

GOLD DEPOSIT EXPLOITATION IN ROMANIA

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Abstract

The Romanian territory hosts several gold deposits which have been mined and processed until the beginning of the III millennium when because of the domestic economy decline, the gold mines were closed.

It is to be noted the situation of the gold mines at the time when the decision about their closure was made and it is to be discussed whether under the current economy circumstances, the Romanian State should or should not reconsider their situation and to partly resume the gold deposit mining.

Key words: ore deposit, vein, method, extraction, processing.

I. Introduction

The Romanian territory covering a surface area of 237,500 km², is characterized by a largely diversified geological structure. Most of the territory belongs to the Alpine orogene zone with tertiary volcanism and includes young mountains, hills, plateaux and field intercalated in tectonic depressions containing rich and varied useful mineral deposits such as: mineral fuels, precious metal ores, ferrous metal ores, non-ferrous and rare ores, non-metalliferous minerals etc.

The presence of the numerous useful mineral deposits on the Romanian territory much influenced the economy condition of the country. The metalliferous ore mining and processing has been developing or regressing throughout the time, but it had never been stopped completely as it happened some years ago.

The gold-silver ore deposit occupies a special place among the metalliferous deposits of Romania.

Throughout the years, on the Romanian territory there were revealed and outlined several mineralization zones, of which some were mined out and depleted and others had been mined until 2006 when for economic reasons, all the metalliferous ore mines of Romania were closed (see figure 1).

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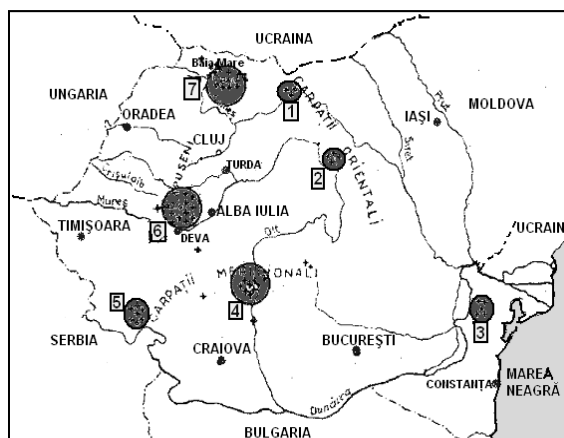


Fig. 1 Distribution of metalliferous regions of Romania: 1- Bucovina; 2- Oriental Carpathians; 3- Dobrogea; 4- Meridional Carpathians; 5- South Banat; 6- Metalliferous Mountains; 7- Maramureş

The most important gold region of Romania are: Baia Mare and the Golden Quadrilateral of Apuseni Mountains.

The metalliferous ore deposits of Baia Mare Region are part of the metal genesis province of the Neogene eruptive. They extend between Ilba and Botiza along 60 km and their maximum width is 12 km. The metalliferous deposits of this region include two main types of deposits: base metal sulphides and native gold deposits.

The main base metal sulphide ore deposits are found at: Ilba, Nistru, Herja, Baia Sprie, Cavnic, Văratice and Băiţ.

The native gold deposits occurring as gold veins, at Băiţa, Săsar, Valea-Roşie, Dealul Crucii and Şuitor are situated at the central part of the mineralized area being associated to the eruptions of andesites, thiolites and dacites which took place in the area.

The veins of Baia-Mare region are minimum 0.4 ÷ 1.0 m wide, their average width being 1.5 ÷ 3.0 m while their maximum width is 5.0 ÷ 10 m, and they reach depths of several hundreds meters and their length range between 200 ÷ 300 m and 1.000 ÷ 2.000 m. The gold content is ranging between 1.5 ÷ 2.2 g/t gold and 4.0 ÷ 4.5 g/t Gold.

