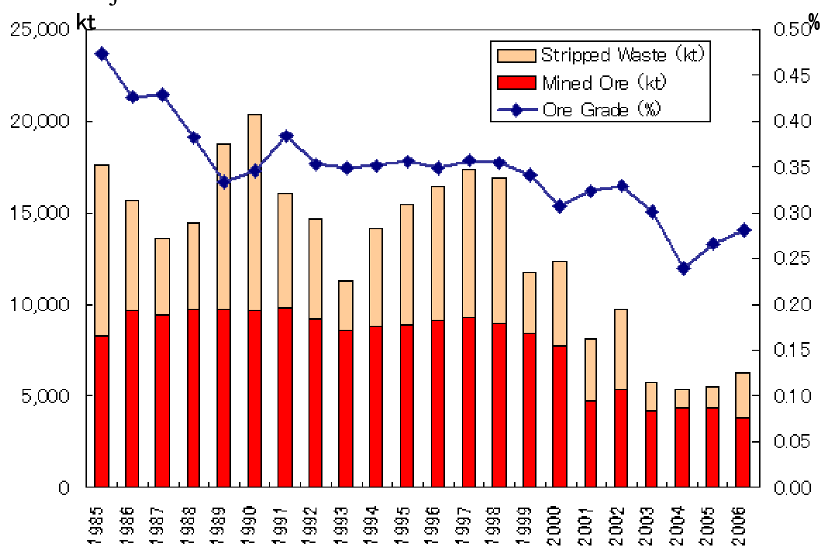


Fig.4.12 Operation Result of the Veliki Krivelj

produced at RTB Bor.

Fig.4.12 shows production data from Veliki Krivelj since 1985. All annual production data are listed in the Appendix. Here, declines due to economic sanctions can be recognized clearly in 1993 and 1999. Operations are managed by computers, using the three dimensional software, Gemcom, with input data of drilling (total length: about 160km) and surface surveying. Ore dilution is also managed well within 5% in comparison with the ore reserve calculation.

Table 4.3 shows a comparison of ore mass exploited from 1983 to 1992, and from 2003 to 2006. The earlier period (1983 to 1992) was a comparatively good period of operation, while the latter period (2003 to 2006) was far less favorable. Annual average of total mass removed declined to less than one third, and average stripped waste decreased to about one fifth. Accordingly, the stripping ratio decreased from 0.86 to 0.36. This indicates partially delayed stripping.

Table 4.3 Comparison of Exploited Mass in the Veliki Krivelj Open Pit

Period	Mined ore	Stripped waste	Total mass	Stripping ratio
1983 to 1992	84,852,005t	73,340,701t	158,192,706t	0.86
Annual average	8,485,201t	7,334,070t	15,819,271t	0.86
2003 to 2006	16,769,965t	6,080,445t	22,850,410t	0.36
Annual average	4,192,491t	1,520,111t	5,712,603t	0.36

The main reason for the recent delayed stripping is superannuated mining machines. Table 4.4 lists the principal mining machines in the pit.

There are some old machines which have been used for more than 20 years, and some machines with low availability.

Table 4.4 Principal Machines used in the Veliki Krivelj Open Pit (source: RTB Bor)

Machine	type	manufacturer	Yr. purchased	Note
Drills	BE 45 R	Bucyrus Erie	1969	Low working rate
	BE 45 R	Bucyrus Erie	1979	
	BE 45 R	Bucyrus Erie	1981	
Shovels	191 M (11.5m^3)	Marion	1970	
	191 M (11.5m^3)	Marion	2001	Low working rate
	PH 2100 (11.5m^3)	P&H	1978	
	PH 2100 (11.5m^3)	P&H	1981	
Dump Tracks	Euclid R 170 (170t)	Volvo	1984	
	MT-3600 (190t)	Terex	1994	
	MT-3600 (190t)	Terex	1994	
	MT-3600 (190t)	Terex	1994	Unworkable
	MT-3600 (190t)	Terex	1997	
	Euclid R 170 (170t)	Volvo	1997	
	Euclid R 170 (170t)	Volvo	1997	
	MT-3600 (190t)	Terex	2000	
	MT-3600 (190t)	Terex	2000	Unworkable
	MT-3600 (190t)	Terex	2000	Unworkable
	MT-3600 (190t)	Terex	2000	
Bulldozers	D 8K	Caterpillar	1981	Unworkable
	D 8L	Caterpillar	1990	Low working rate
	D 355-A	Komatsu	1987	
Grader	16 G	Caterpillar	1990	

Mining is currently operated in three pits, but they will be eventually merged into one pit. Fig.4.13 shows the final pit of the Veliki Krivelj.

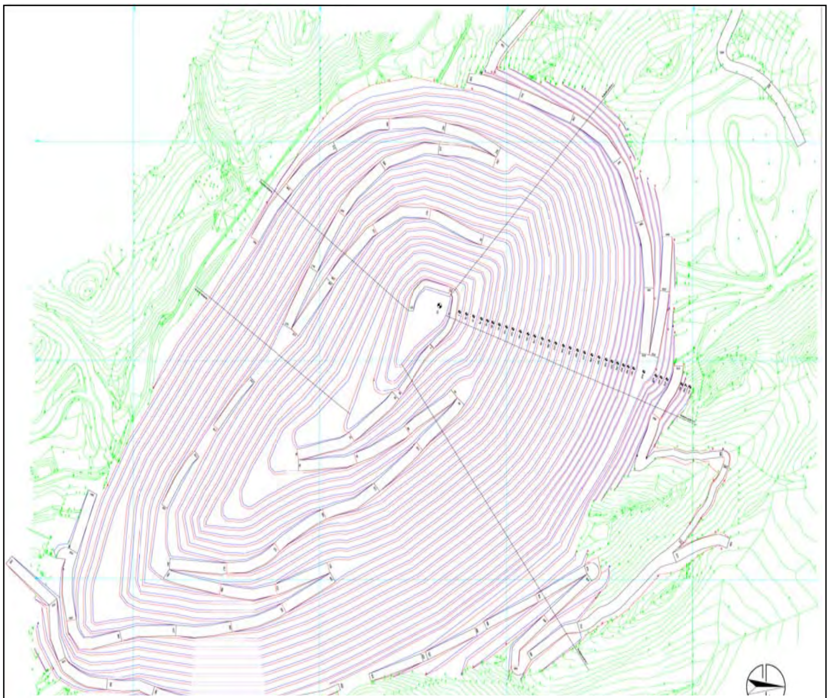


Fig.4.13 Final Pit Design of the Veliki Krivelj (source: RTB Bor)

Fig.4.14 shows a current section and plan of the partial pit. The final slope will be 41 degrees in the lower part and 39 degrees in the upper part. The safety factor is legally determined to be more than 1.3, and the final slope is calculated based on geo-mechanics. This final slope is sometimes lessened to 36 degrees in the weak parts such as faults, etc.

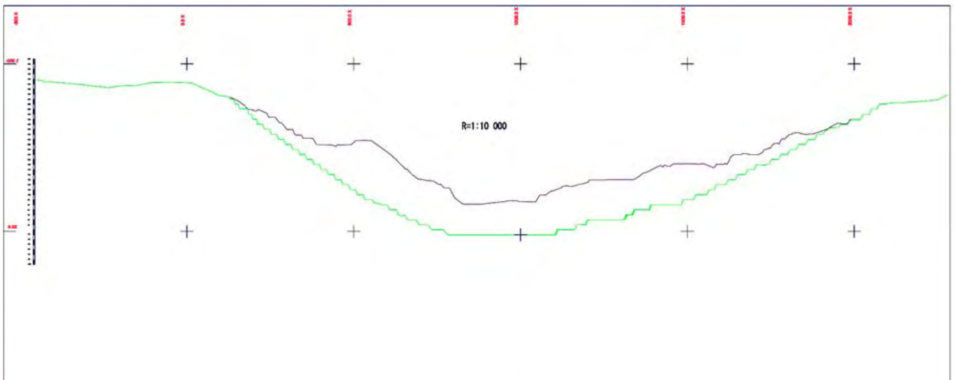


Fig.4.14 Comparison of Current and Plan Section of the Pit (source: RTB Bor)

It should be noted that RTB Bor has a 20-year long-term plan (2007 to 2026) prepared by the Copper Institute. According to the plan, stripping will be increased after 2007, and the stripping ratio will be increased to 1.54 by 2011 to compensate for the delayed stripping. Ore production will be increased to maintain a level of 8.5 million tons after 2010. This would entail increasing exploited mass 3.5 times from the current 5.7 million tons to 20 million tons. To achieve this, it is necessary to prepare mining machines including maintenance of current machines. The internal rate of return is very high, 67%, based on a copper price of $2,940/t.

Waste from the Veliki Krivelj is transported about 1km by dump trucks from benches of the pit to a crushing plant (Allis Chalmeris Emisa) which crushes waste to an adequate grain size. After crushing, the waste is transported by belt-conveyors to the Bor open pit where it is dumped by a stacker into the old pit.

4.1.5 Cerovo Open Pit Mine

The Cerovo open pit is located approximately 8 km to the north-east of the Veliki Krivelj Mine.

The Cerovo Open Pit Mine began stripping the initial burden in 1991, and started production in 1993 when the Bor open pit stopped operation. The Cerovo 1 finished its reserve in 2002. Total operation results are shown in Fig.4.15. The mined ore was sent to a crushing and milling plant (equipped with primary, second and tertiary Allis-Chalmers crushers) constructed in the 1980s at the mine site, and then transported in pulp form to the flotation plant of the Bor processing plant. Current remaining reserve may be up to 320 million tons with a grade of 0.3% Cu and 0.1g/tAu, which are the objective of privatization.

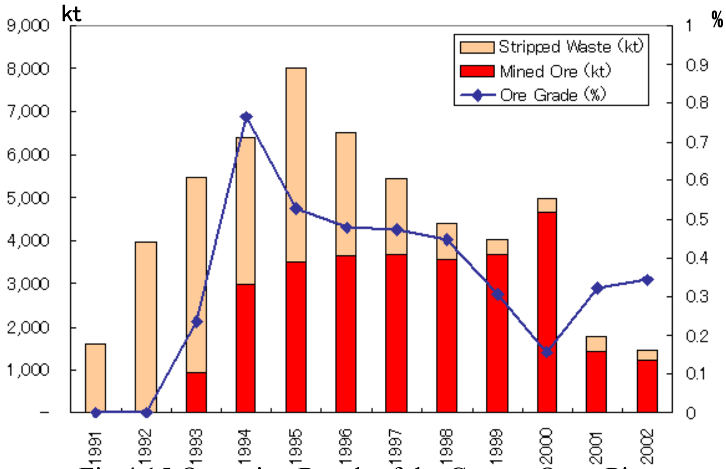


Fig.4.15 Operation Result of the Cerovo Open Pit

The Copper Mine Bor (RBB) was above described, and the RBB personnel was restructured according to the privatization strategy. Table 4.5 shows a comparison of personnel in January 2003, February 2007, and July 2007.

Table 4.5 Transition of RBB Personnel (source: RTB Bor)

Department	Jan. 2003	Feb. 2007	July 2007
Veliki Kreivelj Open Pit	516	405	396
Veliki Krivelj Plant	352	288	278
Cerovo Open Pit	124	11	13
Bor Underground	694	441	416
Bor Plant	342	230	225
Bor Repair Shop	128	87	87
Hydrometallurgy	48	29	34
Exploration	147	92	98
Administration	375	258	250
Zagradje Limestone	163	118	116
Bela Reka Silica Sand	72	67	66
Total	2,961	2026	1979

4.1.6 Slag Mining

Commercial metals from slag discharged from the Bor smelter have been recovered for the past several years by the TIR (see photo). Mining has been carried out by the TIR, but the RBB has taken the opportunity of stopped work in the underground operation of the Tilva Ros and P2A to study full open pit mining operation of slag. And a new operation plan for slag mining was submitted to the MEM.


Heaped slag to be mined

According to the plan, there are a total of 5 five-meter high benches. The elevation of the pit bottom is 310m and the highest bench elevation is more than 350m. The first 3 benches will be cut from the access road to the repair shop of the former Bor Open Pit.

The total amount of slag is about 9 million tons with about 66,000t of copper metal, 2,600kg of gold, and 41,000kg of silver. Ore reserves for each bench are listed in Table 4.6.

Table 4.6 Slag to be Mined

Benches	Slag (t)	Cu (%)	Cu (t)	Au (g/t)	Au (kg)	Ag (g/t)	Ag (kg)
365/350	1,318,973	0.715	9,431	0.28	372.0	4.50	5,935.4
350/340	3,061,392	0.715	21,889	0.28	863.3	4.50	13,776.3
340/332	1,277,730	0.715	9,136	0.28	360.3	4.50	5,749.8
330/330	1,465,830	0.715	10,481	0.28	413.4	4.50	6,596.2
320/320	1,330,959	0.715	9,516	0.28	375.3	4.50	5,989.3
320/310	736,056	0.715	5,623	0.28	207.6	4.50	3,312.3
Total	9,190,940	0.715	65,715	0.28	2,591.8	4.50	41,359.2

Miners for this slag mining will come from both underground mining areas; Tilva Ros and P2A. A total of 130 workers here and elsewhere will work in mining slag.

Mined slag will be treated through a flotation process, as previous test operations have shown this to be the best recovery method. Full scale operation of copper slag flotation is estimated in Table 4.7.

The slag flotation results for January to June 2007 are listed in Table 4.8 and show steadily increasing treatment amounts. Results for June were more than double those of January. This is already about 80% of estimated monthly treatment amount, 920,000t (1,112,000t/12months). Therefore, the monthly treatment amount estimates are expected to be met. Copper recovery has also improved monthly, and in June achieved a recovery rate of 39.492%. This will be improved to 45% in the near future, and eventually up to 50%.

Table 4.7 Estimated Flotation Operation Values

Item	Estimated value
Annual amount to be treated	1,112,400 t
Cu grade in slag	0.715 %
Au grade in slag	0.282 g/t
Ag grade in slag	4.5 g/t
Concentrate	219,050 t
Cu grade in concentrate	15.0 %
Cu recovery	50.0 %
Cu in concentrate	32,857 t
Au grade in concentrate	5.072 g/t
Au recovery	50.0 %
Au in concentrate	1,296 kg
Ag in concentrate	64.748 g/t
Ag recovery	40.0 %
Ag in concentrate	16,544 kg

Table 4.8 Achieved Slag Flotation Values

Month	Item	Value
Jan.	Treated Amount	33,258 t
	Cu grade	0.739 %
	Cu recovery	35.34 %
Feb.	Treated Amount	23,436 t
	Cu grade	0.702 %
	Cu recovery	35.267 %
Mar.	Treated Amount	32,001 t
	Cu grade	0.793 %
	Cu recovery	35.517 %
Apr.	Treated Amount	46,407 t
	Cu grade	0.737 %
	Cu recovery	35.777 %
May	Treated Amount	39,514 t
	Cu grade	0.718 %
	Cu recovery	36.283 %
Jun.	Treated Amount	70,495 t
	Cu grade	0.719 %
	Cu recovery	39.492 %

The total operating cost is estimated to be US$6.57/t, 1.77/t for mining costs and US$4.8/t for processing costs. It will be possible to recover the total investment of about US$ 10 million.

4.1.7 Majdanpek Open Pit Mine

The Majdanpek Mine (RBM) is located in the City of Majdanpeck which is 70km from Bor City. The RBM has two open pits, South Pit and North Pit, and a processing plant. The concentrate is transported to the Bor Smelter (TIR) by train. The central part of the city is located in a valley containing many homes. The main mine facilities are located along a line from the central city, to the North Pit, South Pit and the mineral processing plant. Furthermore, the waste dumps of the North and South pits and tailings pond are somewhat distant from the other facilities, which are fairly close together. The layout of the main facility of the RBM is shown in Fig.4.16. An organization chart of the RBM is shown in Fig.4.17.

