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Editorial Office:

Geological Institute of Romania
Str. Caransebeș Nr. 1
RO - 79678 București - 32
Tel. (+40) 21 224 20 91, 224 15 30
Fax (+40) 21 224 04 04
e-mail geol@igr.ro

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FOREWORD

Gold has been a preferred subject in the research of the Romanian mineral wealth, especially during the 20th century, which witnessed the most valuable works concerning the gold ore deposits: "Étude géologique et minière des Monts Métalifères" by Ghițulescu T.P. and Socolescu M. (1941), „Evoluția geologică a Munților Metaliferi” („The geological evolution of the Metaliferi Mts.”) by Ianovici V., Giușcă D., Ghițulescu T.P., Borcoș M., Lupu M., Bleahu M., Savu H. (1969). Works such as these have integrated the classic Romanian geological and economical knowledge concerning gold metallogenesis.

During the last decades, the gold mineralization of the Carpathian space and especially of the Metaliferi Mts. were brought again to the attention of both Romanian and foreign geologists. Both the scientific progress concerning the origin of gold ore deposits and the political and economical changes which occurred in our country, have contributed to this.

The Society for Economic Geology of Romania has initiated, in co-operation with the "1 Decembrie" University of Alba Iulia, the Fourth National Symposium of Economic Geology – "Gold in the Metaliferi Mountains", to record the present state of knowledge regarding gold deposits in the Apuseni Mts., in relation with the worldwide achievements in this field. For this reason, the Symposium program includes valuable contributions concerning the gold deposits of both the Metaliferi Mts., and other areas of Europe or of the world. In this sense, it is worthy of note the numerous group of contributions concerning the Roșia Montană – Bucium district, in accordance with the recent renewed interest in the geological and economical features of this area.

In addition, the Symposium "Gold in the Metaliferi Mountains" enjoys the favorable circumstances of being organized in the same time with the first IGCP-486 Workshop "Au-Ag-telluride-selenide deposits". As a consequence, the two organizing committees decided for a common session to host the contributions concerning the mineralogy, metallogeny and economic geology of gold deposits in Metaliferi Mts. or other districts. I would like to express my satisfaction with regard to this collaboration which embodies the joint effort of Romanian and foreign scientists

towards a better knowledge of the mineralogical, metallogenic and economic aspects of this worldwide renowned area.

It is my belief that this will be a favorable and useful occasion for the Society for Economic Geology of Romania to settle a framework for fruitful discussions among scientists and experts involved in the research and beneficiation of gold or other mineral deposits, and to contribute in the present process of redefining the scope of the Romanian geology.

Prof.univ.dr. Gheorghe C. Popescu

President of the Society for Economic Geology of Romania

PLENARY LECTURES

ECONOMIC GEOLOGY OF GOLD; THE STATE OF ART

POPESCU C. Gheorghe¹, NEACSU Antonela¹, TAMAS-BADESCU Sorin²,

TAMAS-BADESCU Gabriela², MARINESCU Mihai¹

¹ UNIVERSITY OF BUCHAREST, Faculty of Geology and Geophysics, Department of Mineralogy,

1 N.Balcescu Blvd., 010041 Bucharest; ghpop@geo.edu.ro

² GEOEXPERT S.R.L., Deva; geoexpert@smart.ro

Gold is the metal and mineral best known to man. The history of gold is tightly interleaved with that of Human Kind. Maybe no other natural substance has been more admired and despised, excepting perhaps oil, in the modern times.

It is generally accepted that gold may have been noticed by man from its first conscious manifestations, that is, approximately 20.000 years ago. Since then, all important moments of the human history have been influenced by gold. The ascent and fall of empires which alternated throughout history, is reflected by the quantity of gold they have extracted and used. Here is a convincing example: the weight of the gold coins used in the Roman Empire has continuously decreased throughout its period of decadence, from 10.91 g during emperor Sylla (81 B.C.), 8.18 g under Cesar (46 B.C.), 7.27g under the rule of Nero (60 A.D.) to 3.89 g in the times of emperor Valentine (367 B.C.) (Bache, 1982)

The gold on the present territory of Romania was first mentioned by Herodotus in 513 B.C., who wrote about the Persian king Darius who started a war against the Agathyrsi – a branch of the Scythians living on the banks of River Maris (Mureş) – in order to seize their gold.

Later, in 105 A.D., after defeating the Dacians, the Romans found in the Dacian thesaurus more than 165.000 kgs. of gold. They sent the treasure to Rome, where victory celebrations lasted 115 days. With this capture, the difficult financial situation of the Roman Empire, improved significantly. After the occupation of Dacia, the Romans organized gold extraction and improved mining and processing methods. During the 166 years of ruling over Dacia, the Romans managed to extract more than 500.000 kgs. of gold, that is, three times more than the Dacian thesaurus. Numerous human settlements developed then, to last until present times: Rosia Montana (Alburnus Major), Zlatna (Ampelum), Abrud (Alburnus Minor), etc. Thus, the territory of Romania saw the continuous and tight interaction between the mining of gold and the history of the Dacian and later, Romanian space.