The gold deposits situated between Mureş river, to the South and Arieş river to the North are hosted by a sub-unit well defined from structural petrography and morphology point of view known as **Metalliferous Mountains**, where the „**Golden Quadrilateral of Apuseni Mountains**” is located (see figure 1), with the localities: Baia de Arieş, Zlatna, Săcărâmb, Topliţa and Caraci [1], [4].

Referring to the types of deposit from the Golden Quadrilateral of Apuseni Mountains the following forms were distinguished: simple veins, vein networks, stockworks, lenses, and impregnations.

The telluride veins are mostly found in the deposits of the golden quadrilateral borders of Apuseni Mountains while the native gold veins occur in the deposits situated inside the quadrilateral.

The native gold occurs in nests impregnated in the gangue or sulphides. At some places, there are gold nests and veinlets as plates, threads or even octoedric crystals, and at others, as small gold crystals with the side of $3 \div 4$ mm associated to pyrite, blenda and galena and quartz, calcite and rodochrosite (fig. 2). In other deposits the gold impregnation occurs as fine particles with small sizes that after the gold washing there results a gold powder which hard to be seen.

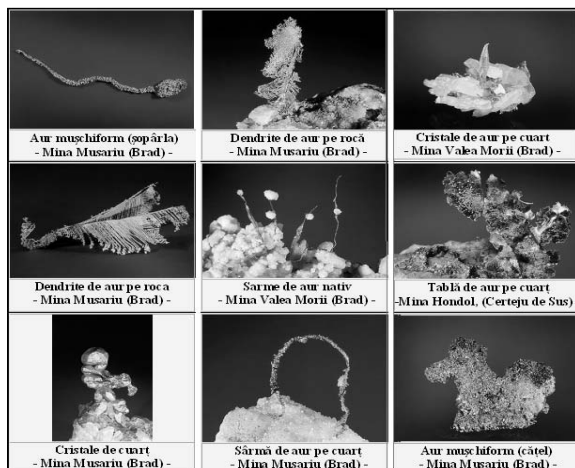


Fig. 2 Different occurrences of native gold

The veins of the golden quadrilateral of Apuseni Mountains are $0.2 \div 2.0$ m thick, variable inclination which may reach $70 \div 80^\circ$, depth up to 450 m and length between several tens of meters up to $800 \div 1,000$ m. The grade is varying between 1.0 g/t gold and maximum 5.0 g/t gold.

Besides it, in the „Golden Quadrilateral of Apuseni Mountains” there are many deposits of Porphyry copper type which show sub-volcanic bodies, mostly andesites of cylinder shape, crossing over the andesite – quartziferous formations of the basement, sedimentary formations and detritus sediments of the surface [5].

Most of the bodies, to the edge and to the upper part of the Porphyry copper mineralization gold-silver veins are developed and they are accompanied by argillaceous alterations (caolinite, montmorillonite, illite) and phyllic (quartz, sercite and clayous minerals).

2. Brief history, gold content of deposits and production rates during different periods

The gold contained in the deposits hosted in Romanian subsoil represented and still representing one more of the main wealths of the country. These wealths had been mined out much time before our era by the Scyths, Agtharians, Dacians and later on the Romans [1].

The old historical documents indicate that a branch of Greek people of the VII BC century had information about the gold deposits of this part of Europe and consequently they came in Apuseni Mountains area where they involved with the exploitation and beneficiation of the gold deposits.

In the beginning, due to its bright colour, gold was recovered by simple collection of nuggets and gold leaves from river placers or by washing it (concentration) of lower grade placers using simple old tools, (fig. 3) such as pan, etc.