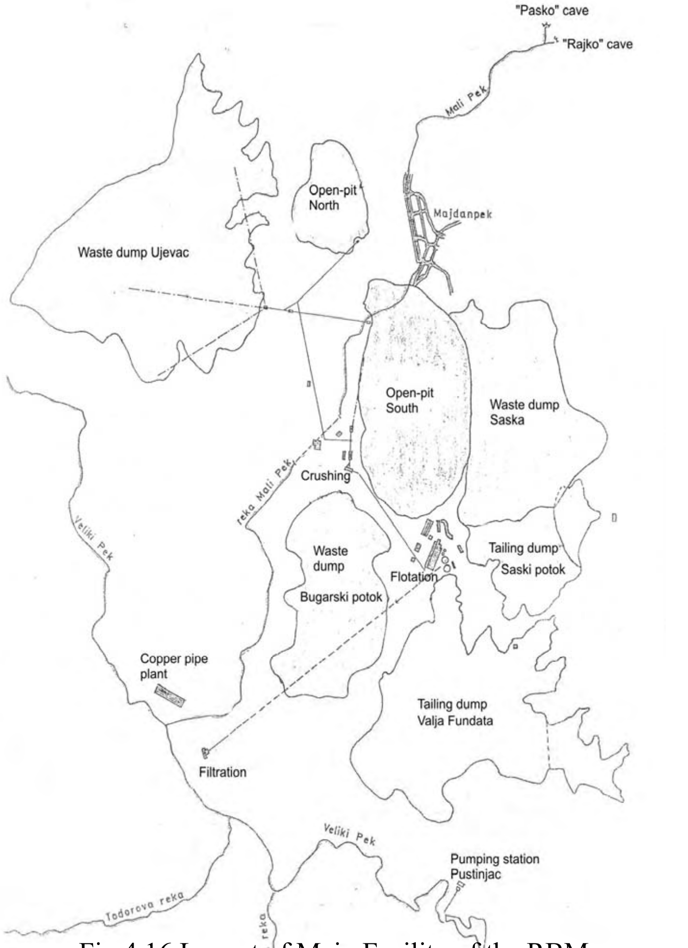


Fig.4.16 Layout of Main Facility of the RBM

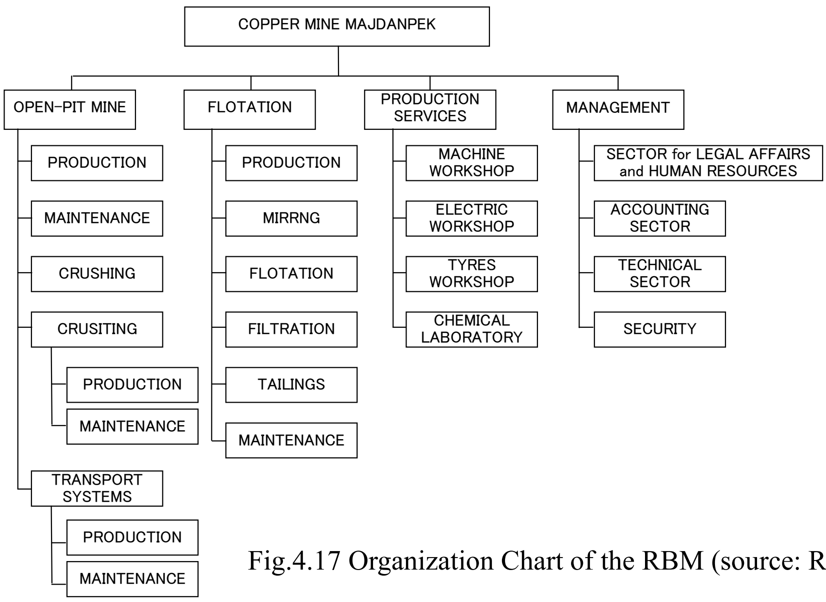


Fig.4.17 Organization Chart of the RBM (source: RTB Bor)

It should be noted that during the past 10 years, the population of Bor city has decreased from 15 000 to 10 000 due to the restructuring of the mine.

The South Pit started stripping in 1959 and production in 1961. The ore processing plant was constructed by 1961 when the mine began to send the concentrate to the TIR. The Pit was expanded after that, and annual production reached 13 million tons in 1976, and remained at that level until 1989. The RBM had been a central player of RTB Bor, accounting for more than half of its total production since the year after its opening. In 1968, the mine accounted for more than 70% of total production, and maintained this share until 1982, when the Veliki Krivelj Open Pit was opened.

The North Pit recorded the first production in 1989 after it had initiated stripping in 1977. In 1990, the pit started full production. Fig.4.18 shows the production results of the Majdanpek Mine. The lead and zinc ore was mined in the Tenka ore body of the North Pit for 2 months in 1993 and 3 years beginning in 1999.

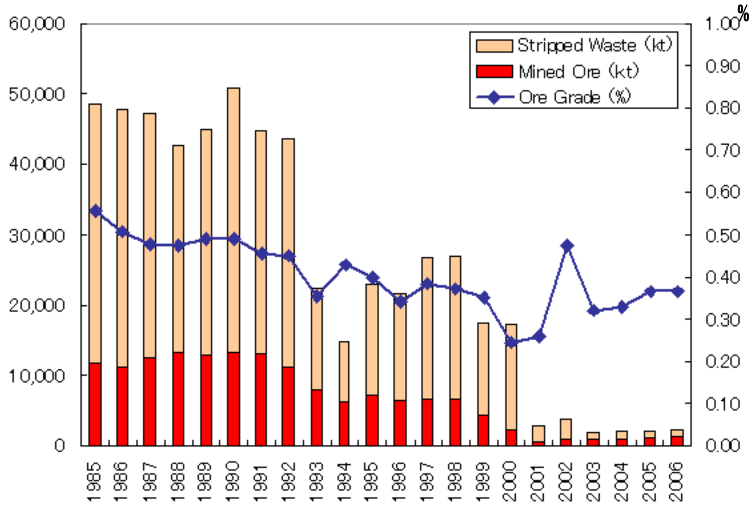


Fig.4.18 Operation Result of the Majdanpek Mine

After the Veliki Krivelj began full production, the RBM was RTB Bor's leading producer until 1992, when the United Nations-imposed economic sanctions severely impacted the mine. In 1993, the Majdanpek Mine gave up its top spot to the Veliki Krivelj Mine. After that the Majdanpek Mine could not return to its former production levels, and its production dropped down to 30% of the peak after 1998 when Western European countries imposed their own economic sanctions. Furthermore, its annual production decreased dramatically to about 540 000 tons in 2001. In 2006, production slightly recovered to 1.3 million tons, but it was far from its former level. The number of RBM workers had decreased as production decreased, as shown in Fig.4.19. In 2002, the RBM carried out a drastic restructuring by laying off 1,370 workers, about half of the total workers. Despite this

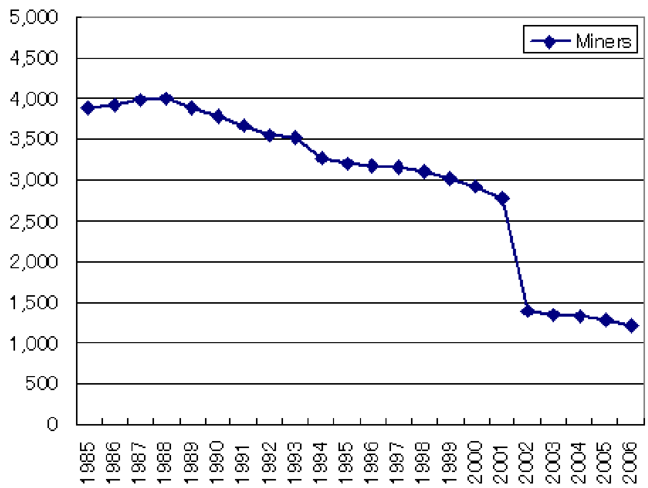


Fig.4.19 Miners in the Majdanpek Mine

action, however, operating efficiency dropped considerably. For example, the mine has maintained its three-shift system, but the first shift is now working only in preparation, not in production. According to the privatization strategy, the total number of workers will be reduced to 950 in 2007.

The top point of the South Pit is 670m and its bottom is 120m above sea level. The summit of the North Pit is 790m and its bottom is 350m. The main ore mineral is porphyry copper in both pits, but the North Pit includes some multi-complex ore deposits as well..

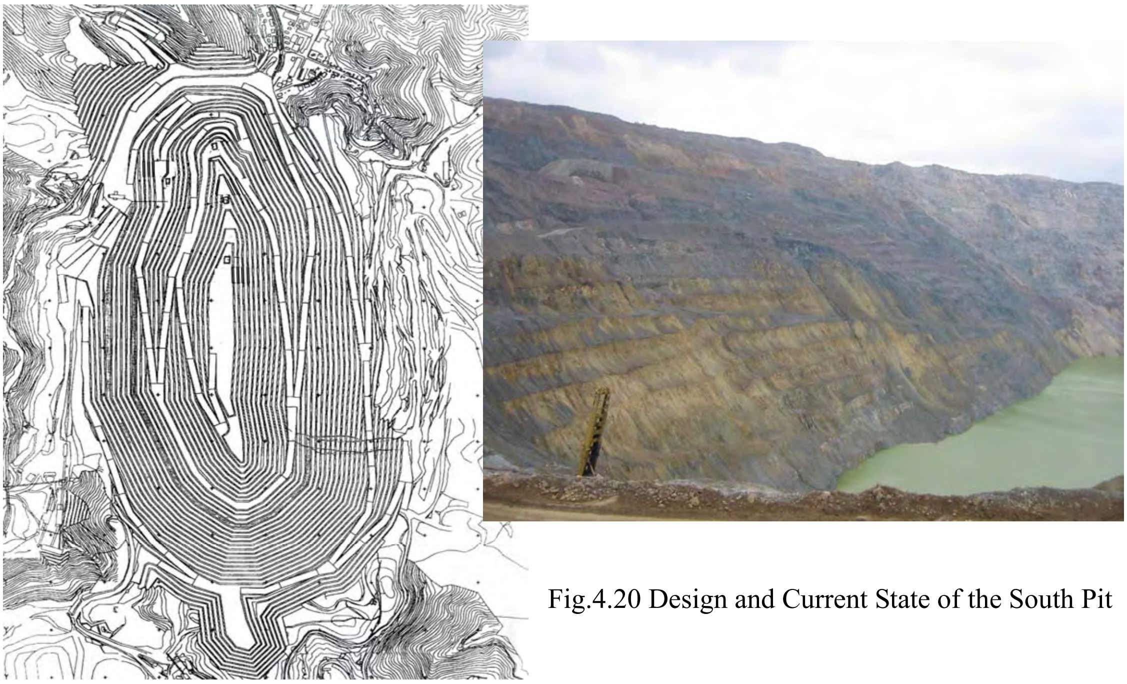


Fig.4.20 Design and Current State of the South Pit

The bottom of the South Pit is currently 80m under water, for it stopped pumping-up water from rain-fall and seepage of groundwater in March 2002 due to the confusion arising from the decreased production and worker lay-offs mentioned above. Total accumulated water is estimated to be 7.5 million m^3 (Fig.4.20). Water quality is pH6, and it can be legally discharged into the river. The North Pit also stopped water-lifting in September 2002, but it lifted water temporarily for 2 months in 2004, and for 7 months in 2005. As it has not pumped up water since then, it has plenty of water, 80m in depth, and 3.5 million m^3 in volume. Water quality is pH3.5 and it contains dissolved Fe. As of February 2007, the RBM had no plan to lift accumulated water.

The main reason for decreased production is the superannuation of mining machines, just like at the Veliki Krivelj Mine. The current main mining machines are listed in Table 4.9. There are some very old machines and some machines are rarely used.

Table 4.10 shows a comparison of exploited mass from 1977 to 1989, and from 2003 to 2006 at the South Pit. The earlier years (1977 to 1989) were a comparatively good period of operation, while the later years (2003 to 2006) were considerably less favorable.

Table 4.9 Principal Machines in the Majdanpek Open Pit (source: RTB Bor)

Type of machine	Model	Manufacturer	Yr. purchased.	Note
Drill	BE 9	Bucyrus Erie	1983	
	BE 10	Bucyrus Erie	1987	
Compressor	DXL 850	Ingersoll Rand	不明	
	XA 350J	Atlas Copco	1989	
Shovel	182 M	Marion	1966	
	M-8	Marion	1977	
	M-11	Marion	1986	
Dump Truck	630 E(170t)	Dresser	1990	
	630 E (170t)	Dresser	1991	
	630 E (170t)	Dresser	1991	
	3600 B (170t)	Terex	1997	
	R-65 (65t)	Terex	不明	
Bulldozer	TG 220 CK	Oktober	2004	
Grader	G-8	Caterpillar	2001	Unworkable

Table 4.10 Comparison of Exploited Mass in the South Pit

Period	Mined ore	Stripped waste	Total mass	Stripping ratio
1977 to 1989	164,933,812t	358,684,295t	523,618,107t	2.17
Annual average	12,687,216t	27,591,100t	40,278,316t	2.17
2003 to 2006	3,500,200t	2,667,000t	6,167,200t	0.76
Annual average	875,050t	666,750t	1,541,800t	0.76

Annual average of exploited mass fell approximately 76%, and average stripped waste decreased by about 98%. Accordingly, the stripping ratio decreased to about one third, from 2.76 to 0.76. This clearly indicates delayed stripping. Waste had been transported by belt conveyers in the North Pit, but these belt conveyers broke down in 2002 and have been out of service since then in the South Pit. Unlike the RBB, the RBM has not introduced IT, so the past operation data is not used efficiently. It is easy to understand the bad state of production merely by seeing the bad condition of the local roads. Table 4.11 shows a comparison of exploited mass from 1990-2000 and from 2003-2006 at the North Pit.

Table 4.11 Comparison of Exploited Mass in the North Pit

Period	Mined ore	Stripped waste	Total mass	Stripping ratio
1990 to 2000	31,609,186t	98,987,692t	130,596,878t	3.13
Annual average	2,873,562t	8,998,881t	11,872,443t	3.13
2003 to 2006	752,800t	1,166,000t	1,918,800t	1.55
Annual average	188,200t	291,500t	479,700t	1.55

The annual average of exploited mass decreased approximately 99%, as did average stripped waste. Accordingly, the stripping ratio decreased to less than half, from 3.13 to 1.55. This clearly indicates delayed stripping. All annual operation data are shown in the Appendix.

The RBM made a new long-term (14-year) plan for the South Pit, but there is no plan for the North Pit. If the RBM is to continue exploiting above the current water level, it will be necessary to reroute the national road and remove a large mass of waste (approximately 8 million tons), which will require a considerable amount of investment.

4.2 Activities of Middle/Small-Scale Mines in Serbia

Many small/medium-scale mines used to mine lead-zinc, rare metals, and other ores in Serbia. However, they have been relatively inactive 1991 because of political uncertainty, so plans were made to privatize all national mines, and some mines have already been privatized. The study team visited three small/medium-scale mines (the Veliki Majdan, Rudnik and Zajaca mines) to investigate their current states. The Rudnik and Zajaca are privatized mines.

4.2.1 Veliki Majdan Lead and Zinc Mine

(1) Overview

The headquarters of the Veliki Majdan Mine is located in Ljubovija City (population: 5,000), in the Macva District, about 200km east of Belgrade. The city lies on the border with Croatia, which is 30m across the River Drina. It was opened as a modern mine in 1934 by an English company which established the Drina Mining Company for full exploration work with the first drift. After a period of inactivity, a national company, Zajaca, restarted exploration in 1940, and began production in 1954. Then it became independent as Veliki Majdan in 1972 but soon joined the Zorka Sabac Group to send the zinc and pyrite concentrate to Zorka and the lead concentrate to Trepca. Operations were modernized in 1978 with expanded processing of 12,000t/year in crushing and 6,000t/year in flotation. Plans also called for flotation capacity to be increased up to 12,000t/year, but these were not materialized due to financial issues. Management was taken over by Trepca in 1996. The Veliki Majdan Mine became independent in 2003, then it was privatized in September 2006 and management was taken over by the Swiss company "Minero". Fig.4.21 shows production results from 1985 to 2001, and in 2001 the mine stopped production.

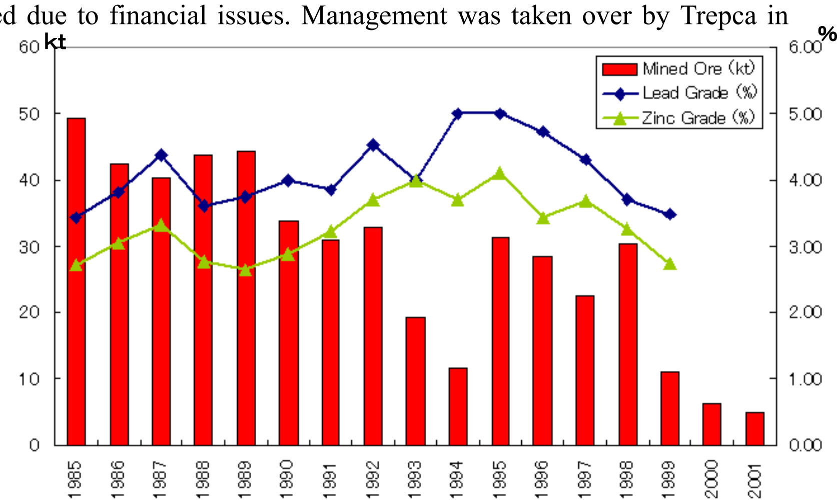


Fig.4.21 Production Result of the Veliki Majdan

The mine operated 5 days per week, with 2 shifts per day in mining and 3 shifts per day in ore processing. The mine had been operating normally until 1992, but production in 1993 to 1994 dropped to one third due to the economic sanctions imposed by the United Nations. Production recovered steadily after the sanctions were lifted, but it again dropped to one third in 2000, due to the economic sanctions imposed by Western European countries in 1999. The mine continued to operate under difficult conditions, but finally stopped operations in June 2001 when heavy rains ruptured its tailings dam. Furthermore, the mine could no longer keep pumping water up from the underground in 2003 (Fig.4.22). After privatization in December 2006, the mine restarted dewatering. Trepca gave up management rights to the mine due to these and political issues. Currently, there are only 5 mine staff: 3 executives (including the female president) and 2 engineers.

In the past, the mine used to be a supplier of concentrate to the parent company, and had financial support from Zorka or Trepca when the metal price was low. Accordingly, these parent companies had large impacts on the mine.

Current issues associated with reopening the mine are a) pumping up water from the drifts 160m under water, b) restoring the damaged tailings dam, c) hiring experienced workers because all previous workers were fired, and d) repairing or replacing the many machines for mining and ore-processing that had been abandoned for a long time. The mine estimates that it will take one million euros to restart operation in September 2007. However, as of February 2007, no detailed plan had been formulated, and many problems still remain.

In 2003, the mine began intermittently lifting water; however, the current volume of water to be lifted is estimated to be more than 100,000 m^3, so the mine began lifting water continuously in December 2006 after privatization. Underground water has a pH of 6.0, and is allowed to flow out to the valley. There is little water in the valley before it joins with the River Drina, so some environmental impact has likely occurred. However, there has not been any social trouble owing to the sparse population of the area.