From its very beginning, the mining of gold has developed relentlessly, sometimes slower, sometimes at a faster pace, in accordance with a given historical period. A thorough insight of the pre-Second World War history belongs to Ilie Haiduc (1940) who provided data about the history of gold production in Romania, compared with the quantity of gold produced worldwide (Figure 1).

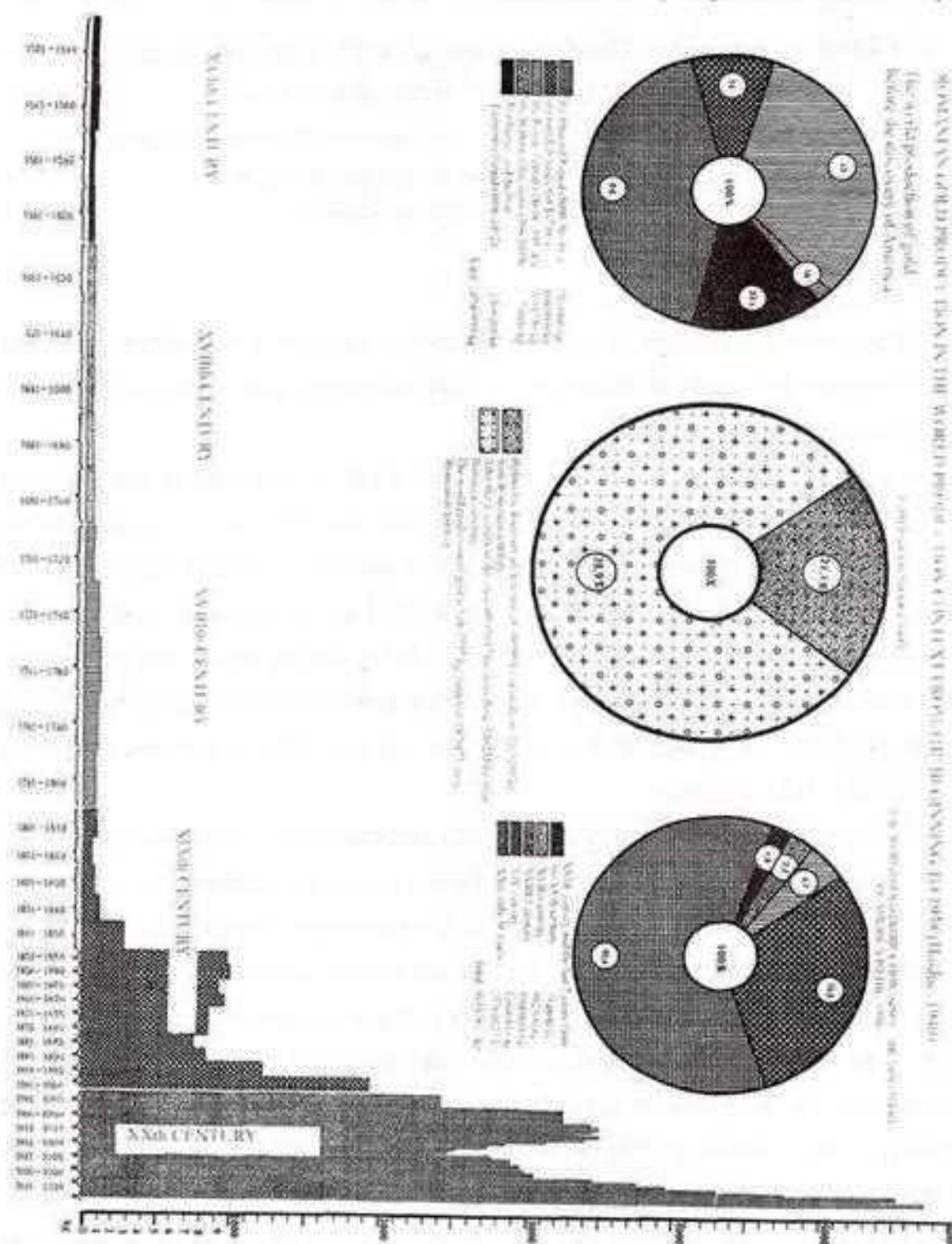


Fig.1. Gold production in Romania till 1938

More recent historical periods were covered by Timothy Green (1969) who gave a more complex picture of the interdependence between the gold production worldwide and various favorable geological and mining factors – such as, the discovery of gold in the Witwatersrand district, South Africa, in 1885, the introduction of cyanide-based processing methods, in 1891 – or unfavorable political factors (the Boer War – 1902-1910, the Great War – 1914-1918, the Great Depression – 1929-1933, the Second World War – 1939-1945) (Figure 2).