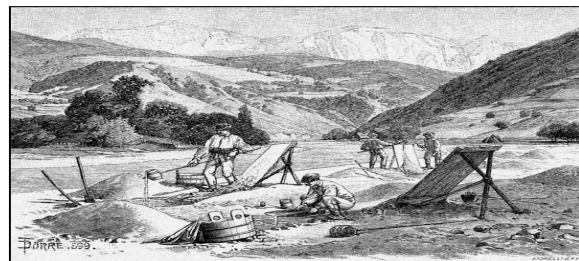


Fig. 3 Overview of the rudimentary exploitation of gold placers

Later on, gold was found in gold veins occurring at surface and were easy to mine out. Thus, the second stage of gold recovery started – mining stage. The gold quartz veins were mined out first by trenches, shallow pits and then with galleries. The mined out ore was crushed in a mill machine and then ground in a grinder, (fig. 4).

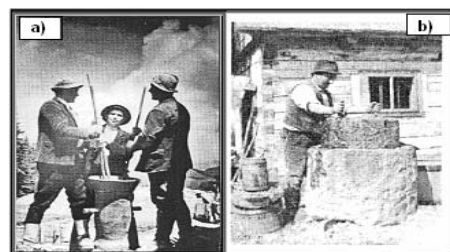


Fig. 4 The manual gold ore mining:
a) crushing b) grinding

In the gold regions of Transylvania, along Aries, Olt, Mures, Bistrita Aurie streams and their tributaries there lived natives and nomad gipsies whose main activity had been gold sand washing for years.

Quartz and kaoline which form the waste fraction of the ground material was lighter and removed by the water which, mixed with the

ground material formed the pulp, and the gold veinlets being heavier fell at the base of the vessels where the material was collected in the pans and could be separated from the other minerals.

The processing methods of gold ore started to get improved more and more and the ore was crushed in special units called stemples, (fig. 5). In the early stage, these installations were manually operated and then the animal force was used to operate them and finally the falling water force while during the last century these were operated by power force using the steam engines and electric ones.

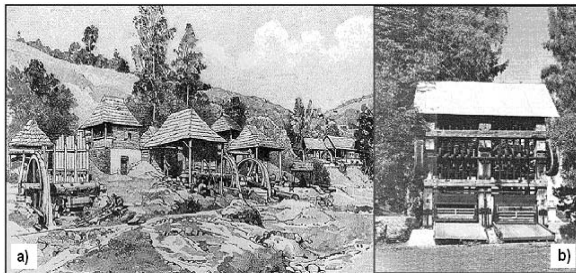


Fig. 5 The gold ore crushing in stemples:

- a) simple stemples with wood arrow;
b) „California” type stemples with metal arrows

At stemples, the gold wool was collected first on tables covered with wool cloths and later by amalgamation with mercury on copper tables.

The Daces were our ancestors whose occupation was dealing with the gold mining. The fame of the rich gold mines held by the Daces determined Traian, The Roman Empire Emperor to begin the war against Decebal, King of Dacia. Further to the war of 105-106 AC the Romans occupied most of the Dacia territory and turned the country into a Roman Empire Province.

Once the Romans occupied Dacia, gold mining was more and more developed. Skilled miners from Dalmatia, Minor Asia and other regions of the Empire were brought here and they improved the gold ore exploitation and processing methods.



Fig. 6 The Cârnic Massif of Roșia Montană was penetrated by the old mining works

The most intense mining works had been focused during the 166 years of Roman ruling on the gold deposits of: Roșia-Montană, Bucium,

Zlatna, Almaș, Stănița, Ruda and Caraci. During the Roman times the underground mining was largely extended and in some mines they reached 300 m depths. The Roman galleries of Cârnic Massif from Roșia-Montană (Apuseni Mountains) totalize about 2.5 km long and were developed on 7 levels (fig. 6).

The gold production during the Roman occupation was about 3,000 kg pure gold by year and the silver amount was almost double. So, during the 166 years of Roman occupation it was estimated that the Romans mined out about 500 tonnes of gold and 950 tonnes of silver from Dacia.