In 2000, there were 133 workers in all (including 60 for mining and processing), and the mine's production was only 14% of the peak when there were 300 to 350 workers. It is estimated that there will be fewer than 200 workers when the mine is reopened. Currently, there are only 18 workers: 9 who are contracted for lifting water, and 9 guards for security.

(2) Mining

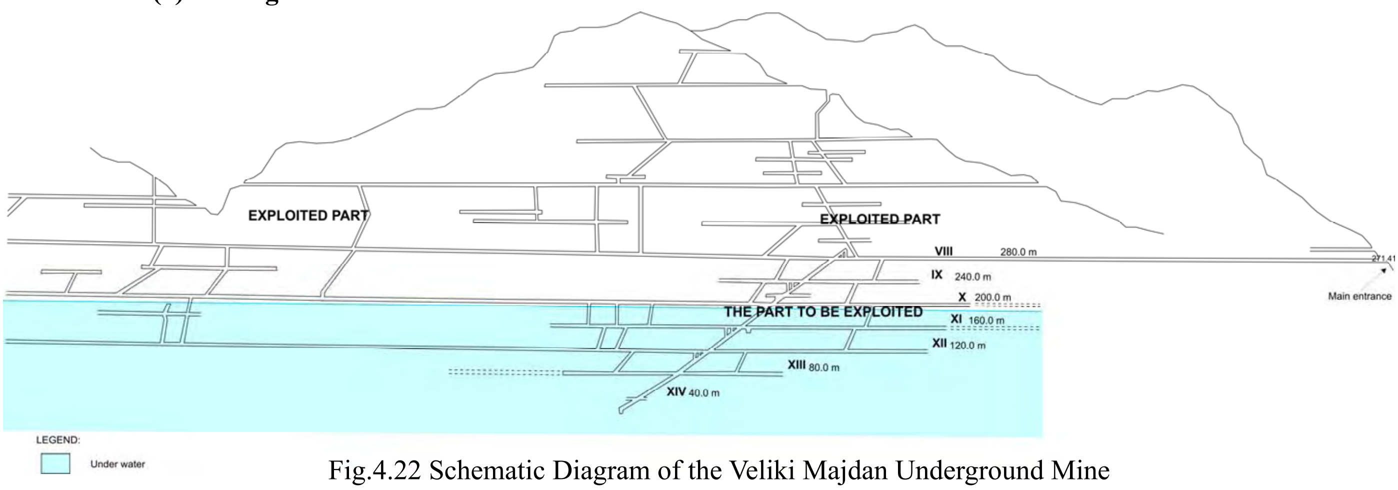


Fig.4.22 Schematic Diagram of the Veliki Majdan Underground Mine

Underground main levels are developed horizontally at each 40 meters of depth, and all deposits are accessible. There are 14 main horizontal levels, and the main adit is located 270m above the sea. Currently, all 6 mining levels are below 270mL. All of the old stopes above 270mL are no longer being mined.

The mine used to be operated 5 days a week with 2 shifts a day for mining, and 3 shifts a day for processing. Annual production was about 40,000 to 50,000 t from 1973 to 1989, when the mine was being operated normally.

The volume of sump water in the underground is 15 liters a second (1,296m^3 a day), and there are 2 lines in dewatering: 40mL to 270mL via 120mL, and 200mL to 270mL. Currently the mine is pumping up water at the rate of 25 liters a second (2,160m^3 a day).

All workers walked to stopes from the adit, and ore and waste were lifted by an inclined railway (angle: 34 degrees) which was connected with each horizontal level. Ore and waste were lifted to the 270 mL where they were transported by electric locomotives to the processing plant and waste dump, respectively, on the surface.

Ore deposits in the mine were generally small (approximately 200m^2 at maximum), and irregular in shape.

The main mining method was room and pillar. In some large deposits, mining heights could reach up to 40 m, which was the interval between main levels.

Waste was picked out of mined ore in the underground before the ore was transported to the surface to prevent ore dilution.

Ore grain in the milling process was 60% under 60μ. Ore recovery was about 90% for lead and 82% for zinc. Filtration results were also good, with water content of 7% in the lead concentrate and 9% in the zinc concentrate.

Awareness of the need for improvement is probably not so high, because the mine used to be supported by the parent companies.

From the viewpoint of operation efficiency, the potential for mechanization may be limited due to the small size and irregular shapes of the ore bodies. Mine officials think that 45,000t/year may be an achievable operating scale when the mine is reopened.

4.2.2 Rudnik Poly-Metal Mine


Mine office located in Rudnik Village

(1) Overview

The mine is located in Rudnik Village (population: about 2,000), Gornji Milanovac, Sumadija District, approximately 110 km south of Belgrade. This was the first privatized mine which was bought by Contango (director: Mr. Darko Vukobratovic) in a public auction held in September 2004. Contango bought 70% stock of the company, and the other 30% was given to workers of the company, who have already sold most stock to banks and investment companies. Currently there are more than 10 shareholders.

This mine was established in 1948 by Trepca, and ore production began in 1952. It produces lead, zinc and copper ore. The lead and zinc ore deposits are small massive skarn type while the copper deposits are mainly stock work type which are somewhat larger than the lead-zinc deposits.

Mine production had been stable until 1992, when it fell sharply due to economic sanctions. In 1994, the mine could not produce ore. In 1995, the mine re-began production, but debt was accumulated owing to low production and low metal prices. Finally, the company was privatized in 2004.

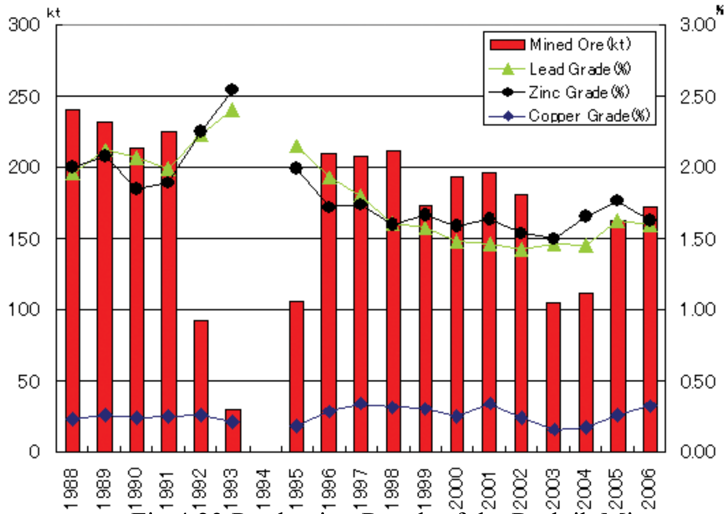


Fig.4.23 Production Result of the Rudnik Mine

As this mine had been managed autonomously before privatization, a new owner had difficulties in labor management.2 former managers and 3 leaders of miners were fired to break with the old habits. After privatization, the mine became profitable (160 million Dinars) in 2006 due to high metal prices. Production dropped shortly after privatization, but it has recovered year by year, and will reach the peak level of the past in 2007 (Fig.4.23). Contango has already paid off the auction fees (US$1.5 million) and all debt (US$3.0 million) of the company thanks to the high metal prices for the past few years, and its management is pretty good. It should be noted that the stock price of the company has increased ten times from 1,200 Dinars to 12,000 Dinars for this half year (April 20, 2007 to Oct. 22, 2007).

Concentrates of lead and zinc were sent to the Trepca Smelter and copper concentrate was sent to the Bor Smelter. As payment from the Trepca was suspended because of the Kosovo conflict and other reasons, the company became independent from Trepca in 1996. However, each concentrate was sent to the same smelters as before. After the Trepca Smelter stopped operation in 1996, lead concentrate was to sent to the Plovdiv Smelter in Bulgaria, and zinc concentrate was sent to the Zorka Smelter in Sabac. From 1999-2002, zinc concentrate was sent to the Veles Smelter in Macedonia. Since then, it has been sent to the Plovdiv Smelter, same as with the lead concentrate. Copper concentrate has been treated in the Bor Smelter.

All expenditure data is compiled by a accounting office, and transmitted by email to the head office which checks it again in Belgrade. All cost data in each department is monthly calculated compiled, and monthly profit is calculated according to monthly production and sales price of concentrates.

(2) Mining

The underground structure of the mine is comparatively simple, consisting of three horizontal levels: 725m above sea-level (0mL); the main entrance level, 675m above sea-level (-50mL) and the haulage level 575m above sea-level (-150mL). The mining areas are separated vertically into 2 parts, the Srednji Sturac area (0mL to -50mL) and Gusavi Potok area (-50mL to -150mL). Almost the same volume of ore is produced from these two areas.

The mining method of the mine is descending “Room and Pillars”. Each small ore-body prepares one stope, but large ore-bodies are separated vertically into 2 or 3 portions. Each portion is mined from top down by “Room and Pillars”. There are 14 stopes in the Srednji Sturac area and 11 stopes in the Gusavi Potok area.

Total amount of the sulfide orebody, P2, beneath the oxide ore is about 800,000t which lies near the surface. The oxide ore has been tested by the Ore Processing Department of the mine. However, the mine gave up exploitation of the oxide ore due to its low recovery rate. Currently, the mine is preparing the sulfide orebody just beneath this oxide ore by the underground method. Drift has a face of 3.5m (height) x 3.2m (width) with total length of 200m. As of 2007 October 25, drift has finished 20m. Also, an orepass with length of 15m will be prepared. Horizontal drift are fully supported due to its rock bad condition Room and Pillar method, main mining method of the mine, is not applicable for this orebody, and Cut and Fill method may be adopted.

An exploitation plan for P2 orebody is shown in Fig.4.24.

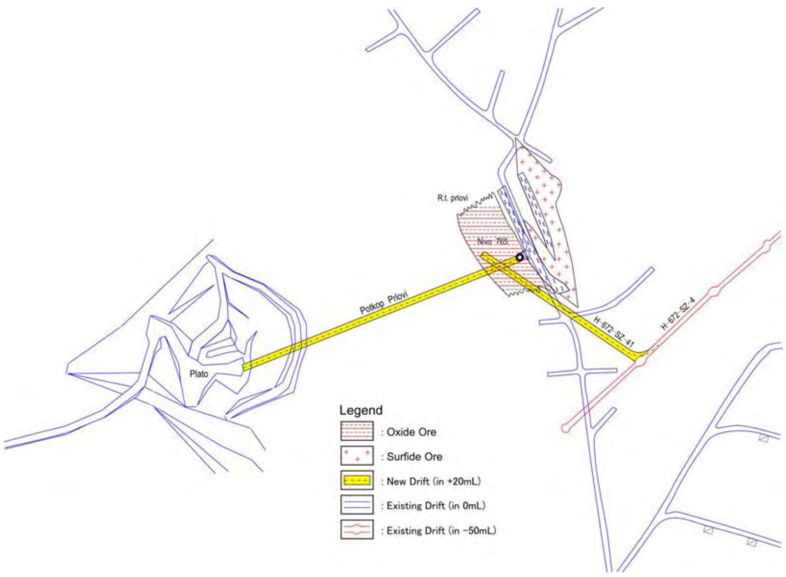


Fig.4.24 Exploitation Plan for P2 Orebody

One of current problems is a shortage of good workers, and it is notable in the underground. There are 148 currently employed miners, but only 76 miners work in the underground. Absentees consist of 12 injured miners, 13 miners on vacation and 47 on leaves of absence. One reason for this phenomenon is that many Macedonian miners sometimes return home temporarily. The average worker's wage roughly doubled after privatization. Wages of underground miners are the highest, at 23,400 Dinars/month and their rate of increase is also the highest, 2.2 times. Accordingly, mining costs increased by 37% from 890 Dinars/t in 2005 to 1,217 Dinars/t in 2006. However, inflationary prices of metals could compensate for this increasing cost.

4.2.3 Zajaca Mine

(1) Overview

The Farmakom Ltd. is located in Sabac City (population: 50,000), Macva District, which is about 200 km west of Belgrade.

The company was established about 20 years ago. Although the core business of the company is agriculture, it has been gradually expanding and diversifying its operations since its founding. Currently it is a large (200-million-euro) operation employing a total of 2,000 workers.

The company deals in milk, agricultural products cultivated in greenhouses, and spare parts for cars, and also runs a metal foundry and a lead smelting business. It bought out the Zajaca Mining Co. Ltd. in March 2006 to acquire antimony mines

The Zajaca area is rich in metallic minerals with a metallogenic length of 25km (300 to 500m wide) in the NW-SE direction, and many mines have been developed in this area in the last 130 years. There are many nonferrous metal ore deposits such as lead, zinc, tin, and arsenic, as well as antimony in this area, including in the Veliki Majdan Mine.

Total production of antimony was 140,000t in metal base. Antimony production was begun after World War 2, and the average annual production was about 2,000t from 1945 to 1990. The production peak was during 1965 to 1977, when the average annual production was about 3,200t.

Serbia was a leading antimony production country in the world up to the 1980s. In the latter half of the 1980s, however, antimony prices dropped dramatically due to excess antimony production, mainly from China.

Trends in antimony prices are shown as follows (Unit: metric tonne):

Antimony price up to 1980: US$6,000/t

Antimony price during 1980 to 1996: US$1,800/t

Antimony price during 1996 to 1998: US$3,500/t

Antimony price during 1998 to 2003: US$2,000/t

Antimony price after 2003: US$6,000/t

The Zajaca Mining Co. Ltd. stopped producing antimony in 1991 due to decreased metal prices. After that, the company produced lead for car batteries from scrap lead using its smelting facility. Before 2005, the average annual production of lead was 5,000t for 10 years, but production increased to 6,500t in 2006, and will be 8,000t in 2007. This September, a new technology will be introduced from Italy and production is planned to be 15,000t in 2008.

(2) Mining Concessions

The Zajaca Mining Co. Ltd. was privatized in March 2006, and its management was transferred to Farmakon. Since that time, Farmakon has studied reopening mines. They target lead, zinc, tin, rare earths such as CaF_2, and antimony.

Farmakon has many mining concessions, as follows:

In the Zajaca Area

a. Rujevac Concession (Sb, Pb, Zn, and As)
b. Zavorje-Stira Concession (Sb)
c. Brasina Concession (Sb)
d. Dolic Concession (Sb)
e. Kik Concession (Sb)
f. Stolice Concession (Sb)

In the Kopaonik Mountains Area

a. Rajiceva Gora（Pb, Zn, Sb）

Priority is given to reopening the following mines:

1. Rjiceva Gora
2. Rujevac
3. Zavorje-Stira
4. Brasina

This priority was determined by considering the dimensions of ore-bodies, ore grade, and difficulty of operations after reopening.

Production scale of mines after re-opening for 1. and 2. (number of workers including mines and processing plants)

1st year production : 40,000t/year (with 40 workers)

after 3rd year: 120,000t/year (with 90 workers)

The filling method will be used as the mining method. The company is currently preparing documentation to reopen mines with following 2 tasks;

(1) More than 80% of underground facilities are expected to be in bad condition, including partial collapses.
(2) It will be difficult to hire experienced miners, as the mines have been closed for 20 years.

(3) Clean-up Work at the Zavorje Mine

Zajaca Mining operates three underground mining areas: Turin, Pit 28, and Pit 500 in Zavorje Mine, which was closed 16 years ago. The main mining areas in the Zavorje Mine have already been mined out, so the current mining targets are located at the end of main deposits which were not previously mined. Therefore, ore veins are small (1.0 to 1.5m wide), plunges of ore bodies are comparatively flat (40°～50°), and most veins are irregular in shape.

In Turin, clean-up, supporting, and dewatering work in partially collapsed zones has been completed in the main haulage level (373mL), and investigation of approximately 350m long underground drifts is possible. In Pit 500, the drift entrance has been reconstructed, and it is now possible to enter about 30m into the underground. They will continue to clean up old drifts and possibly begin development in 2007. For Pit 28, there is currently no plan to clean up the old drifts, but they are considering the many preparations to be done before production.

The Zavorje Mine used to employ the Sublevel Caving method (Schematic sections show the Non-support style in Fig. 4.25 and the Support style in Fig.4.26). However, current mining targets are very small, and the drifting is sufficient to mine these veins.