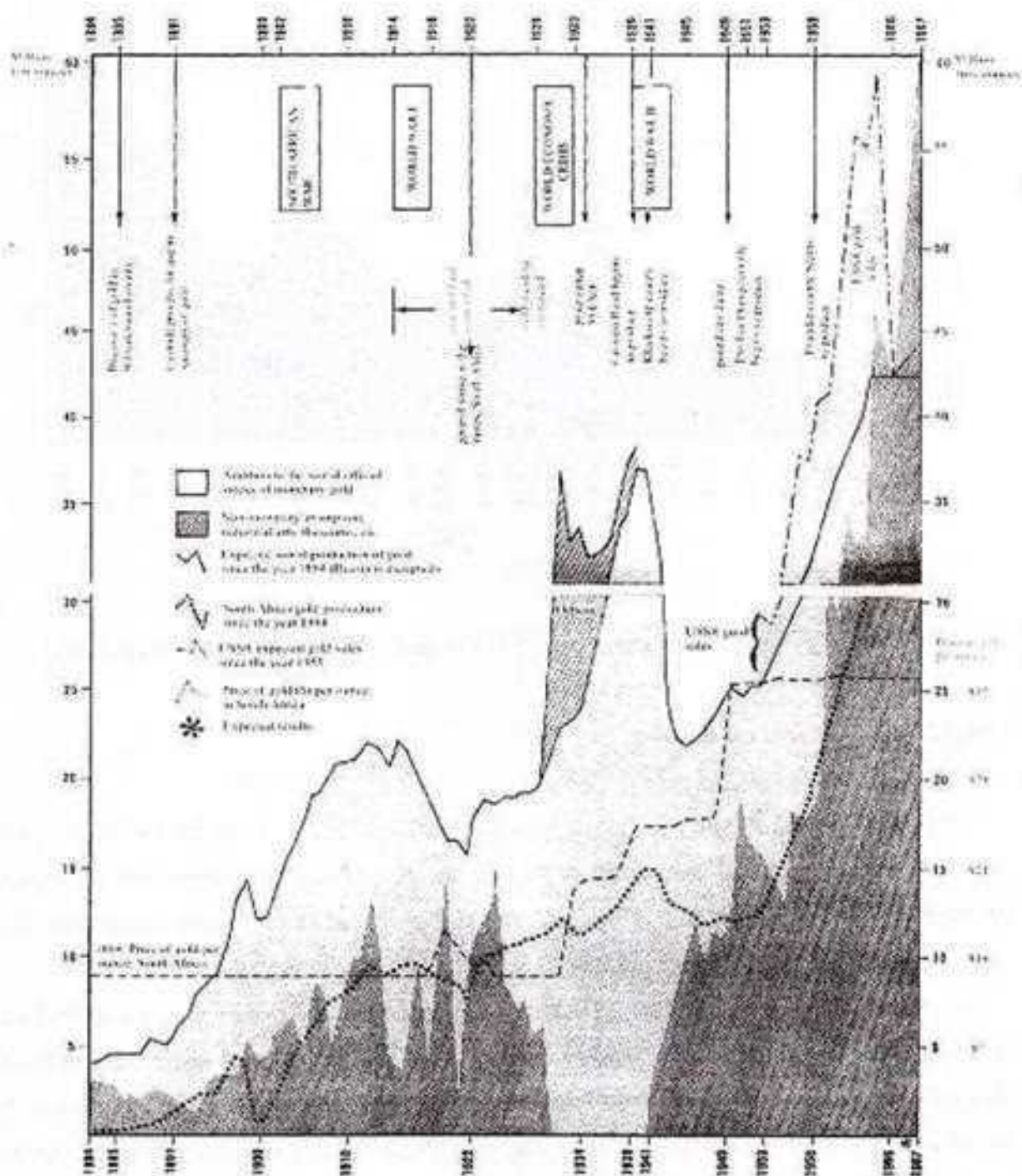


Fig. 2. Gold production and price of gold between 1884 and 1967 related to the main historical events (Green, 1969).

As concerns the 20th century and its last decades, they witnessed less spectacular oscillations of the gold production, but with several minima (1921, 1941, 1953, 1980, 1995) and several notable maxima (1940, 1970, 1993, 2001 – approx. 2600 tones) (Figure 3).