The beginning of the gold mining in our country interweaves with the Romanian people history. Since then, gold mining has been developing continuously even if sometimes the development rate slowed down because of the hostilities during the centuries. In the years following the Roman retreat from Dacia, for more than 100 years (272-395) the gold production was dropping, achieving only 100 kg/year. This activity revival commenced early in the II millennium AC and largely developed in Europe around the year 1320 when gold mining development actually started up in Transylvania.

During the Middle Ages (396-1492) it is estimated that gold production achieved 450 kg/year. After the year 1500 there was a revival of the mining activity for gold extraction and thus we noticed the enhancement and maintenance of high production rate of over 1.000 kilos per year.

Briefly, it can be noticed that since the gold mining start up on Romanian territories and until today there were mined and rendered valuable more than 2,200 tons of gold, the production was varying during different periods as shown in the table 1:

Table 1 Gold production extracted from the Romanian territory

	PERIOD		GOLD AMOUNT (kg)
I	Ancient Times		720,500
II	Middle Ages	396 ÷ 1492	492,750
III	Middle Ages	1493 ÷ 1943	746,827
	and	1944 ÷ 1947	28,300
	Contemporary period	1948 ÷ 1960	70,000
		1961 ÷ 2005	215,384
TOTAL			2,273,761

It is interesting to notice that until the year 1600, the gold mines of Apuseni Mountains and from Baia-Mare zones produced about 20% of the world gold production and when Habsburg ruling started in Transylvania, gold mining developed even more.

In the XX century the gold production of Romania had been continuously decreasing. Thus,

in the period between 1944-1947, approximately 7.0 tonnes of gold by year, in the period 1948-1960 it decreased to 6.0 tonnes per year and between 1961-2000 the production was of 5.0 tonnes per year. Since 2000 until 2005 approximately 2.5 tonnes of gold per year were obtained and since 2005 until 2010, the production has been only 500 kg gold per year and this amount resulted at the processing of secondary resources.

As a result of the long time mining of the gold deposits on Romanian territory, the gold grade of the mined out ores much decreased from one period to another while the involution with the time of the industrial grades is shown in table no.2:

Table 2 *Gold grade of ores mined out on Romanian territory*

No.	Period of time	Industrial grades g /t Gold
1	1920 ÷ 1940	10 ÷ 20
2	1940 ÷ 1960	4 ÷ 10
3	1960 ÷ 2006	1 ÷ 3

The production costs of gold mines of Romania remained high because of the labour force and of the difficult geological mining conditions which required the use of underground mining and at high depths for most deposits.

Taking into account the average grades of our deposits and the estimated reserves disclaimed on different occasions by the entitled Government authorities, it can be estimated that Romania still has more than 150 million tons of gold-silver ores on its territory which can be mined out and sold with profits.

3. Opening, preparation and mining of gold-silver deposits

During the last decades, the gold-silver ore reserve mining in Romania was carried out by mining works performed in the underground mines of Brad, Baia de Arieș, Zlatna, Certej-Săcărâmb, Bolcana, Șuitor, Săsar, Baia-Sprie, Ilba, Nistru, Herja and Băiuț as well as by open pit operations in Roșia-Montană, Valea - Morii, Coranda - Hondol, Șuitor and Bolcana [4] [5].

The particular variety of Romanian deposit occurrence as well as the surrounding land shape required the use of adits or vertical shafts for the opening of the deposits in order to prepare them and for their underground mining.

Most of the mines included a developed and complicated network of works with horizontal extension over several horizons which determined the difficult organization of activities and high transport expenses, a aeration, water discharge, maintenance and lighting, (figure 7). The open pit

opening works was carried out using some trenches and semi-trenches with complex routes and spiral return ways or one lane traffic, as the deposits are situated in mountaineering zones characterized by uneven relief with deep valleys and steep slopes.