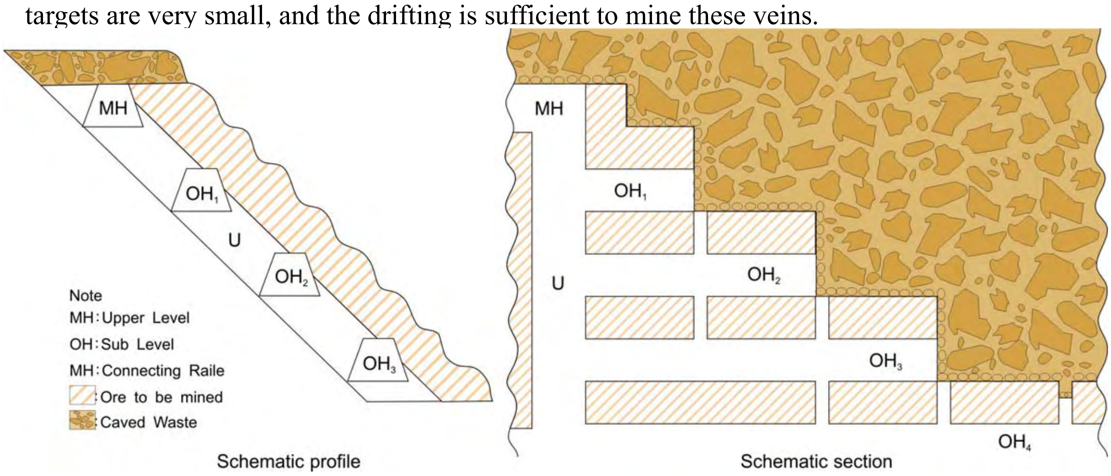


Fig.4.25 Non-support Style Sublevel Caving Method (source: Zajaca Mine)

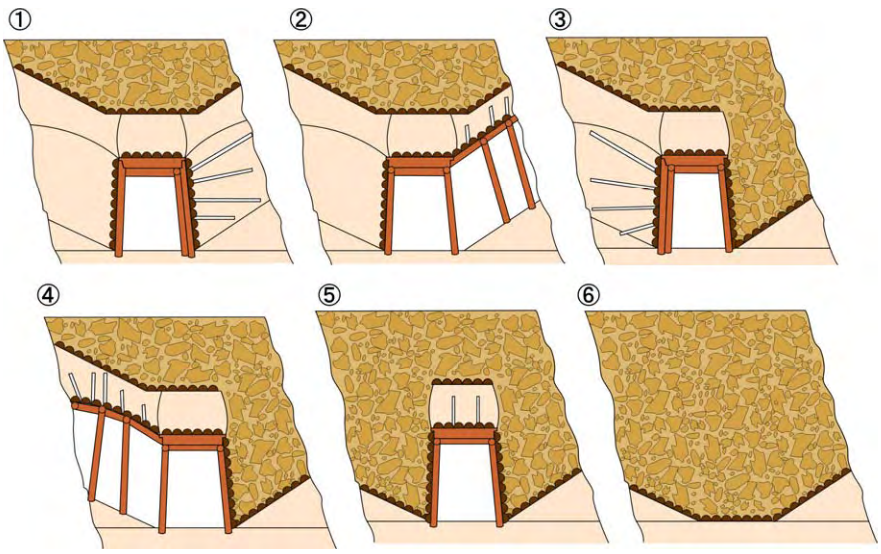


Fig. 4.26 Support Style Sublevel Caving Method (source: Zajaca Mine)

Currently clean-up works is progressing in the Zavorje Mine for redevelopment. However, explanation survey is not sufficient in the target areas for redevelopment. For example, geological recommendation maps are not prepared, so it is likely to be problematic for formulating an exploitation plan. It is necessary to prepare all necessary geological maps for an exploitation plan.

According to the Serbian Mining Law, some institutes will be selected to design mining procedures, but there are many restrictions to the adoption of modern mining methods due to the condition of the ore bodies.

Some mines would like to introduce small diesel machines like the ST1/2 for transportation, but these would cause a serious ore-dilution problem due to the narrow width of the veins. Furthermore, reliable ventilation in blind drifts may be a major issue for internal-combustion engines. Therefore, reliable underground ventilation must first be established. For instance, the old ventilation network in the mine was shown to the study team, but it may be insufficient for diesel machines. However, even if several fans were used in blind drifts, closed circuit ventilation might occur. Careful attention should be paid to prevent a lack of oxygen to the mine. Another serious problem is how to transport a large diesel machine into the underground. Also, a diesel machine in the underground would have to be broken down to be transported out of the underground for periodic overhauls. Moreover, when the ground condition is bad, a lot of support would be necessary. It would be another issue to employ experienced miners with support skills.

In the overall picture, drifting an LHD tunnel from the surface would have advantages such as a) transporting diesel machines directly from the surface, b) assuring ventilation directly from the surface, c) using vehicles to transport timber and miners directly from the surface. However, it would not be a small investment. So the question is whether ore reserves will be sufficient to offset the required investment. For instance, the total antimony (Sb) reserves in Zavorje Mine are 2,058t according to the current ore reserve calculations. If the minable ratio is assumed to be 50%, the net income might be about US$ 6 million. Taking uncertain underground factors into account, more ore reserves might be an incentive to invest in LHD drifting. Therefore, more exploration should be done around the current mining areas to better understand the precise amount of total ore reserves, and design an LHD drift in the most appropriate location.

4.3 Other Mining Activities

Serbia is rich in mineral resources, and several mining activities besides metal mining are in operation. Coal mining operation and a limestone quarry are presented here. The study team investigated the Kostolac Coal Mine belonging to the state-owned EPS, and the Kovilovaca Quarry, which was privatized in 2003. Current state of these mines and their tasks are reported here.

4.3.1 Kostolac Coal Mine

Currently, the Kostolac mine produces approximately 7 million tons of coal for 4 billion kWh/year with a 1,000 Mw facility. They plan to increase coal production to 9 million tons/year in the future to meet increased electrical demand. Fig. 4.27 shows mine production for the last 20 years. The mine suffered less than metal mines under economic sanctions, because the Russian-made spare parts for mining machines were continuously available. Post-1976 production results are shown in the Appendix. In Kostolac, there are 2,600 workers employed in coal mines, and 1,000 workers in electricity generation plants. It should be noted that the mine does not have a privatization plan, because its production is directly linked to the Serbian people's lives.

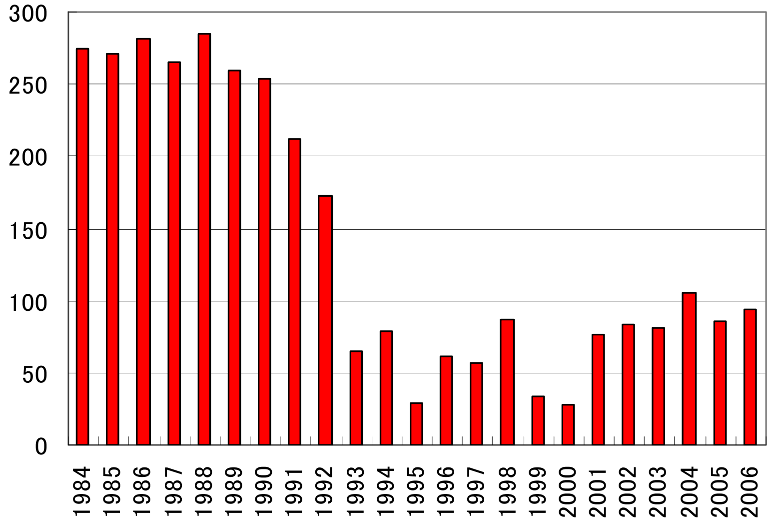


Fig. 4.27 Kostolac Mine Production in the Last 20 Years

The Thermal Power Plant and "Kostolac" Mine are located in Kostolac, Pozarevac Municipality in the Branicevo District about 100 km to the east of Belgrade. They are operated by the state-owned company, EPS. The mining cost is €7- 8 /t and the mine runs profitably.

The Kostolac Mine started coal production in 1870, and changed the local economy drastically. The first mine was an underground mine called "Stari Kostolac" The second underground mine, "Klenovinik", was opened in 1885. These underground mines were closed in the 1960s, when a third underground mine, "Cirikovac", was opened and continued operating for 18 years. The open pit "Kostolac" was opened as the first Serbian open pit mine in 1943. 5 years later, the first Serbian thermal plant was constructed (8MW), and operated with coal produced in the mine. The plant expanded continuously for next 10 years, and open pit "Cirikovac" began operation in 1980. Also, the open pit "Drmno" was opened in April 1987.

Currently at the Kostolac Mine, there are 3 open pits, Drmno (mining area: 2.5 km × 5.0 km), Cirikovac (1.5 km × 2.0 km), and Klenovnik (0.8 km × 1.0 km).

In the Drmno pit, stripping is carried out with draglines, and coal is mined with 4 continuous excavators and transported directly to the plants by


Pit of the Drmno open pit

2-meter wide belt-conveyors.

The pit bottom of Drmno Pit is located 50 to 80m under the water level of the Danube River, which is about 500m from the pit. Therefore, the pit continuously operates dewatering with 200 wells. Two tons of water must be dewatered for every 1 ton of coal. Additional wells are needed to facilitate pit moving in the future. They expect to drill 40 to 50 new wells for each 500m move of the pit.

Another problem with Drmno Pit is avoiding the nearby Roman ruins known as “Viminacijum” on the coal layers. 20 million Dinars (about 250,000 Euros) per year will be needed to move most of the ruins to another location. However, as some ruins cannot be moved, approximately 40 million tons of coal will be remain unmined.

30 years have already passed since Cirikovac Pit was opened. There are 2 coal layers to be mined. However, mining has already encroached to within about 700m of a local villagers' residence area. Thus, it will be impossible to continue mining without changing the current mining method, so underground mining may be adopted. The current stripping ratio of this pit is about 7:1, but dewatering is unnecessary. A total of 900 miners work in this pit.

Klenovnik Pit produces about 150,000t per year with a stripping ratio of 7:1. Mining is done by dragline, and coal is transported 2km to the plants by train. The reserve is insufficient, and transportation costs are significant. So, the pit is scheduled to be closed 3 years from now.

Kovilovaca Limestone Quarry

The Kovilovaca Limestone Quarry is located in Pozarevac Municipality, Branicevo District, about 135km to the east of Belgrade. The quarry was privatized in 2003, and the quarry owner is former high school teacher. He has successfully managed the modernization of the quarry.

The quarry was opened in 1960. Pre-privatization production data does not exist, so the history of the condition of the quarry is not known. The current proven reserve is 21.65 million tons, but the quarry has a vast concession area, so quarry life is not an issue. Since the thickness of the overburden waste is about 0.5m, the mining condition is very good. Limestone is distributed according

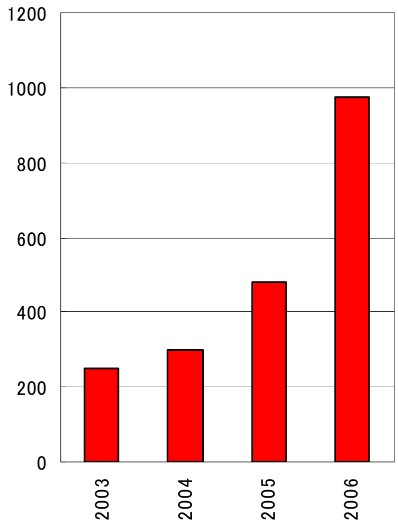


Fig. 4.28 Kovilovaca Production

to purity and grain sizes. There are 15 degrees of grain sizes, from very fine to 700 mm in diameter. Product distribution is separated into 60% for material for asphalt roads, 30% for solvents for US Steel iron smelting, and 10% for sugar factories. The company has strategic partnerships with US Steel, such as a 10-year contract to feed limestone, as well as a joint exploration for dolomite. Annual production trends are shown in Fig.4.28. Production has drastically increased since privatization through several management efforts, such as renovation of machines and introduction of an efficiency wage system. In 2007, production is expected to increase to 1.5 million tons.

The number of workers was reduced from 68 to 40 due to weak morale and lack of working skills. However, based on the efficiency wage system, good wages are paid to workers who achieve satisfactory results. The current workers have been increased to 73 to allow for 3 work shifts for increased production. The owner maintains a stable relationship with his clients by providing superior quality and reliable delivery of orders.

Currently, the company is facing environmental problems. Foremost, muddy water produced in the purification process is sent to 7 sedimentation ponds. Also, noise during night operations since changing to a 3-shift system in 2006 is impacting on residents near the quarry. A fence will be constructed around the quarry to reduce noise. Also, water spray is used to prevent dust in summer.

Contractor Co. is in charge of designing of the quarry, which has 3 20-meter benches. The quarry is operated as a standard open pit system. It should be noted that there are 59 authorized non-metal mines (as shown in the Appendix), but almost the same number of mines are operating without licenses. This is an urgent issue for the MEM.

4.4 Smelting Activities

4.4.1 Overview of the Copper Industry in Serbia

(1) Import and Export of Copper (Statistical Yearbook of Serbia 2006)

tons/year

	Export			Import		
year	2,003	2,004	2,005	2,003	2,004	2,005
Total	39,319	37,788	59,723	20,812	47,897	41,747
Cyplus	1,673	3,809	19,015	824	4,564	19,386
Italy	2,526	4,164	7,416			
Gemany	4,054	6,040	5,821	950	493	376
USA	3,089	4,341	3,695			
Romania	1,333	1,746	3,111			
Bosnia	1,127	1,010	2,084			
Bulgalia				4,379	23,614	13,077
Russia				4,255	4,974	4,312
Austria				1,298	1,620	2,366
Others	25,517	16,678	18,581	9,106	12,632	2,230

(2) Production by TIR Bor

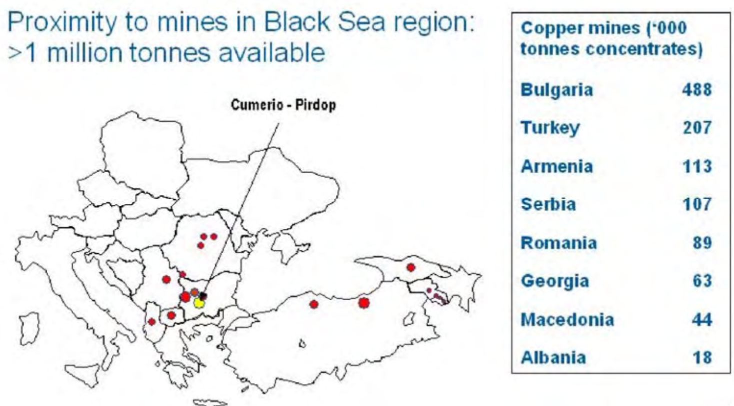
Year	2003	2004	2005
Cathode	14,000	12,000	31,000

According to a report from Bor, in 2004 they sold 3,584 tons of cathode and 1,214 tons of wire and foundry products in Serbia, and 3,800 tons of cathode and 1,337 tons of wire and foundry products overseas.

In the 1980's, production of the Bor smelter reached 150,000 t/y and approximately 70% of this production was supplied to fabricators in Yugoslavia.

(3) Copper Industry in the Balkans

1) Copper Mines



Total copper concentrate quantity 11,129,000 tons

Assuming the copper content in concentrate to be 25%, the net copper quantity is 282,000 tons

2) Copper Smelters

Country	Location (Name)	Capacity x 1,000	Process Type (S); secondary
Albania	Kukes (Gjegian)	5	Reverberatory
	Lac	7	Blast Furnace
	Rubik	5	Reverberatory
Armenia	Alaverdi	7	Reverberatory
		3	Reverberatory (S)
Bulgaria	Eliseina	14	Blast Furnace (S)
	Pirdop	190	Outokumpu Flash
Hungary	Csepel	4	Reverberatory (S)
Italy	Porto Marghera	24	Reverberatory (S)
Poland	Glogow District (Glogow I)	220	Blast Furnace
	Glogow District (Glogow II)	205	Outokumpu Flash
	Wroclaw (Hutmen S.A.)	9	Blast Furnace (S)
	Legnica	93	Blast Furnace
Romania	Baia Mare	35	Outokumpu Flash
	Zlatna	10	Reverberatory (S)
	Zlatna	40	Outokumpu Flash
	Zlatna	13	Reverberatory
Serbia	Bor	170	Reverberatory
Slovakia	Krompachy	20	Reverberatory (S)
Turkey	Samsun	42	Outokumpu Flash

Total 1,032,000 tons

In the Balkans, the total copper quantity is 282,000 tons, meaning that there is relatively little copper concentrate in this area.

Baia Mare and Zlata in Romania have been converted into secondary smelters using scrap as the raw material.

4.4.2 Operation at the TIR Bor

Features of the RTB Bor and TIR Bor are as follows;

1) Copper content in concentrate from RTB Bor is low and the concentrate cannot be sold in the international market when its copper content is 20% or less. Therefore, RTB Bor needs to have its own smelter.
2) The production at TIR Bor is essentially based on raw materials from Bor mines and imported concentrate is used to maintain the copper content in charged concentrate at 20% Cu. Although there is no problem with using up to 28% Cu at the smelter, operations are carried out with the minimum amount of imported concentrate.
3) Before economic sanctions were imposed in 1990, there were fabrication plants in Serbia that used electrolytic copper as a raw material and approximately 100,000 t/y electrolytic copper was consumed locally in Yugoslavia. At present, the domestic fabrication in Serbia is approximately 20,000 t/y, and all fabrication plants except RTB Bor are privatized.
4) Because purchases of imported concentrate and sales of electrolytic copper are entrusted to East Point Co., Ltd. of Cyprus, electrolytic copper produced by TIR Bor is not given priority for domestic sales.
5) The theoretically calculated copper recovery rate of TIR Bor is about 93%, which is lower than the contract recovery rate of 95%.
6) The cut-off grade (for trading) of gold and silver in copper concentrate is 1g/t gold and 30g/t silver and they, unlike copper, are producing a profit. However, RC (refining charges) are not taken into account.
7) The sales price of sulfuric acid is now 0.5 euros per ton, meaning the more that is produced, the less profit there will be. When fixing SO_2 as sulfuric acid for pollution prevention, it must be considered as a pollution control cost. (In the following study, it is not considered in the operating costs for copper production.)

(1) Organization

1) Organization of the RTB

The organization of the RTB Bor is as follows;

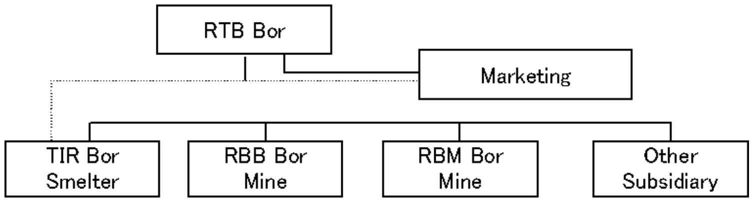


Fig.4.29 Organization of the RTB Bor

RTB Bor is a holding company and under 100% control of the government. RTB Bor has a marketing section and other companies under it as production and fabrication companies.