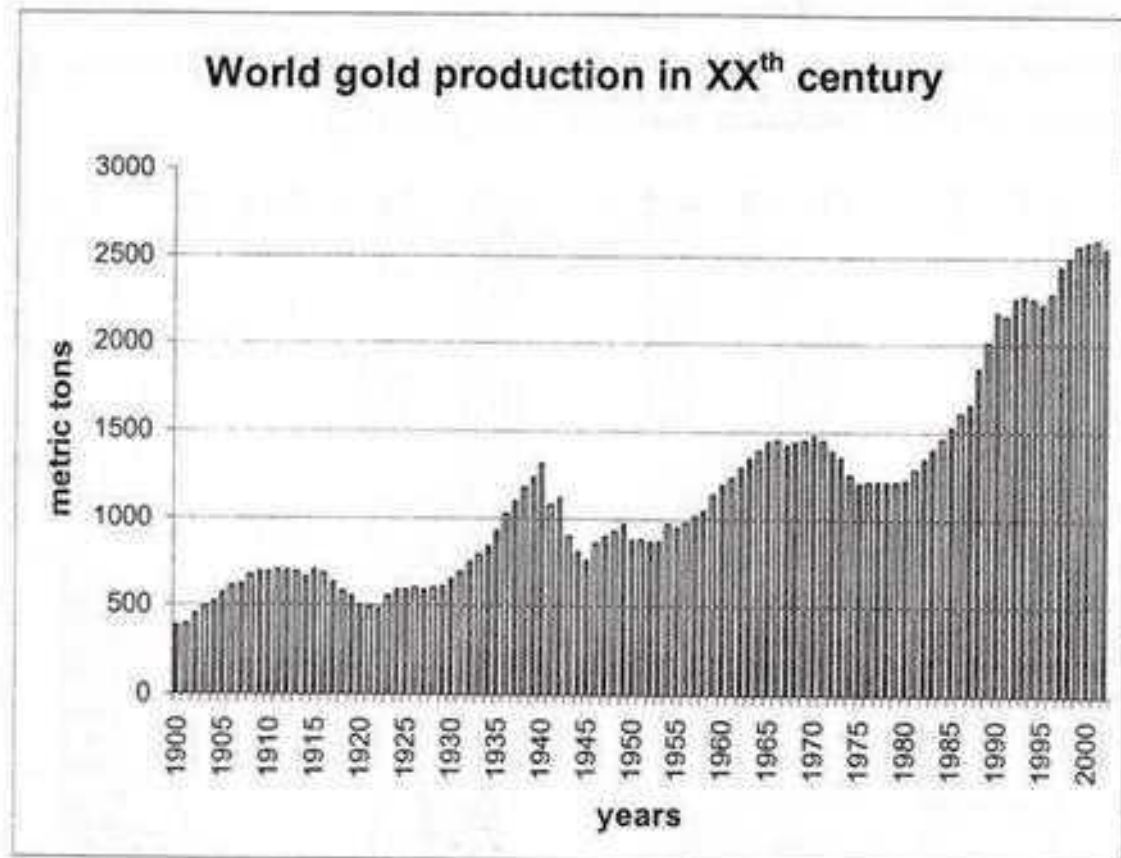


Fig.3. World gold production since 1900 to 2002 (after USGS in <http://minerals.usgs.gov>).

The philosophy of gold exploration

The philosophy of gold exploration has varied through history. Until the 19th century, self-educated and encyclopaedist prospectors could meet the demands of discovering new ore deposits for handicraft and manufacturing. However, with the advent of the Industrial Revolution, such empirical methods quickly became obsolete.

During Antiquity and Middle Ages, the search for gold and for other metals complied with the dictum "*ore deposits are to be found where they occur...*" The empirical research that followed up, used a step by step strategy, a "centrifugal" principle, "*from known to the unknown*", stating that "*ore deposits are to be found near other ore deposits*". This strategy explains why in the Ancient world, for centuries or even millennia, gold has been extracted from roughly the same mining districts, such as those from Spain, Egypt, Greece and Dacia. As regards the contemporary "poles" of gold production – Siberian Russia, California, Australia and South Africa – they still had to wait,

as their discovery could not be accomplished in the context of the Antiquity, when neither the new ideas, nor the principles and theories to sustain the practical quest for metals and especially gold, were yet available. Geology had to become a science in order to substantiate the predictive exploration of ore deposits.

Geology has achieved the status of science relatively late. In the beginning it was almost exclusively a field science. However, the mineral, rock or fossil collector could not understand much beyond just wondering of the odd matters "produced" by the Earth. The miners, on the other hand, were so absorbed by ores and by the slightest indications pointing to their potential existence, that they have never had the curiosity or gathered the knowledge to explain ore genesis and history, and less so, the structure and history of the Earth.