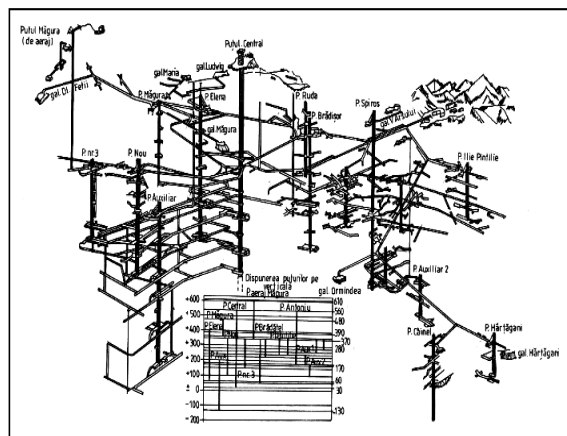


Fig. 7 *Opening of the vein deposit of Barza – Brad*

The exploitation methods and working technologies used in our mines have been developed and implemented considering the technical and mining conditions, the existing financial opportunities and resources for purchasing the range of machines and equipments necessary for the technological process.

If the exploitation methods were the most suitable ones for the deposit, the equipments used for drilling, blasting, loading and transport have not caught up with the modernization and consequently, a whole range of machines and equipments were much less reliable than the ones used worldwide by famous companies in the field.

The particular variety of the deposits indicated by the accumulations of ores in the fissures as stocks and lens developing over hundreds of meters horizontally and vertically as well as the resistance of the surrounding rocks determined the design and putting into practice of a wide range of exploitation methods, and the most used were those of figures 8 and 9.

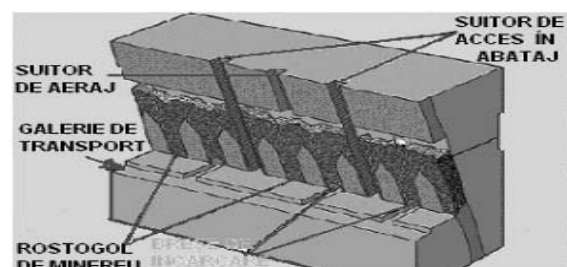


Fig. 8 *Method of exploitation with ore stockpiling applied at Săcărâmb, Brad, Roșia Montană, Băiuț, Herja, Ilba, Nistru, Săsar, Șuitor and Turț mines*

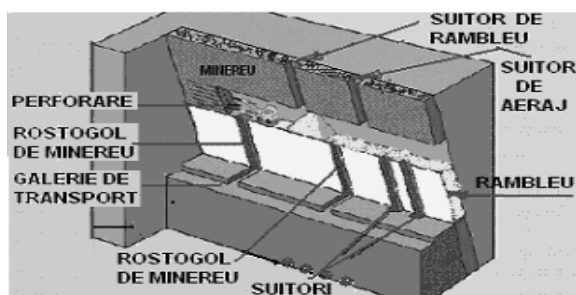


Fig. 9 Backfill exploitation method applied at Băiuț, Baia Sprie, Barza, Băița, Baia de Arieș, Herja, Săcărâmb mines

According to the above data it has been noticed that the gold grade of the ores mined out in the gold deposits regions of Romania much decreased and in most cases it is less than 2g/t Gold. The high grade gold of the ores mined out of the main gold areas of Romania much decreased and for more than three decades the grade was below 2 g Au /t.

So, for continuing the gold deposits mining operations with profits, technical, economic and organisational measures are required to significantly cut the exploitation and processing costs, to increase the ore mining rate and the metal recovery rate in the processing plant.

In gold ore mines, the most used method was „exploitation method and waste haulage to external dumps”, (figure 10).

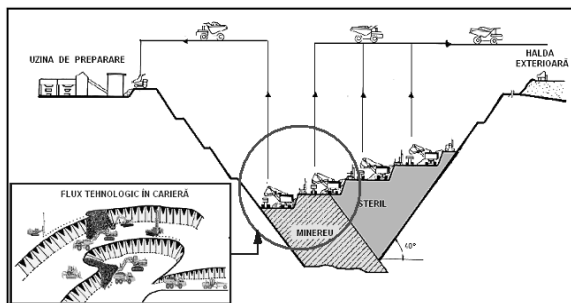


Fig. 10 Mining method with waste haulage to external waste dumps

The working technologies consisted of the tailings and useful material extraction by drilling-blasting operations with explosives of nitramon type placed in large diameter boreholes.