This marketing section is importing copper concentrate and selling cathode through East Point Co., Ltd. of Cyprus. Further, the invoice price of copper concentrate produced from the Bor Mine is based on the international market price for the past 2 to 3 years. For reference, the current price is US$700/t Cu (31.75 ¢/lb).

The contract recovery rate for copper is based not on a unit but on international trade.

The production of smelters is determined as follows.

- Production of copper concentrate from the Bor Mine (Cu content) From Marketing to Smelter
- Imported copper concentrate required for blending From Smelter to Marketing

2) Organization of the TIR

The organization of the TIR is as follows;

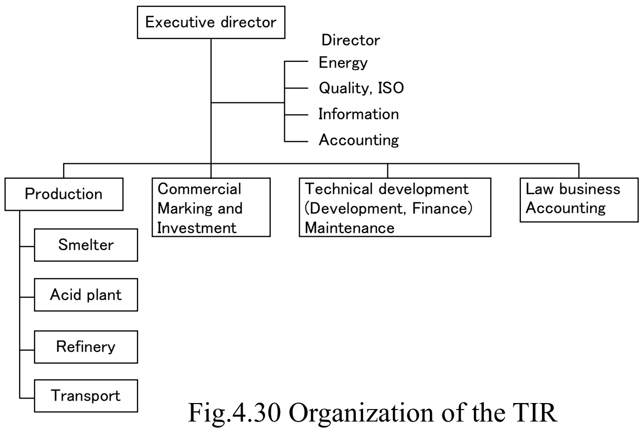


Fig.4.30 Organization of the TIR

Quality control is already registered for LME electrolytic copper, and some sections have acquired ISO 9001 (Quality Control). Also, Refinery, Blending control ISO 14000 (Environment Control) is scheduled after privatization.

Concerning accounting, financial reports are issued yearly and quarterly. A summary of financial reports for the 3 years is shown in the table below.

Table 4.12 Summary of Financial Reports

year	2004	2005	2006
On business			
Sales income	4,719,515,000	972,833,566	8,349,505,494
Raw material	2,131,885,563	416,129,030	4,636,136,492
Other direct cost	2,533,952,437	497,773,759	3,811,487,246
Profit and loss	53,677,000	58,930,777	-98,118,244
Financial cost			
Financial income	563,139,973	568	582,696,040
Financial outgoing	1,101,050,971	15,678,646	506,113,018
Profit and loss	-537,910,998	-15,678,078	76,583,022
Non-business profit/loss			
Other income	16,654,434	315,416	118,517,138
Other outgoing	131,990,056	3,443,512	67,889,965
Profit and loss	-115,335,622	-3,128,096	50,627,173
Accounts receivable			30,019,966
Grand total			
Profit Loss (Din)	-599,569,620	40,124,603	59,111,917
Profit Loss (US$)	-10,240,301	603,204	883,342
Din/US$	58.55	66.52	66.92
Electrolytic copper t/y	11,997	31,284	41,387
LME price US$/t	2,866	3,679	6,722

Because the profit and loss are settled each year, they cannot manage to have re-investment fund. (When invested, it is depreciated.)

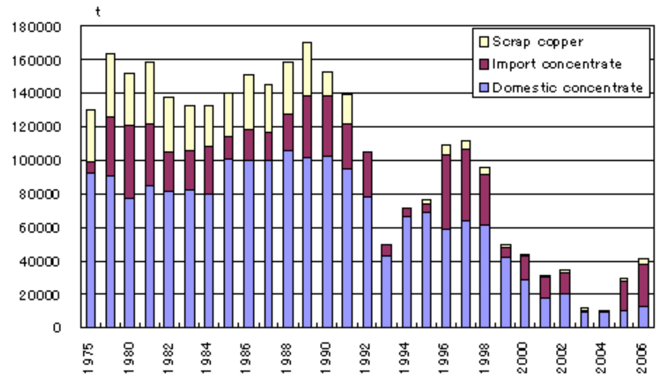
There are 3 labor unions at the TIR.

- Smelter
- Non- Smelter, such as Refinery, Dore, etc.
- Union that split from the Refinery union.

(2) Past Production

The Smelter/Refinery of Bor started production in 1961 using one reverberatory furnace. In 1971, the plant began using 2 reverberatory furnaces and its capacity was expanded to 175,000 tons.

Fig.4.31 Past Production



In 1990, the country was in a civil war and with the imposition of international economic sanctions, production dropped drastically (because they were unable to import spare parts). The economic sanctions were lifted in 1993 but production has continued to decline.

The greatest copper production from a mine in Serbia (RTB Bor) was 100,000 t/y. The copper concentrate imported today is mainly from Bulgaria and is handled by East Point Co., Ltd. of Cyprus.

(3) Operating Costs

The copper production capacity is 160,000 tons but in recent years, the production has only been 10 to 20% of this capacity. Because of this, the operating costs are becoming high. We estimated the operating costs based on past operation results.

(4) Estimation of Operating Costs under Full Capacity Operation

We received basic data on operating costs from 1991 to 2006 and calculated operating costs versus production. Fig.4.32 shows the calculated operating costs (cents/lb) by production amount.

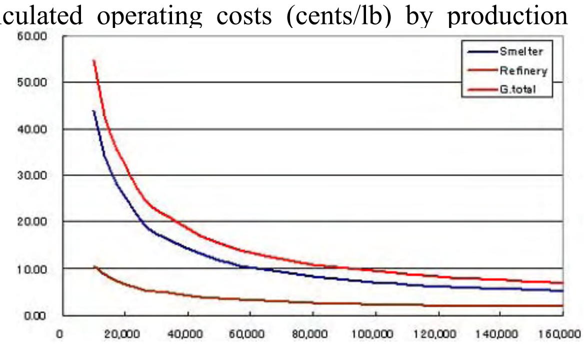
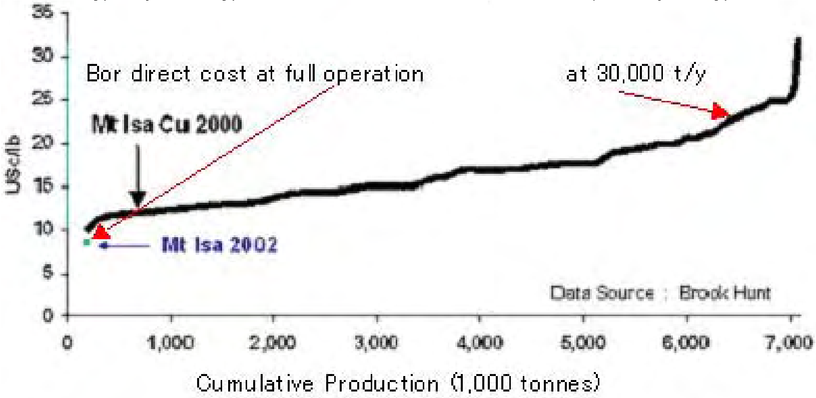


Fig.4.32 Operating Cost by production

At 165,000 t/y production, the direct operating cost is 6.9¢/lb. The minimum production to have a profit under current concentrate purchase price of 31.75 ¢/lb is 19,500 t/y. However, this is on a direct cost basis and this minimum production quantity will increase when indirect costs are included. (For example, when a desulfurization plant and wastewater treatment facilities are installed for pollution control, approx. 1.5 ¢/lb has to be added to this operating cost. Total 8.4 ¢/lb)

The graph below shows the average operating costs of smelters in the world, comparing operating cost of the Bor.

Fig.4.33 Operating Cost for Smelting and Refining



The operating costs of Bor will be the cheapest in the world if the plant is operated at full capacity. However, this calculation is based on the actual costs in 2005.

Electric power	0.3C/kwh
Fuel	120US$/t
Labor cost	US$5,000 per man per year

These costs are low compared to international level and will likely increases the economy grows. Thus, operating costs will likely rise in the future.

(5) Quality of Copper Concentrate

Smelter operation is based on the quantity of concentrate. A large portion of cost derives from the quantity of the concentrate. When the copper content in this concentrate is low, the production cost based on copper quantity becomes high. The quality of concentrate used at RTB Bor is quite low compared to the average world concentrate of 28%. Copper, silver and gold content in concentrate from the mines of RTB Bor is as tabulated below.

BOR	10～12 % Cu	12～18g/t Au	150～350 g/t Ag
Veliki Krivelj	16～22 % Cu	50～200g/t Au	600～1500 g/t Ag
Majdanpek	10～16 % Cu	4～7g/t Au	30～60 g/t Ag

International trading of copper concentrate is normally with Cu 20% or higher. The copper content in concentrate of BOR is lower than this international trading quality. Therefore, it is difficult to sell copper concentrate from RTB Bor mine on the international market so RTB Bor needs to have a smelter of its own. It is an important task for the TIR Bor and indispensable for cost cutting to improve the floatation process in order to produce copper concentrate with a copper content of at least 20%.

Meanwhile, gold and silver are saleable when the content is 1g/t or higher for gold and 30g/t or higher for silver. Silver content in copper concentrate of Majdanpek is 30 to 60 g/t and when sold outside, silver below 30g/t is not evaluated in the price. Even when it is 60g/t, the evaluation is only 30g/t.

The copper content in blended concentrate is adjusted to 20 to 22% Cu by blending with imported concentrate having a higher copper content. However, since 2000, the quality of imported copper has dropped down to approx. 15%. However, there is some sign of recovery in 2005 with the use of imported concentrate. Matte grade is within the range of 35% to 45%. Slag is kept at around the 0.5% level. The figure below shows copper content in copper concentrate, in matte and in slag.

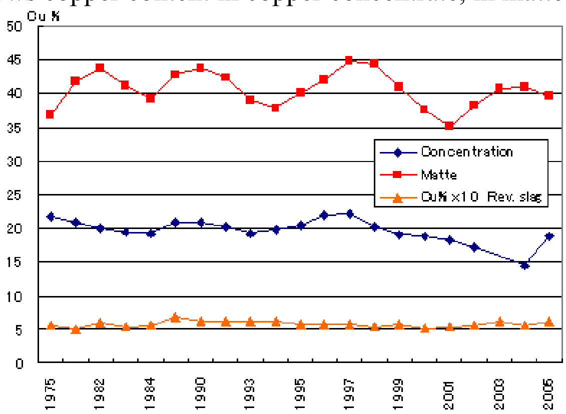


Fig.4.34 Cu Grade Trend of Concentrate, Matte and Slag

4.4.3 Copper Smelting/Refining Business

(1) TC/RC and Operating Costs

TC/RC is a processing cost which is borne by the smelter/refinery. Therefore, in order to have a profit, the total operating costs should be lower than TC/RC.

TC is a unit cost per quantity of concentrate and is expressed as ¢/lb of copper quantity. Therefore, it varies depending on the copper content in concentrate. The following table shows conversion values for various concentrations. For example, at TC70$/t, the TC will be 11.8¢/lb with copper content of 28% but when it is 10%, TC will become 35.3¢/lb as a copper base.

Table 4.13 List for TC/RC

		Cuncentrate Cu %	Combined TC/RC C/lb	TC C/lb	RC C/lb	Cu recovery Contract %
TC $/t	100	10	60.4	50.4	10.0	90.0
RC C/lb	10	15	42.4	32.4	10.0	93.3
		20	33.9	23.9	10.0	95.0
		28	26.8	16.8	10.0	96.4
TC $/t	90	10	54.4	45.4	9.0	90.0
RC C/lb	9	15	38.2	29.2	9.0	93.3
		20	30.5	21.5	9.0	95.0
		28	24.1	15.1	9.0	96.4
TC $/t	80	10	48.3	40.3	8.0	90.0
RC C/lb	8	15	33.9	25.9	8.0	93.3
		20	27.1	19.1	8.0	95.0
		28	21.4	13.4	8.0	96.4
TC $/t	70	10	42.3	35.3	7.0	90.0
RC C/lb	7	15	29.7	22.7	7.0	93.3
		20	23.7	16.7	7.0	95.0
		28	18.8	11.8	7.0	96.4
TC $/t	60	10	36.2	30.2	6.0	90.0
RC C/lb	6	15	25.4	19.4	6.0	93.3
		20	20.3	14.3	6.0	95.0
		28	16.1	10.1	6.0	96.4
TC $/t	50	10	30.2	25.2	5.0	90.0
RC C/lb	5	15	21.2	16.2	5.0	93.3
		20	16.9	11.9	5.0	95.0
		28	13.4	8.4	5.0	96.4

Profit is indicated as (TC/RC – production cost). Fig.4.35 shows both TC and TC/RC together, along with operating costs.

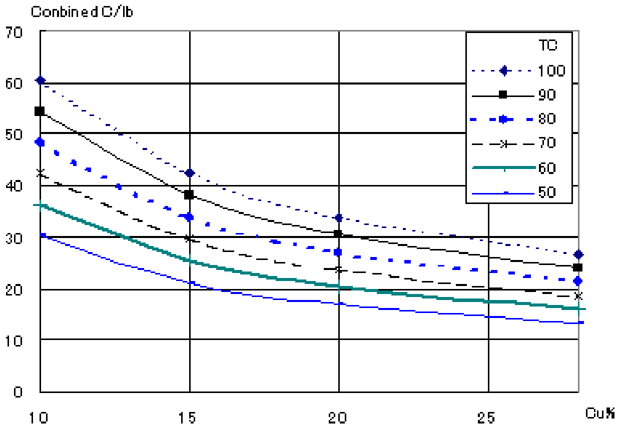


Fig.4.35 Relation between TC/RC and Operating Cost

Past trends in TC/RC are shown in Fig.4.36. The standard for copper content in concentrate is 28% Cu. According to this figure, TC/RC is changed by LMC prices. TC/RC in the RTB Bor is unknown, but sale and cost should be managed according to the international standard.

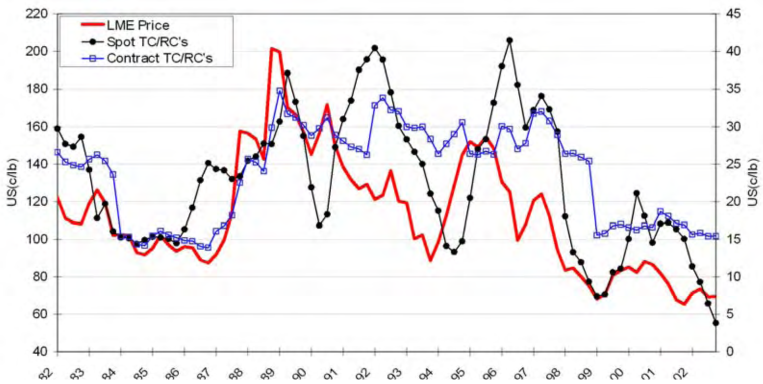


Fig.4.36 Trend of LME Copper Price and TC/RC (US /lb in 2002)

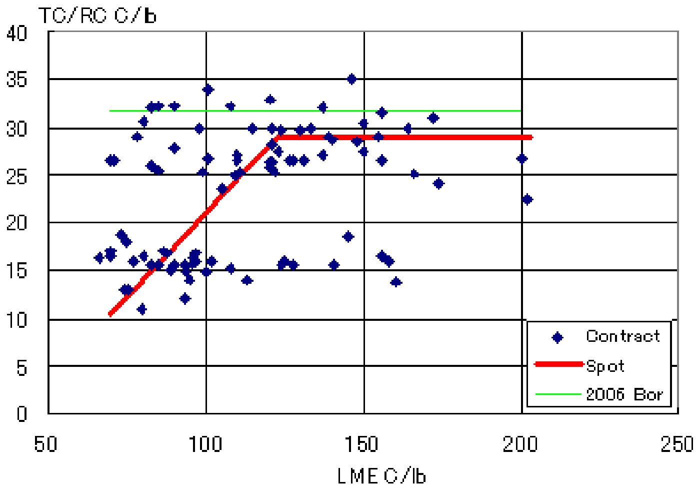


Fig. 4.37 Relation between LME Price and TC/RC

There is no specific relationship because it is determined by the supply and demand conditions of concentrate and the relation between the seller (mining side) and the buyer (smelter side). However, the maximum was something like 35¢/lb (TC/RC=130/13) and the minimum was 10¢/lb (TC/RC=40/4). Also other sources of smelter profit are described as follows..

(2) Margin Profit/Loss from Copper Recovery

Transactions in copper concentrate are based on the copper content minus 1%. In other words, if the actual recovery is higher than that, there will be a profit. Profit/loss per % of recovery is shown in Table 4.14.

Table 4.14 Marginal Profit/Loss from Copper Recovery (at 160,000t/year)

LME price $/t	$/y	$/t	C/lb
2,000.0	3,200,000	20	0.91
3,000.0	4,800,000	30	1.36
4,000.0	6,400,000	40	1.81
5,000.0	8,000,000	50	2.27
6,000.0	9,600,000	60	2.72
7,000.0	11,200,000	70	3.18
8,000.0	12,800,000	80	3.63
9,000.0	14,400,000	90	4.08

Copper recovery rate at TIR Bor is shown below.