In his famous "*Theory of the Earth*" – 1795, James Hutton exposed a revolutionary concept – the *uniformism* – which meant that geological features are the result of driving forces or processes that are active also today. For this reason, Hutton is considered the founder of scientific Geology. As his successor – the English Lyell – later demonstrated: *the Present is the key to explain the Past*. Lyell amended the *uniformism* and renamed it as the *principle of actualism*, which together with the *principle of superposition of rock strata* – stated two centuries before by Nicolaus Steno – constitute the foundation of scientific Geology.

Alexander von Humboldt was the first to observe the relation between metallic concentrations and igneous rocks. This idea has been perfected and scientifically substantiated by Ellie de Beaumont, in his theory regarding volcanic and metallic emanations. In fact, this theory was an expression of two fundamental principles governing the contemporary metallogeny – the *principle of actualism* (as long as today we observe deposition of metals – especially sulfides – in volcanic fields, the old ore deposits should have formed in the same way), and the *principle of similarity* – the rocks and ores were formed by the same geological processes.

The concentrated expression of the above is reflected by the saying: "*if you want to discover ore deposits, then go to the mountains*". This kind of thought had a practical and guiding meaning and reflected in the "centrifugal" principle of prospecting new ore deposits in the vicinity of known ones.

An illuminating example in this sense, is the discovery of the famous *Mother Lode* gold belt in the Sierra Nevada Mts., U.S.A., where two dictums seem to have applied "the new ore deposits are located near the known ones", and "if you want to discover ore deposits, then go to the mountains". Californian gold seekers have discovered gold in the alluvia of Sacramento River, and then, by gradually following upstream the rivers which transported the gold from Nevada Mts., they discovered the veins – "the mother lodes", which were the primary source of alluvial gold, and

eventually they managed to outline an extraordinary metallogenic unit – the *Mother Lode* – extended on approximately 250 km.

The 20th century witnessed the outlining, the clarification and uphold of new metallogenic theories and concepts: the *zoning*, the *alignment theory*, the *regeneration theory* and the *global tectonics concept*. Each of these theories had a positive yield for the strategy of gold discovery, offering a scientific support for exploration programs.

The *zoning* concept – applied at either regional scale (in the sense defined by Emmons) or local scale (the *spot zoning*), allowed a bolder and more efficient economical development of districts or metallogenic structures, and yielded positive effects on the companies which promoted such programs. Illustrative examples are those of the Transylvanian ore deposits (Ghitulescu 1934) and of the vein fields at Baia Sprie and Sacaramb, in Romania. Although such ore deposits have been known since the 18th and 19th centuries for their gold and silver resources, by the advance of mining works, they have gradually become base metal ore deposits, with silver and gold, as by-products.

The theory of *metallogenic regeneration* was stated by Schneiderhöhn, in the years 50s of the last century, in order to explain the discrepancies between the age of ores and their host rocks, in several Alpine districts. The theory imposed itself especially when strong metallogenic “pre-concentrations” influenced the upper mineralized levels and thus, the determined radiogenic age of the deposit.

The theory achieved a wider interest through the concept of *metallogenic heredity* which assumes that a geological or petrographical context have a fundamental role in the formation of metal concentrations, due to abnormal contents of certain metallic components. Such components are then found in the newly formed ore deposits. The role of the Techereu ophiolite massif (Metaliferi Mts.) in defining the gold and copper character of the Apuseni Mts. metallogenic subprovince, in comparison with the East Carpathians Neogene metallogenic subprovince (Udubasa et al., 2002), should be interpreted in the sense of a metallogenic heredity.

Owing to the progress achieved in the research of the extraterrestrial space, Geology benefited from a new technology perfected in this field – the remote sensing. By investigating the interaction between electromagnetic waves and terrestrial environments, it was possible to see some extraordinary images of the geological structures, including those rich in mineral resources. Cartographic and geological images of territories still unseen by man – in deserts or under the ice covers, could thus be obtained, and by analogy with lands well known for their mineral resources it has been possible predict mineral concentrations even in such remote, still unknown areas. This has brought back an old concept that had been abandoned for a long time – the *theory of alignment*. The re-actualization of this concept has been made possible only by the remote sensing, and has helped

in the discovery of several gold deposits in old terrains such as those from South Africa, Namibia, Australia, and in our case, in the South Carpathians. This theory has brought new genetical perspectives on the gold occurrences of the Getic Domain.

By the end of the second millennium, Geology contributed to the human knowledge with a profound and revolutionary concept, whose implications were far beyond the scope of this science: the *global tectonics*. The theory and practice of ore discovery could not escape the influence of this concept. Metallogeny has thus placed the formation of ore deposits and of related rocks at the areas of interaction between lithospheric plates, opening the way for an unprecedented exploration strategy of ore deposits.