The blasted material was loaded with excavators and it was trucked with high capacity and medium capacity trucks of 27t, 40t and 55t. Most of the equipment used, were manufactured either in the country or in the ex-USSR (fig. 11). The open pit mechanization rate, the performances and reliability of the equipment used allowed productivities of only 50÷80 t/post at maximum and it was completely inadequate to what other world companies obtained under similar work conditions.



Fig. 11 Overview of an open pit in operation which objective is the mining of a gold deposit

The technical - economic parameters obtained for the open pits were the most advantageous of the whole mining sector for the gold deposit mining and recovery.

For large scale gold deposits the combined mining method was used and it consisted of the exploitation of the upper part of the deposit by means of open pit method and exploitation of the lower part by underground works, (figure 12).

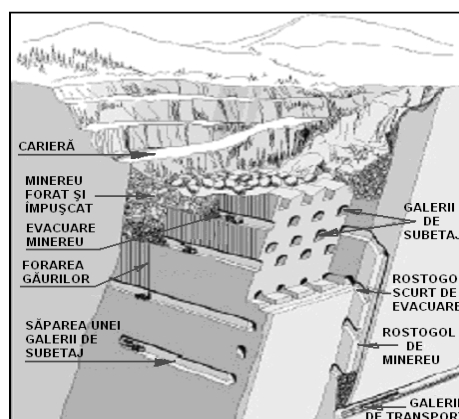


Fig. 12 Method of combined exploitation applied for large scale gold deposits

The processing technologies applied for gold-silver ores were based on flotation, the gold and silver being predominantly bound to sulphides. In case of the ores where free gold occurred, the combined technologies were used. For instance [3]:

- At Brad – for the ore containing 1÷2 g/t gold amalgamation on tables followed by flotation, the products obtained being an amalgam with 25÷30 % gold and a pyrite concentrate with 14÷18 g/t gold;
- At Baia de Arieș – flotation followed by concentrate cyanidation obtaining a gold pyrite concentrate with 23÷25 g/t gold and a cyanidation precipitate (slurry) containing over 2g/t gold;
- At Roșia Montană – drum amalgamation of free gold settled during the grinding – classifying circuit, periodically collected and flotation obtaining a gold pyrite concentrate with 23-24 g/t gold and amalgam with 20-35 % gold.

4. Restructuring of gold mining in Romania

Since 1990, several strategic concepts about the basic restructuring of the gold mining industry were established and they included among others:

- Technological and production restructuring;
- Organisational and managing restructuring;
- Restructuring of the employment;
- Restraining or cessation of production activity

As a result of the difficult geological and mining conditions of the mineable deposits, of the low grade ores and low reliability of the technological equipment, the total production costs of most mining products were after 1989, higher than the metal selling price and thus, the Romanian Government had to provide funds as subsidies to maintain these activities, of precious metal ore mining and recovery. The subsidies rate granted by the Romanian Government to the mines for the gold they produced, was calculated so as the price obtained further to the product sales plus the subsidy covered entirely the production costs of those times.

To increase the profitability of the precious metal mining process and to reduce the state budget subsidies and based on the provisions of the Mining Act, after the year 1997 the mine closure process started including here some mining sectors and even unprofitable mines.

A significant number of mines were closed gradually, and even mines from the gold region of Baia Mare and Golden Quadrilateral of Apuseni Mountains were closed; it was mutually agreed that the mines which remained in operation would implement rehabilitation programs and minimum investment start up.