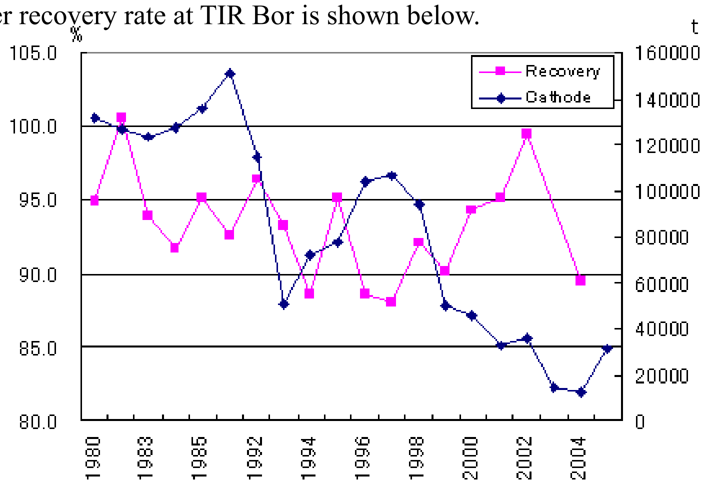


Fig.4.38 Copper Recovery Trend of the TIR Bor

The copper recovery rate has been 93% since 1980. When the copper content in concentrate is 20%, the contract recovery rate is 95%, meaning there is a loss of about 2%. At a typical smelter, the copper recovery rate is about 98% so unlike Bor, it is making a profit from copper recovery. The loss that can be measured is the slag from the reverbertory furnace, which is estimated to be 2.3%. In order to improve the copper recovery rate, Bor has been dressing the accumulated reverberatory furnace slag and recovering about 50% copper from the slag since 2001. It is necessary to investigate in detail the causes of copper loss and take proper measures to maintain at least the contract recovery rate as soon as possible.

(3) Profit from Sulfuric Acid

Sulfuric acid is produced from sulfur in the copper concentrate but sulfur is not included in the concentrate price. If it can be sold at a price higher than the operating cost, it will produce a profit. However, sulfuric acid has been in over-supply recently and it is difficult to sell it under favorable conditions. At present, the operating cost is 20 euros per ton of sulfuric acid while the sales price is 0.5 euros per ton, meaning the loss is increased when more is produced. Therefore, it is needed to use sulfuric acid. If it is viable to introduce SXEW method to extract copper from tailings which is under investigation in this study, it may be linked with a solution of the sulfuric acid problem. There are 3 sulfuric acid plants but because of the unavailability of spare parts, 2 plants are not operating.

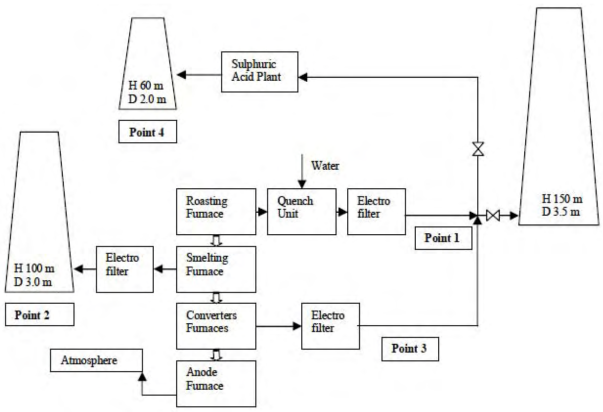
(4) Profit/Loss from Gold and Silver Recovery

The average grades of Au and Ag in concentrate in the past were 5.5g/t and 36.7g/t, respectively. Assuming that the cut-off is 1g/t Au and 30g/t Ag, the contract recovery rate will become 82% Au and 18% Ag. The actual recovery rate is approximately 95% Au and 88% Ag, meaning there is a profit from this difference in recovery. It is linked with improvement of management to manage this profit/loss from gold and silver recovery.

4.4.4 Pollution Control Measures

Present status of pollution (with low rate of operation) was studied based on " Environment Assessment of RTB Bor Operation, August 2006".

(1) Gas



Gas treatment methods

Roaster	Treated in sulfuric acid plant
Reverb. furnace	Only dust is recovered in EP.
Converter furnace	Sulfuric acid plant
Refining furnace	Not treated

Fig.4.39 Gas Flow and Gas Treatment Methods

1) SO_2 gas

a. Estimation of exhaust gas from sulfuric acid plant (not operating at full capacity)

Exhaust gas from the acid plant is discharged from a 60m high smokestack (point 4 in Fig.4.39).

	Gas volume Nm3/h	SO2 %	Dust g/Nm3
Roaster	34,211	8.8	0.04
Converter	92,905	5.6	0.52
Total	127,116	6.5	0.39

↓

Sulfuric acd plant
Conversion efficiency 95%

↓

S.A plant out	120,760	0.34

Fig.4.40 Emission of SO_2 Gas

b. Reverbaratory furnace gas

Table 4.15 Gas Emission from Reverbaratory Furnace

	Gas volume Nm3/h	SO2 %	Dust g/Nm3
Rev. furnace	55,146	0.58	1.23

Exhaust gas from the reverbaratory furnace is discharged from a 100m high smokestack (point 2 in Fig.4.39). SO_2 emission standard is 2,000 mg/m^3 (as 700ppm) in EU, and 1,200 mg/m^3 (as 420ppm) in Serbia.

2) Dust

The design specifications of electrostatic precipitators for reverberatory furnaces are 100,000Nm^3/hr (for 2 furnaces) and an outlet concentration of 0.5 g/Nm^3. However, the discharged concentration is more than twice this value despite the fact that gas flow is half of the design rate. Fig.4.39 shows the relationship between gas volume and gas density. At present, the operations involve only 1 furnace and the gas volume is 55,000 Nm^3/hr; therefore, under normal operation, the concentration should be about 0.012 g/Nm^3. But the measured figure is 1.23 g/Nm^3. This indicates that maintenance is insufficient.

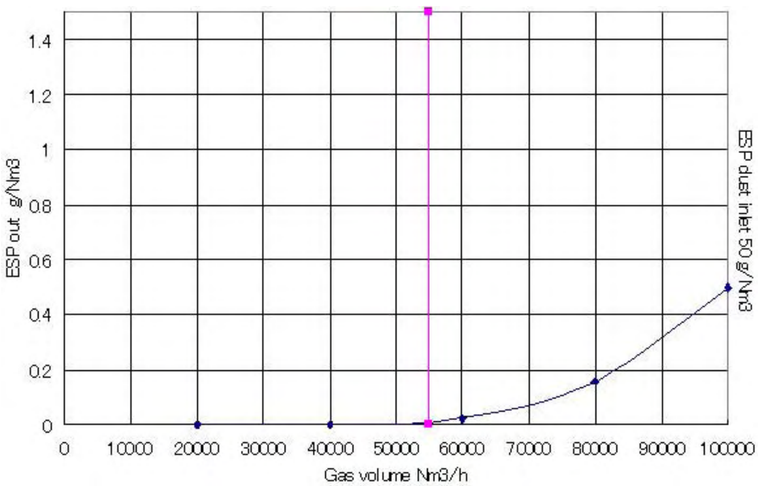


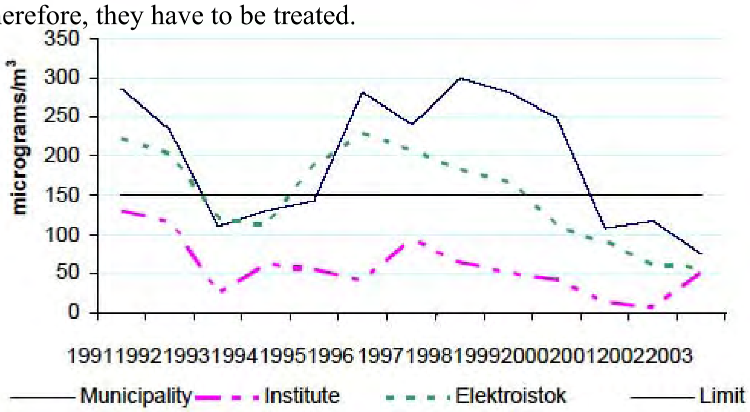
Fig.4.41 Relation between Gas Volume and Gas Density

Further, in terms of copper loss, the copper discharged as dust will become 55,000 Nm^3/hr x 1.23 g/Nm^3 x 10% x 24 hours 360 days ＝ 60t/y when the copper concentration in dust is 10%.

At a copper price of \$7,000/t, it will become a loss of \$420,000/y. It is assumed that the recovery profit will be higher than the maintenance cost. This electrostatic precipitator is scheduled for repair in September 2007.

3) Other SO_2 gas sources

Refining furnace exhaust gases are gas emitted when transporting the molten metal, and fugitive gas from converter furnace in power plant. These gases are also harmful and give impact to environment. Therefore, they have to be treated.



Year	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
Smelter production 000t.y	95.8	?	70	69	70	59.9	59	50	54	45	34	42	18

Regulation limit Serbia 150 μg/m^3 (as 0.053ppm)

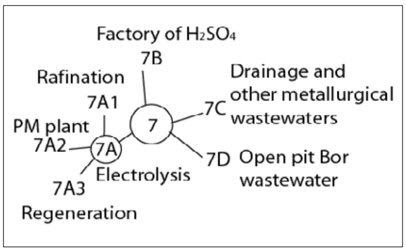
EU 125 μg/m^3 (as 0.044ppm)

Fig.4.42 Example of SO_2 Landing (Near the Bor Smelter)

The municipal government has so far installed ground level concentration meters at 3 locations around the smelter. There is also a concentration meter is installed in the central control room of the smelter. When the concentration rises above the specified level, the operation rate is decreased. There are 3 production lines in the sulfuric acid plant but at present, only line #2 is in operation.

(2) Wastewater

Emission standard and discharged locations are shown in Fig.4.43, and Serbian emission standards and guideline of the World Bank is listed in Table 4.16.



		Rafinate	Acid plant	Total
Effluent	m3/day	80	360	440
PH			1.92	
Zn	g/l	0.16	0.057	0.076
As	g/l	0.16	0.12	0.127
Cu	g/l	10	0.07	1.875
Cd	g/l		0.002	
Pb	g/l	0.0061	0.0087	0.008
Fe	g/l	0.4	1.18	1.038
S.S	g/l			
Hg	g/l			
Mn	g/l			
Mn	g/l			
Cl	g/l	0.025		
H2SO4	g/l	100	0.54	18.624
Total salt	g/l			
Soluble substance	g/l	0.48	1.5	1.315

Fig.4.43 Emission Standard and Discharged locations

Table 4.16 Serbian Emission Standards and Guideline of the World Bank

Parameter	Unit	Serbian Legislation (1) Class I and II	Serbian Legislation (1) Class III and IV	EU Legislation	WB Guidelines Mining and Milling	WB Guidelines Base Metal & Iron Ore Mining	WB Guidelines General Guidelines	WB Guidelines Copper Smelting
pH		6,8 ÷ 8,5	6 ÷ 9 (2)			6 ÷ 9		
BOD_5	mgO/1				50			-
COD	mgO/1					150	250	-
Oil and greases	mg/1				20	10	10	-
Total Suspended Solids (TSS)	mg/1	10 Class I 30 Class II	80 (2)			50		
Total Dissolved Solids (TDS)	mg/1							
Heavy metals – Total	mg/1					10		10
Arsenic	mg/1	0.05	0.05		1.0	0.1		0.1
Cadmium	mg/1	0.005	0.01	0.2 (3) (5)		0.1		
Chromium (hexavalent)	mg/1	0.1	0.1		0.05	0.1		-
Chromium Total	mg/1				1.0			
Copper	mg/1	0.1 (0.01)*	0.1		0.3	0.5		0.5
Iron	mg/1	0.3	1.0		2	3.5		3.5
Lead	mg/1	0.05	0.1	(5)	0.6	0.2		0.1
Mercury	mg/1	0.0001	0.0001	0.05 (4) (5)	0.002	0.01		0.01
Nickel	mg/1	0.05	0.1	(5)	0.5	0.5		-
Zinc	mg/1	0.2	1.0		1.0	2		1.0
Cyanide	mg/1	0.1	0.1		1.0			
Free	mg/1				0.1			
WAD	mg/1	6.0	10.0		0.5			
Temperature Increase	°C				<5°C** <3°C***			≤ 3°C****

(1) Maximum Allowable Concentrations
* for salmonides
** Max 5° C above ambient temperature of receiving waters
*** Max 3° C if receiving waters >28°
**** The effluent should result in a temperature increase of no more than 3° C at the edge of the zone where initial mixing and dilution take place. Where the zone is not defined, use 100 meters from the point of discharge.
(2) the limit value is not defined for Class IV waters
(3) Directive 83/513/EEC. Limit value applicable since 01/01/1989 to the industrial sector "extraction of zinc, refining of lead and zinc, industry of non-ferrous metals and of metallic cadmium". Average monthly concentration of total cadmium,
(4) Directive 84/156/EEC. Limit value applicable since 01/01/1989 to the industrial sector "extraction and refining of non-ferrous metals".
(5) Included in the Priority Substances list of the Decision 2455/2001/EC. According to art. 16 specific measures shall be adopted by the EC for the progressive reduction and the cessation or phasing out of discharges, emissions and losses.

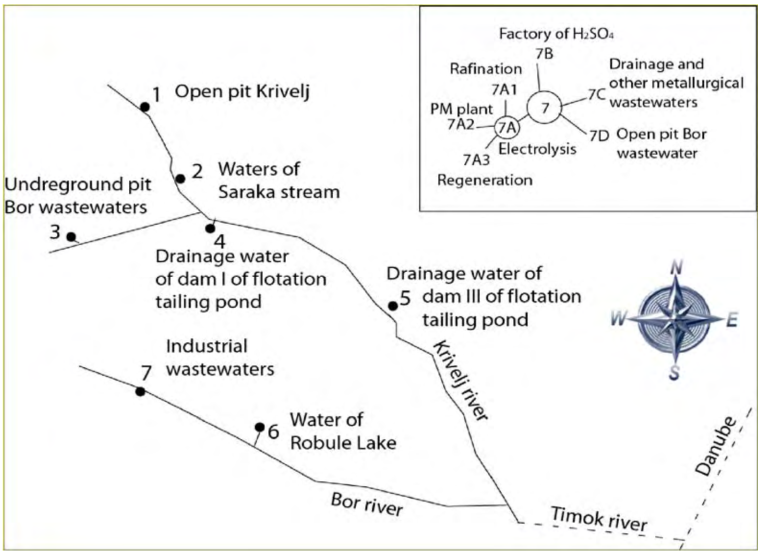


Fig.4.44 Discharged Points and Water Quality Measurement Points in the Bor Area

Table 4.17 Measured Water Quality in the RTB Bor

Sampling point	1	2	3	4	5	6	7	Standard
Water amount m3/day	2,330	3,802	3,599	1,944	3,024	484	2,330	Class IV
material	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
Fe	0.380	26.129	616.201	1.465	2.090	895.000	322.500	0.100
Cr+6+/Cr3+	0.000	0.002	0.003	0.003	0.006	0.002	0.009	0.1/0.5
Cu	127.500	76.680	174.677	0.200	0.069	55.160	54.040	0.100
Ni	0.076	0.113	0.154	0.004	0.005	0.322	1.046	0.100
As	0.000	0.004	0.244	0.006	0.040	0.001	0.017	0.050
Zn	3.100	1.020	31.327	0.311	0.219	26.500	1.920	1.000
Pb	0.000	0.009	0.007	0.009	0.009	0.010	2.083	0.100
Cd		0.011	0.026	0.002	0.003	0.034	0.225	0.010
Mn		11.490	10.043	0.633	1.063	129.000	9.630	

4.4.5 Modification of the BOR Smelter

(1) Reverbertory Furnace Process

1) the production capacity is to remain at the present 160,000 t/y, incorporating pollution control measures into present facilities.

The present reverberatory furnace process has low operating cost and when the production is increased, the operating cost can be reduced further. At present, the operation is only to treat the copper concentrate from the Bor Mine, but it may be possible to increase profits by increasing the production and minimizing the operating cost.

The operation results up to 1990 show actual production of 165,000t/y. It is possible to continue operations by conducting maintenance which had been neglected and by implementing the pollution control measures.

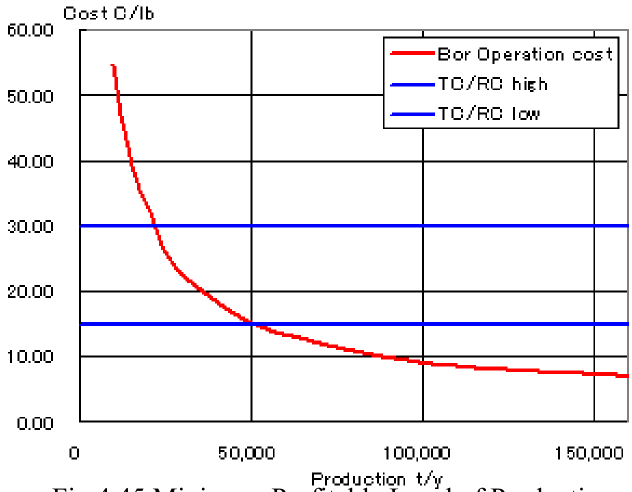


Fig.4.45 Minimum Profitable Level of Production

As shown in Fig.4.45, if the upper limit of TC/RC in the past was 30¢/lb, profit could be expected at a production level of 20,000t/y or higher and if the low limit of TC/TC was 15¢/lb, a profit could be expected at production of 45,000t/y or higher. Thus, TIR Bor should have a minimum production of 45,000 t/y.

The material balance under full-capacity operation is estimated in Table 4.18.