Starting from a deterministic relationship between subduction areas and calc-alkaline (andesitic) magmas which are in their turn, always associated with large accumulations of copper, molybdenum and gold – the *porphyry copper type* – a veritable copper and gold rush broke out in the actual and pre-quadernary subduction areas. Results have arisen very quickly. New ore deposits have been found in areas that had been previously well known for their mineralized structures – such as the *porphyry* ores in the Metaliferi Mts. – but also in areas where no clue existed on any ore deposits: as in the Philippines and Polynesia. It is equally true that geophysics contributed a lot to this success. The magnetometry proved to be a very efficient method to spot porphyry structures, especially due to the high magnetite contents of these deposits.

We will give two examples to illustrate the above considerations. The first example comes from the Indonesian Irian, the Papua-New Guinea Island. The **Ersberg** (The Ore Mountain) ore deposit, discovered as early as 1936 by a Dutch expedition, in a dense rain forest, at over 4300 meters in altitude, has remained inaccessible for a long time. During the '60s, the American mining company Freeport – McMaran decided to invest about 1 billion USD in this project. The helicopters began to fly over the jungle, modern roads began to advance slowly (4-6 m/day) in rough terrains with inclines exceeding 70 %. Huge efforts were made, but eventually everything was worthy, as an immense profit expected the explorers: a "capture" of 40 billion USD. In 1988, the Freeport geologists discovered another ore-deposit: **Grasberg**, lying at an even higher altitude – 4600 m. Its exploitation involved even more extensive use of helicopters and giant bulldozers, working in an extremely rugged terrain, with water falls of over 600 m. The ore deposit – estimated at 60 billion USD – represents the biggest and richest gold deposit in the world, with a daily ore production of approximately 300,000 tons.

The second example refers to the Metaliferi Mts. During the 1970s the geology of this area was re-examined in the new context of the plate tectonics. In the new economic context, mineralized structures with disseminated copper – much poorer in comparison with their vein counterparts – could pass the productivity test. This could be achieved only with adequate

technological support adapted to intensive large-scale exploitation, involving the excavation and hauling of huge mining volumes, and in favorable economic circumstances. In just few years, so many copper and gold deposits have been discovered, that they exceeded in volume all that had been discovered in the previous decades and centuries

The problem of adakites

The notion of adakite was introduced by Kay (1978) to define intrusive or extrusive rocks rich in Al and Na, with a Sr content of over 600 ppm and with a strong fractioning of REE (depleted in HREE, enriched in LREE). Adakites are the product of a slow melting process in which garnets and amphiboles are residual phases (Reich et al., 2003).

The name of these rocks comes from Ila Adak (Aleutines Archipelago, Alaska). Their age is <25 ma; adakites are considered volcanic arc rocks with the following geochemical characteristics: $\text{SiO}_2 > 56\%$, $\text{Al}_2\text{O}_3 > 5\%$, $3\% < \text{MgO} < 6\%$, $\text{Y} < 18$ ppm, $\text{Sr} > 400$ ppm (Defaut and Drummond, 1990, in Oyarzun et al., 2001).

The problem of adakitic magmatism and of its relation with the copper-gold metallogeny has raised considerable interest during the last decades. The association of adakites and mineralized areas was observed for instance, in Pinatubo Mt, Ila Luzon, the Philippines, where several porphyry Cu-Au ore deposits, of Pliocene-Quaternary age, occur in the vicinity of the summit of a volcano. In the Chilean Andes, which host the largest concentration of world-class copper deposits on Earth, adakite-like rocks have been recognized associated with Oligocene porphyry copper deposits, suggesting a metallogenic connection between this particular magmatism and porphyry copper formation (Thiéblemont et al., 1997 in Reich et al., 2003). Furthermore, a controversial causal relationship between adakitic magmatism and the size of porphyry copper deposits in northern Chile has been suggested by Oyarzun et al. (2001) (Fig. 4). They proposed that Late Eocene-Early Oligocene giant porphyry copper deposits such as Chuquibambilla, are related to adakitic, highly oxidized, water-rich melts, and suggested that these melts were eventually derived (Fig. 5).

Adakite-like rocks have been recently mentioned in the Metaliferi Mts. (Rosu et al., 2001), with high contents of Sr, and elevated values of the Sr/Y ratio (Udubasa et al., 2001) (Fig. 6).

As concerns the "metallogenic benefits" of the adakite issue, we can consider that this is a case of a refined metallogenic *principle of analogy*. The deterministic correlation between subduction, calc-alkaline magmatism and metallogeny, especially of porphyry type, which substantiated the exploration strategy during the 70s and 80s in the last century, gets an annotation in the new context. Many ore deposits are associated with adakites, but this does not deny the old correlation.