The disadvantageous circumstances occurred could be also attributed to the National Bank of Romania which in the year 2000, refused to buy the gold produced in the Romanian mines motivating that the bank could not afford to hold a reserve of precious metal bigger than 15% of the currency reserve of the country. By those times, the mines were not allowed to sell the gold to other entities but only to the National Bank because they were subsidized by the Government; until new legislative and marketing opportunities were created, the mines economic situation had become critical and rushed up to the production closure.

In our opinion, the decision to close the mines was a quick one and it was not based on a due diligence review of each project and it was made by people and bodies which had not much to do with mining. Consequently, we think it was a big mistake, as it proceeded directly with the mine closure instead of their preservation to be able to resume the mining activity.

And most of all, the industrial plants and the mine supplies were sold and decommissioned while the main mining projects were irreversibly undergoing the closure process and the so-called environmental rehabilitation.

5. Conclusions

We think that gold deposit mining and processing in Romania must be reconsidered and the Romanian Government must provide the legislation, technical, organisational and economic measures to resume the research and exploitation operations both through private and state mining operators taking into account the favourable circumstances of the current economy when mining development is a profitable option.

The most important issues are presented below:

- The gold price has risen spectacularly in the last 12 years. Thus, if in year 2000, the gold price was 280 \$/ounce, in 2011 it reached the value of 1,900 \$/ounce, after which, it has fluctuated around the value of 1,650 \$/ounce until today.
- World consumption of gold metal has increased to about 4,500 tonnes/year, in comparison with the achievements of about 2,500÷2.600 tonnes/year;
- Exploitation and processing technologies were much modernized ensuring the profitable surface exploitation of some deposits with contents below 1.0 gram of gold per ore tonne. Also, the use of modern and efficient techniques for gold processing such as ore cyanidation in closed circuit allowed the significant decrease of costs. Currently the cyanide based processing is a safe and well developed process so that it is successfully used in most world gold mines.
- The ever increasing demand of precious metal in different national economy activity. It has to be mentioned here that the countries of the European Union consume about 145 tonnes of gold by year, so 90% of the required amount is imported.
- The need of an economic and banking stability for each country to which the gold reserves of the National Central Bank also contribute to a large extent, represents a permanent target, for each nation.

For Romanian conditions at the same time there can be organized and crystallized two main sectors in gold mining field, namely the state owned sector and the private owned sector, by establishing powerful and stable economic companies, should focus on the construction of high capacity mines and modern mining.

It is preferred to encourage the „joint venture” type companies respectively the association of state owned entities with private ones because the risk associated to high investments in gold mining is more easily borne by the state.

For this reason and because the investment rate is amounting to hundreds millions of dollars, the practice showed that, it is better that the state conclude partnership with a private partner which has expertise in the field and the said partner should be in charge with the operations management to obtain the expected success.

In Romania, after 1998 by implementation of the Mining Law it was possible to obtain the exploration/ exploitation licence by private operators with international capital and it resulted in the occurrence of private mining companies associated to the Romanian State and among them there is also S.C. Deva Gold S.A. Certeju de Sus.

The private investments may have a positive impact in the mineral resource mining and beneficiation so that the main benefits will be as follows [1]:

- Continuation of the mining operations within traditional areas;
- Profitable mining of some deposits that have been closed;
- Establishment of new jobs;
- Payment of taxes, fees and mining royalties as per the legislation in force;
- Social – economic development of mining zones;
- Practicing mining operations in a friendly manner both for the environment protection and occupational health and the geological patrimony of the country.

It has to be mentioned that the large scale gold mining has always been the target of strong companies as this activity requires big technical, organisational and financial measures. In many

countries where mining is well developed the mining of these deposits is performed exclusively by private companies where the state imposed itself by a tax and fee system well focused on actual issues so that mining is efficient for it and for the mining communities and attractive for investors.

In conclusion, safe and sustainable mining is possible and can be beneficial for state budget, for jobs and regional development.

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