Table 4.18 Material Balance under Full-Capacity Operation

	OTY	Cu %	Cu	S %	S	Fe %	Fe	Si02 %	Si02
Cu CONCENTRATION	829, 165	20. 00	165, 833	34. 00	281, 916	27. 00	223, 874	9. 00	74, 625
SILICEOUS ORE	174, 398							85. 00	148, 239
SLAG CONC.	0	20. 00	0	8. 30	0	37. 00	0	10. 00	0
TOTAL	1, 003, 563	16. 52	165, 833	28. 09	281, 916	22. 31	223, 874	22. 21	222, 864
CONCENTRATION	1, 002, 560		165, 667		281, 634		223, 651		222, 641
TOTAL	1, 002, 560		165, 667		281, 634		223, 651		222, 641
FS CHARGE	1, 002, 560		165, 667		281, 634		223, 651		222, 641
RETURN DUST	65, 166	22. 40	14, 597	3. 80	2, 476	23. 70	15, 444	12. 00	7, 820
CF BOILER DUST	4, 483	25. 00	1, 121	13. 00	583	7. 00	314	10. 00	448
DUST TOTAL	69, 650	22. 57	15, 718	4. 39	3, 059	22. 63	15, 758	11. 87	8, 268
CF SLAG	274, 215	7. 80	21, 389	2. 20	6, 033	52. 00	142, 592	16. 00	43, 874
TOTAL	1, 346, 424		202, 774		290, 726		382, 001		274, 783
MATTE	460, 798	40. 00	184, 319	25. 50	117, 504	31. 10	143, 308		
REV. SLAG	636, 760	0. 57	3, 655	1. 20	7, 641	35. 00	222, 866	35. 00	222, 866
REV. DUST	65, 166	22. 40	14, 597	3. 80	2, 476	23. 70	15, 444	12. 00	7, 820
BURNT SULFER					162, 814				
TOTAL			202, 571		290, 435		381, 619		230, 686
MATTE	460, 798	40. 00	184, 319	25. 50	117, 504	31. 10	143, 308		
ANODE SCRAP	29, 490	98. 50	29, 047						
RETURN from AF	11, 496		10, 451						
SILICEOUS ORE	56, 181							80. 00	44, 945
D49 TOTAL	557, 965		223, 817		117, 504		143, 308		44, 945
MOLTEN BLISTER	203, 788	98. 00	199, 712						
CF SLAG	274, 215	7. 80	21, 389	2. 20	6, 033	52. 00	142, 592	16. 00	43, 874
CF BOILER DUST	4, 483	25. 00	1, 121	13. 00	583	7. 00	314	10. 00	448
CF EP DUST	2, 649	18. 00	477	12. 00	318	8. 00	212	15. 00	397
CF BURNT SULFER					109, 983				
CF TOTAL			222, 698		116, 916		143, 117		44, 720
REV. SLAG	636, 760	0. 57	3, 655	1. 20	7, 641	35. 00	222, 866	35. 00	222, 866
SLAG CONC.	0	20. 00	0	8. 30	0	37. 00	0	10. 00	0
SLAG TAILING	636, 760	0. 57	3, 655	1. 20	7, 641	35. 00	222, 866	35. 00	222, 866
TOTAL	636, 760		3, 655		7, 641		222, 866		222, 866
BLISTER	201, 729	99. 00	199, 712						
ANODE	190, 011	99. 50	189, 061						
CAST MOLD	3, 800	99. 50	3, 781						
REJECT ANODE	5, 700	99. 00	5, 643						
AF SLAG	1, 900	50. 00	950						
OTHERS	95	80. 00	76						
TOTAL	201, 507		199, 512						
REFINED ANODE	190, 011	99. 50	189, 061						
RECYLE ANODE	0	99. 50	0						
FS GAS					159, 558				
CF GAS					107, 783				
TOTAL					267, 341				
SULFURIC ACID	791, 196			32. 10	253, 974				
TOTAL RECOVERY %			97. 01		90. 09				

Prerequisite is shown as follows;

- Desulfurization system

The specifications of desulfurization system for 160,000 t/y production are estimated in the following table.

	Nm3/hr	SO2 %	SO2 Nm3/h
Reverberatory gas	140,872	0.75	1057
Sulfuric acid exhaust gas	278,650	0.32	900
Total	419,522	0.47	1957

- Construction cost (Lime/Gypsum process) US$30 million

- Operating cost US$ 2.1 million /y including indirect costs
  0.59 ¢/lb as 160,000 t/y copper production
  (These are very rough figures.)

- Wastewater treatment system

  At present, there is 440m3/day waste water discharge and that at full capacity operation is assumed to be 530m3/day.

  Construction cost (Neutralization + iron coprecipitation process) US$3.5 million

  Operating cost US$ 3 million /y including indirect costs
  0.85¢/lb as 160,000 t/y copper production

- Grand total for pollution control measures

  Construction cost US$33.5 million

  Operating cost 1.44 ¢/lb

It should be noted that in the World Bank Report（Environmental Assessment of RTB Bor Operation, the investment is reported as 63 million euros. This is based on the switch from reverbertory furnace to electric furnace to minimize gas generation and to do gas desulfurization.

(2) Smelting Process

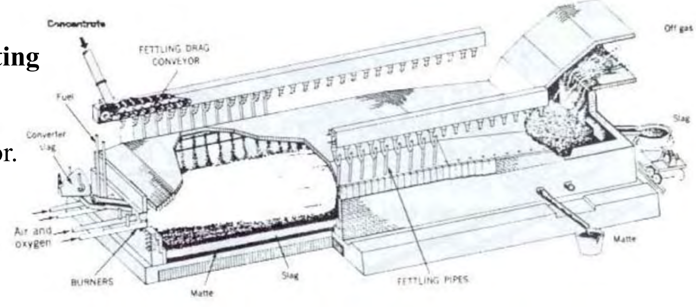
The copper smelting has a long history, and there are many processes developed. Basically, the process is divided to two steps, which are primary smelting and converting.

Many types of furnaces are used for primary smelting, but currently in most cases PS converter is used for converting.

1) The first Step of Copper Smelting

A. Reverberatory Furnace

This furnace is used in RTB Bor.

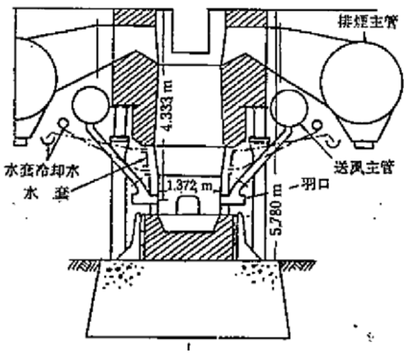


The huge amount of exhaust gas is generated. And SO_2 concentration in the gas is less than

1%, so this gas cannot be treated in the sulfuric acid plant. Reverberatory furnace is now being changed to other type of furnace.

Converter treats further the produced matte. But the copper content in this matte is low, so the load of converter is high.

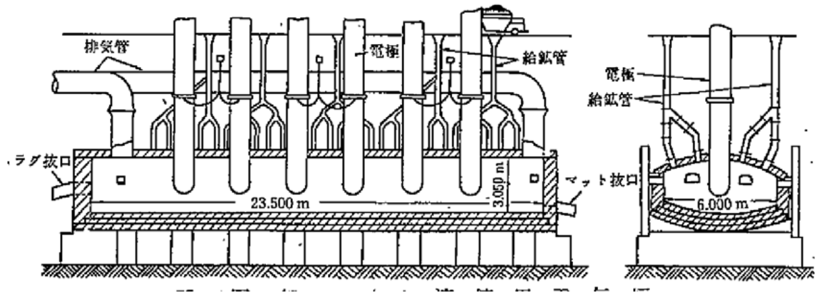
B. Blast Furnace



The material and fuel should be in solid form. The SO_2 concentration in the gas is less than 1%, so this gas cannot be treated in sulfuric acid plant. And the blast furnace is not suitable for mass production, so the blast furnace is recently being switched to other type of furnace.

Converter treats further the produced matte. But the copper content in this matte is low, so the load of converter is high.

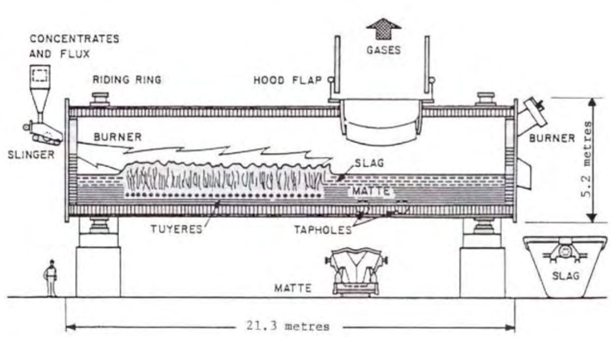
C. Electric Furnace The purpose of this furnace is melting the concentrate only. For the smelting function, a roaster is necessary before the electric furnace.



The huge amount electric power is consumed, so this furnace is used only at the location where the power cost is cheap.

Converter further treats produced matte. But the copper content in this matte is low, so the load of converter is high.

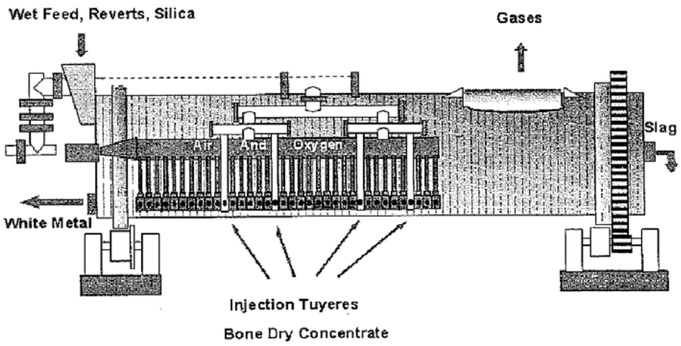
D. Noranda Furnace



The SO_2 concentration in the exhaust gas is high, so this gas can be treated in the double contact type sulfuric acid plant. (Refer to 5.1.2.3)

Converter further treats produced matte. The copper content in this matte is high, so the load of converter is low.

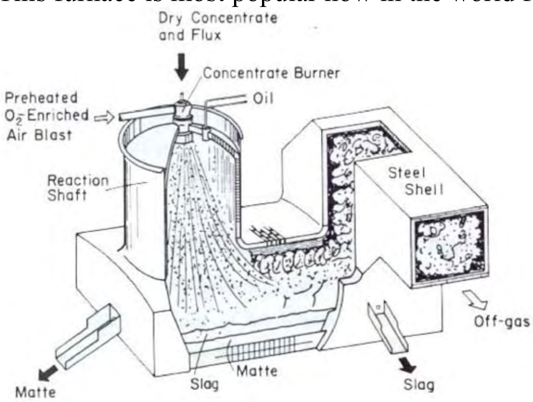
E. CMT It is very similar to Noranda furnace.



The SO_2 concentration in the exhaust gas is high, so this gas can be treated in the double contact type sulfuric acid plant.

Converter further treats produced matte. The copper content in this matte is high, so the load of converter is low.

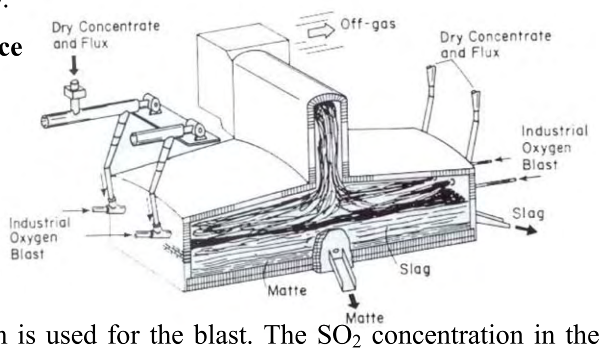
F. OKO Flash Furnace This furnace is most popular now in the world for primary smelting.



The SO_2 concentration in the exhaust gas is high, so this gas can be treated in the double contact type sulfuric acid plant.

Converter further treats produced matte. The copper content in this matte is high, so the load of converter is low.

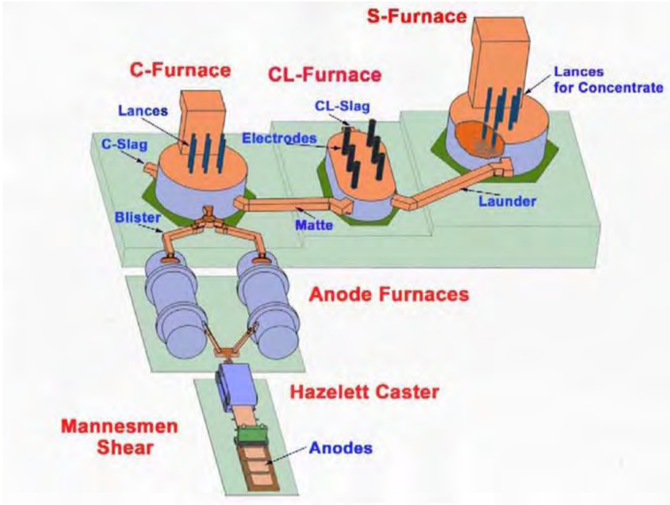
G. INCO Flash Furnace



100% oxygen is used for the blast. The SO_2 concentration in the exhaust gas is high, so this gas can be treated in the double contact type sulfuric acid plant.

Converter further treats produced matte. The copper content in this matte is high, so the load of converter is low.

H. MI Process



This process is operated continuously from the primary smelting to the anode furnace. The SO_2 concentration in the exhaust gas is high, so this gas can be treated in the double contact type sulfuric acid plant. C-furnace has converting function.

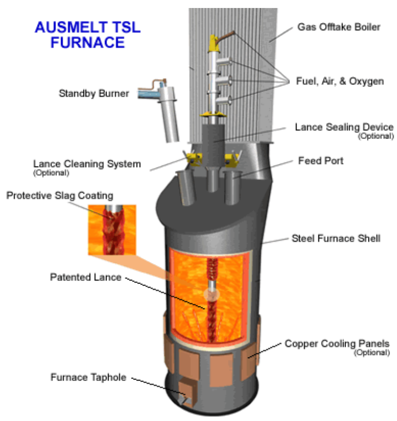
The continuous operation means that no fugitive gas is generated from ladle of molten matte and blister. MI process is the most environmental friendly at present.

I. ISASMELT furnace（Refer to Fig. 4.46）

The SO_2 concentration in the exhaust gas is high, so this gas can be treated in the double contact type sulfuric acid plant. The copper content in this matte is high, so the load of converter is low.

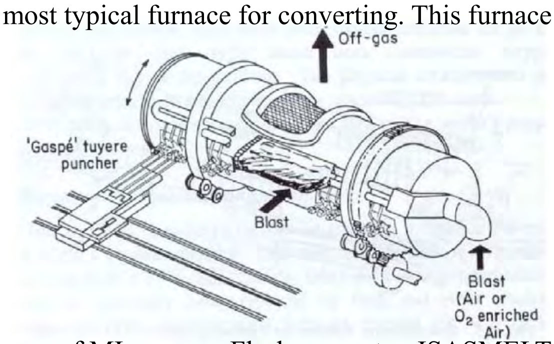
J. AUSMELT Furnace It is very similar to ISASMELT.

The SO_2 concentration in the exhaust gas is high, so this gas can be treated in the double contact type sulfuric acid plant. The copper content in this matte is high, so the load of converter is low.



2) Second Step (Converting)

PS converter is most typical furnace for converting. This furnace is used in RTB Bor.



Recently, C-furnace of MI process, Flash converter, ISASMELT and AUSMELT are being used instead of PS converter for the converting process.

3) Sulfuric Acid Plant

There are tow types, namely, single contact type and double contact type. The SO_2 gas in the smelting gas reacts with oxygen and turns to SO_3 at over 410 ℃ condition. This reaction generates heat. 95% of SO_2 turns to SO_3. SO_3 is absorbed in water and turns to sulfuric acid.

The reaction heat keeps the reaction temperature. If the SO_2 concentration in the gas is too low, the reaction temperature cannot be maintained due to a lack of generated heat. This is called as a single contact system.

Remaining 90% SO_2 gas after absorbing SO_3 can react with oxygen again and generates SO_3. This SO_3 gas is absorbed in the water and turns to sulfuric acid. This process is called as a double contact system. Total 99.5 % SO_2 gas is removed by the double contact system.

SO_2 gas concentration is required to be 4% or more for single contact and 6% or more for double contact to maintain the reaction temperature without out side heat. In case of 6% SO_2 concentration in the material gas, the treated SO_2 gas concentration is 3,000ppm by single contact system sulfuric acid plant and 300ppm SO_2 by double contact system sulfuric acid plant. The exhaust gas from rebervertory furnace contains only 1 % or less SO_2, so this gas cannot be treated in the sulfuric acid plant. The sulfuric acid plant at Bor is a single contact system and the materials are the exhaust gas from roaster and converter.

The treatment of 1% or less SO_2 concentration gas such as reverberatory furnace gas is done in a desulfurization plant, which fixes SO_2 by alkali. .

(3) Implementing a New Copper Smelting Process

Table 4.19 shows a comparison of operating costs among smelting processes. The areas are divided because the labor cost and energy cost are different in each area.

The smelting cost of reverbertory furnaces is the second highest in all areas following blast furnaces. At Bor, there is a special situation in that the smelting cost is low because of the low unit costs of energy and manpower, but as internationalization progresses, there is a likelihood that smelting costs will increase.