Fig. 4. Porphyry copper belts (including selected epithermal deposits) in northern Chile (porphyry copper belts after Sillitoe 1988; Makshev 1990; Camus and Dilles, 2001). Fide Oyarzun et al., 2001

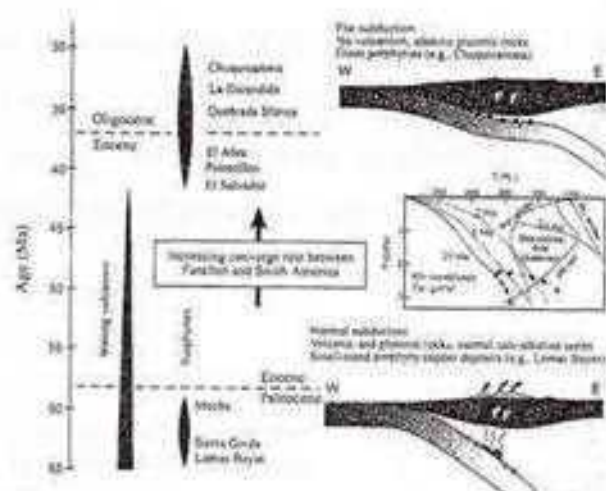


Fig.5. Evolution in time of volcanism, porphyry emplacement, and plate tectonic setting. Age of porphyries after Makshev (1990). Inset P-T-t metamorphic and melting reactions diagram displaying P-T-t paths for 2-, 5-, and 25-Ma old subducting plates. Note that only the 2-Ma plate will directly melt. The 25-Ma plate will melt directly if flat subduction occurs (solid dots; see also upper plate tectonic scheme). Open squares (see also bottom plate tectonics scheme) show the normal trajectory of a 25-Ma old subducting plate undergoing dehydration (H₂O out) at greater depth. Based on Gutscher et al., (2000). Fide Oyarzun et al., 2001.

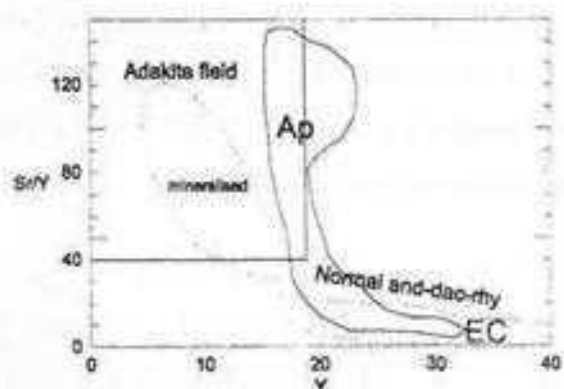


Fig. 6. Sr/Y vs. Y for Apuseni (Ap) and East Carpathians (EC) Neogene magmatic provinces. Adakitic field from Defant and Drummond (1990) and Thieblemont et al., (1997) and mineralized field characteristic for adakite-like magmatism from Thieblemont et al., (1997). Fide Udubaşa et al., 2001

Gold exploration in the context of worldwide geological exploration

According to Metals Economics Group, during the last 25 years, the worldwide expenditures for the exploration of mineral substances excepting coal, have fluctuated between 1.5 and 6 billion USD, with a strong descending trend from 1997 (Fig.7).

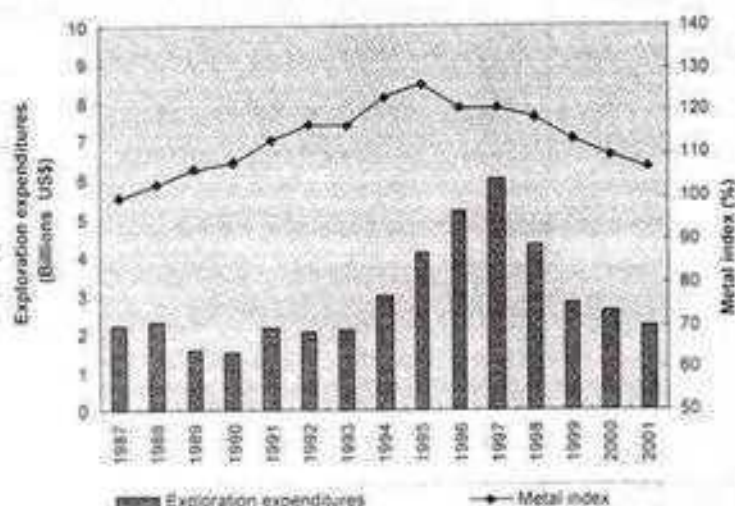


Fig. 7. Exploration expenditures versus metal index (based on Metals Economics Group data)

The political factor (reflected by the index of political factor IFP) represents another important element in the allotment strategy of exploration funds by the international companies. It comes to the fore that exploration expenditures have been reduced more significantly in areas perceived by the investors as politically "insecure" – such as Africa and Asia, including Indonesia and Papua-New Guinea (Fig. 8).