Table 4.19 Comparison of Operating Costs by Smelting Process (direct cost)

Smelting cost C/lb 1993

	Africa	Asia	Australia	W Europe	Latan America	N.America
Reverberatory	8.8	25.1		28.2	10	16.6
OKO Flash		17.8	5.7	16.4		11.3
Inco flash						12.6
Noranda						13.6
MI		20.1				9.9
ISASMELT			12.4			12.6
Blast	27.6				39.8	
Electric	7.6	10.6		23.4		
Noranda			12.6			
CMT					9.7	

1) New Smelting Process

In the new smelting process, the functions of the roasting furnace and reverbertory furnace of the Bor will be performed by only one furnace. This will eliminate production of low-concentration SO_2 gas from the reverbertory furnace and will allow the use of a double contact system sulfuric acid plant that requires rich SO_2 gas. In this double contact system sulfuric acid plant, the conversion rate to sulfuric acid can be improved by a single contact system from the present 95% to approximately 99.5%, thus eliminating the need for a separate desulfurization plant. The mainstream smelting process has been transitioning from Flash -> MI-> CMT->ISASMELT or AUSMEL (Fig.4.46).

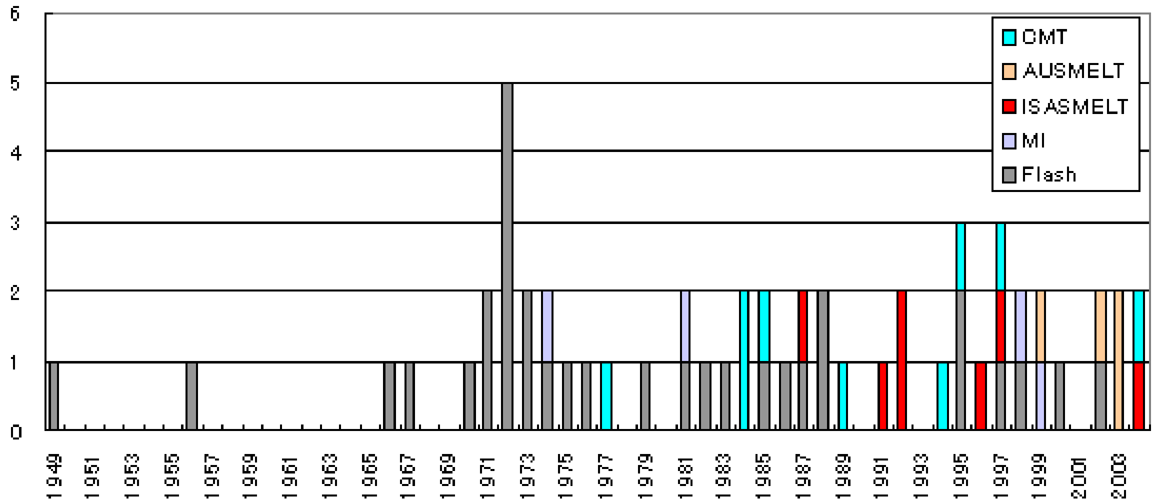


Fig.4.46 Trends in the Use of the New Smelting Process

The TIR Bor was planning to convert to the new process in 1979, 1990 and 1998, but it still has not been materialized. Its reason was not known. The large investment needed for this undertaking requires the approval of RTB Bor, which means government approval. Therefore, it was guessed that the TIR Bor could not attain the government approval.

2) Example of ISASMELT

a. Process Flowchart is shown in Fig.4.47.

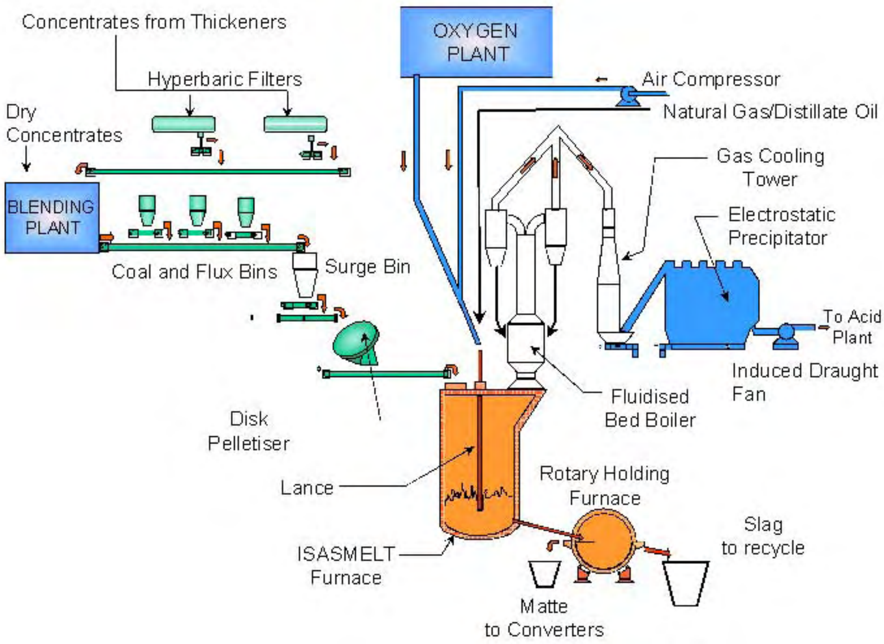


Fig.4.47 Flow Sheet of ISASMELT

b. Main operating parameters

Table 4.20 Main Operating Parameters

Parameter	Rate	Unit
Concentrate Rate	160	tph
Dry Concentrate Assay	23.8	%Cu
Silica Flux	3.4	tph
Reverts	1.6	tph
Coke Breeze	0.7	tph
Natural Gas	706	Nm3/h
Lance Air	20,210	Nm3/h
Lance Oxygen (95%)	23,580	Nm3/h
Lance Oxygen Enrichment	60.8	%
Bath Temperature	1172	degC
Matte Grade	57.0	%

c. Operating costs

It is reported that this process is the one with lowest operating costs. (Approx. 10¢/lb vs. BOR Smelter 21.7¢/lb)

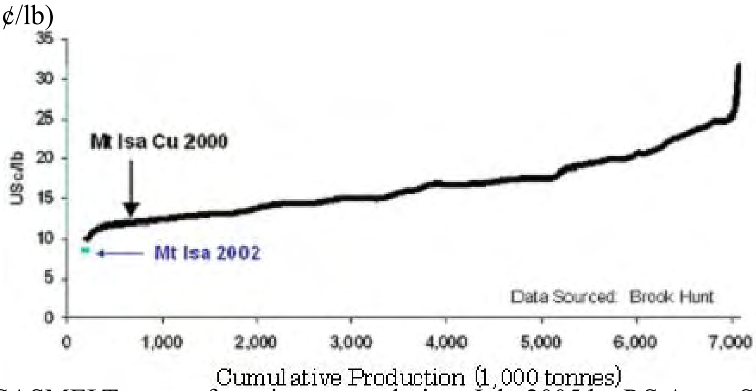


Fig.4.48 ISASMELT-years of continuous evolution; July 2005 by P.S.Artur, S.P.Hunt

d. Example of ISASMELT

Sterite Tuticorin of India has expanded production to 120,000 t/y recently by converting to the ISASMELT Process. The construction cost is reported to be approx. US$87 million. (Scope is unknown.) It is necessary to replace the existing single contact system sulfuric acid plant with a double contact system (together with a wastewater treatment plant).

US$140 million

Total investment Approximately 140+87= US$230 million

The downstream process starting from the converter furnace can be continued without modification. It should be noted that In the World Bank Report"Environmental Assessment of RTB Bor Operation", the investment is reported to be 250 million euros. The material balance of the ISASMET Process is shown below.

Table 4.21 Material Balance for ISAMET

	OTY	Cu %	Cu	S %	S	Fe %	Fe	SiO2 %	SiO2
Cu CONCENTRATION	821,072	20.00	164,214	34.00	279,164	27.00	221,689	9.00	73,896
SILICEOUS ORE	132,052							85.00	112,244
SLAG CONC.	8,829	20.00	1,766	8.30	733	37.00	3,267	10.00	883
TOTAL	961,953	17.25	165,980	29.10	279,897	23.39	224,956	19.44	187,023
CONCENTRATION	961,953		165,980		279,897		224,956		187,023
TOTAL	961,953		165,980		279,897		224,956		187,023
ISASMELT CHARGE	961,953		165,980		279,897		224,956		187,023
RETURN DUST	62,527	22.40	14,006	3.80	2,376	23.70	14,819	12.00	7,503
CF BOILER DUST	4,483	25.00	1,121	13.00	583	7.00	314	10.00	448
DUST TOTAL	67,010	22.57	15,127	4.42	2,959	22.58	15,133	11.87	7,952
CF SLAG	92,133	7.80	7,186	2.20	2,027	52.00	47,909	16.00	14,741
TOTAL	1,121,095		188,293		284,883		287,998		209,716
MATTE	298,325	57.00	170,045	22.61	67,451	16.14	48,150		
ISASMELT SLAG	588,608	0.69	4,054	0.69	4,061	38.18	224,741	31.82	187,284
ISASMELT DUST	62,527	22.40	14,006	3.80	2,376	23.70	14,819	12.00	7,503
BURNT SULFER					210,709				
TOTAL			188,105		284,598		287,710		194,788
MATTE	298,325	57.00	170,045	22.61	67,451	16.14	48,150		
ANODE SCRAP	29,490	98.50	29,047						
RETURN from AF	11,496		10,451						
SILICEOUS ORE	19,582							80.00	15,665
D49 TOTAL	358,892		209,544		67,451		48,150		15,665
MOLTEN BLISTER	203,788	98.00	199,712						
CF SLAG	92,133	7.80	7,186	2.20	2,027	52.00	47,909	16.00	14,741
CF BOILER DUST	4,483	25.00	1,121	13.00	583	7.00	314	10.00	448
CF EP DUST	2,649	18.00	477	12.00	318	8.00	212	15.00	397
CF BURNT SULFER					64,186				
CF TOTAL			208,496		67,114		48,435		15,587
ISASMELT SLAG	588,608	0.69	4,054	0.69	4,061	38.18	224,741	31.82	187,284
SLAG CONC.	8,829	20.00	1,766	8.30	733	37.00	3,267	10.00	883
SLAG TAILING	579,779	0.39	2,288	0.57	3,329	38.20	221,474	32.15	186,401
TOTAL	588,608		4,054		4,061		224,741		187,284
BLISTER	201,729	99.00	199,712						
ANODE	190,011	99.50	189,061						
CAST MOLD	3,800	99.50	3,781						
REJECT ANODE	5,700	99.00	5,643						
AF SLAG	1,900	50.00	950						
OTHERS	95	80.00	76						
TOTAL	201,507		199,512						
REFINED ANODE	190,011	99.50	189,061						
RECYLE ANODE	0	99.50	0						
ISASMELT GAS					209,656				
CF GAS					62,903				
TOTAL					272,558				
SULFURIC ACID	840,601			32.10	269,833				
TOTAL RECOVERY %			97.83		96.66				

4.4.6 Plan for Improving the Program

Assuming privatization, tentative improving program and scheduling is shown as follows;

(1) Countermeasure against Pollution

1) Air Pollution

As a first step, the priority should be given to re-starting of existing sulfuric acid plants that have been shut down due to lack of spare parts.

At present, Bor has two reverberatory furnaces and one is in operation, but only one sulfuric acid plant out of three is operated. The gas processing capacity is not in proportion to production amount of copper, but to the number of reverberatory furnaces in operation. It seems that the operation of two sulfuric acid plants is necessary. It is very likely that a part of the exhaust gas (about 5 or 6 % of SO2) from a roaster and from converter is discharged from a stack without being treated because of lack of capacity of sulfuric acid plant.

The air antipollution measure should be given priority to in terms of time, and it is necessary therefore to return to the original design capacity of the existing facilities, and to settle the deficiency of the existing facilities ability.

As a second stage, it is necessary to reduce the SO2 discharge from the smelting facilities in operation. In the first stage, the lack of capacity of existing facilities should be determined and decide the remodeling specifications. Based on the current information, the desulfurization processing objective is mainly the reverberatory furnace exhaust gas (55,146Nm3/hr, 0.58% SO2) and sulfuric acid plant exhaust gas (120,760Nm3/hr, 0.34% SO2). As for the desulfurization method, the process that matches the geographical convenience of BOR should be chosen.

Generally, the SO2 removal rate of desuslfurization plant is expected to be around 90%, therefore, the ground level SO2 concentration can be expected to become 1/10 of that shown in Fig.4.41 by installation and it can be expected to become lower than EU regulation value. （The above gas specifications should be decided based on a future rate of operation.）

In the third stage, the establishment of the SO2 removal facilities matched with remodeling of smelting process is necessary. A long construction period may become necessary in order to make a decision of the plant capacity, the choice of smelting process, preparation of a large amount of investment. So, it is desirable to carry out this stage in two steps.

Meanwhile, if the production cost by a reverberatory furnace process does not have a problem, the reverberatory furnace process may be continued, but in that case, the investment for the pollution prevention facilities that matches the increase of production capacity is necessary.

2) Effluent

An existing plant has only wastewater treatment facilities for #3 sulfuric acid plant. It is necessary to expedite the decision on the quantity and the quality of wastewater of sulfuric acid plants, refinery and others, and it is necessary to start the construction of wastewater treatment facilities immediately.

(2) Plan for Improving Schedule

a. 2007 Selection of desulfurization process Cu production 40,000 t/y
Order for wastewater treatment facility

b. 2008 Order for desulfurization plant, construction Cu production 40,000 t/y
Completion of the wastewater treatment facility
Ameliorate poor maintenance including restoration of acid plant

c. 2009 Completion of the desulfurization plant Cu production 40,000 t/y
Start operation of the wastewater treatment facility
Ameliorate poor maintenance including restoration of acid plant

d. 2010 Start operation of the desulfurization plant
Production expansion by reverb. furnace Cu production 160,000 t/y
When concentrate from Bor mine is not enough, imported concentrate is used.

e. 2011 Start research on the introduction of a new smelting process
Determine production capacity, select smelting process, execute feasibility study, etc.

f. 2013 Place order for new smelting process

g. 2017 Start operation of new smelting process plant

4.4.7 The Zorka Zinc Smelter/Refinery

(1) Production Trend

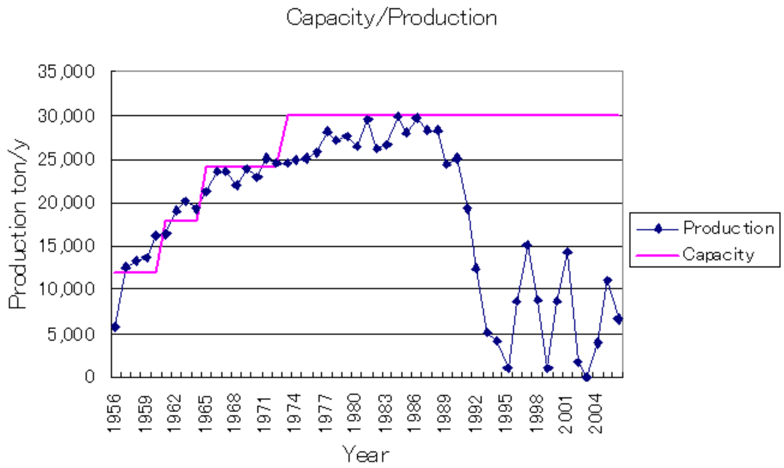


Fig.4.49 Production of Zinc in the Zorka Smelter

Similar to the Bor Smelter, the Zorka Zinc Smelter/Refinery had been steadily increasing production. However, production dropped sharply because of the outbreak of the war in 1990 and the subsequent economic sanctions by EU countries. In 2006, production was 6,000 tons compared with an annual production capacity of 30,000 tons.

(2) Process

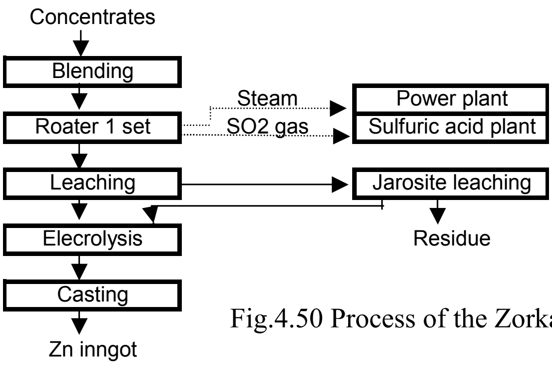


Fig.4.50 Process of the Zorka Smelter

Steam from the roaster boiler is sold to an electric power company. SO2 is sold to a fertilizer company. The residue treatment system is a jarosite process.

(3) Issues

1) Cannot procure concentrate
2) 10% zinc remains in residue and the zinc recovery rate is 87%.

4.4.8 Current State and Task of Metallurgical Education

In Serbia, metallurgical education is provided at the Faculty of Metallurgy in the University of Beograd and at Technical Faculty of the University of Beograd in Bor.

Beograd HQ	Student capacity 80/year, faculty- 5 years Professors (including assistant and associate professors) 19 (12 are women) In 1995, it was a big organization with 55 professors, 29 assistant professors, 27 associate professors, 90 assistants. There are 8,058 graduates.
Bor faculty	3 professors, 3 assistant professors, 0 associate professors, 3 assistants, 5 students

The Technical Faculty in Bor offers 6 courses, namely Mining, Metallurgy, Technology, Management, Information and Electrotechnique, with 15 professors, 12 assistant professors, 10 associate professors, 19 assistants, and 21 others. Thus there are many instructors, but recently, there has been much more interest in popular courses like management and there are only a few students in metallurgy. Thinking of the Bor Smelter in the future, improvement shown in 4.4.6 should be implemented to recover production, and it would be linked with employment of students and fosterage of successors. It is necessary to restudy appropriate scale of metallurgical education (professors, staffs, student), based on the current state smelters (TIR Bor and Sabac) as well as application fields of metallurgy.