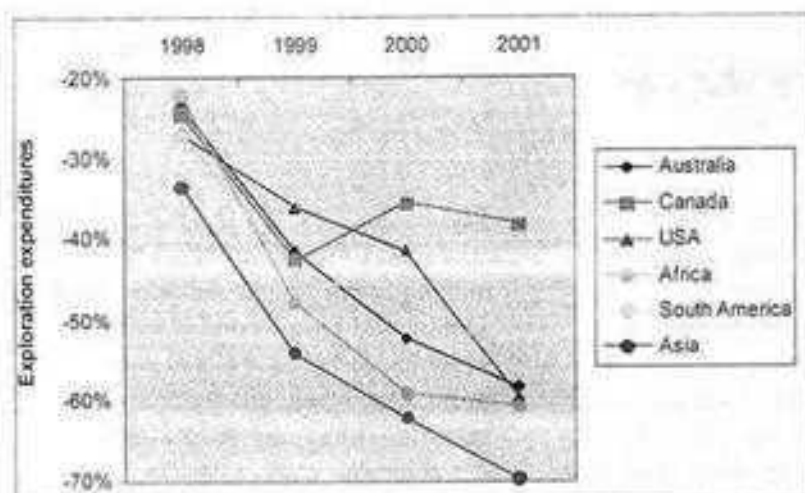


Fig. 8. Variation of the exploration expenditures reported to 1997 (based on Metals Economics Group)

At present, the majority of the world exploration expenditures (approximately 29% in 2001) are directed to South America (Fig.9). This is due both to the high mineral potential of this area and to the recent discovery of some important ore deposits.

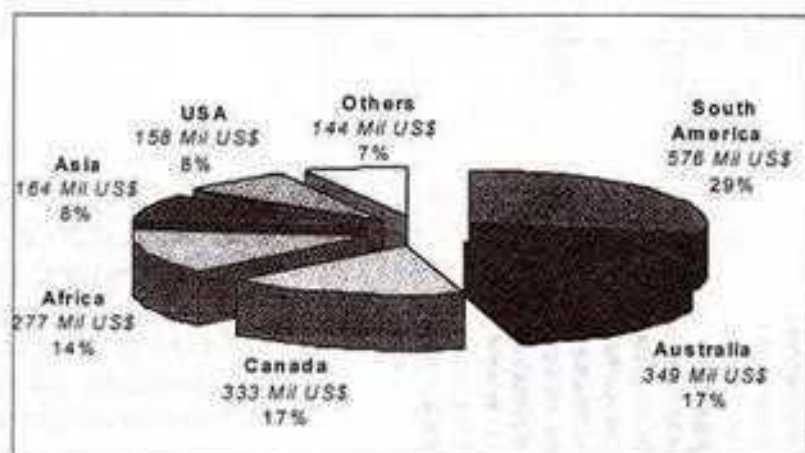


Fig. 9. Exploration budgets for selected regions (based on Metals Economics Group data)

The huge majority of exploration funds come from Canada and the United Kingdom (Fig.10) which is explained by the fact that (according to Metals Economic Group) approximately 1200 mining and exploration companies are listed with the Canadian stock exchange markets, representing 75% of the similar companies listed with stock exchange markets worldwide. In the same time, most of the international mining corporations are registered in the United Kingdom and listed with the London stock exchange.

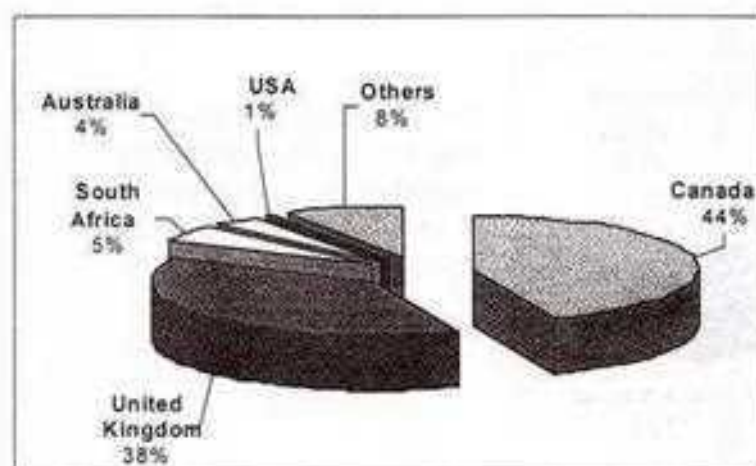


Fig. 10. Sources of equity financing for mineral exploration and development in 2000 (based on Natural Resources Canada data).

The last 20 years of geological exploration witnessed an increasing role of the so-called *junior* companies. Against the trend of worldwide exploration expenditures cut-off which started in 1997, the share of junior companies has increased with approx. 10% (Fig.11). It should be mentioned however that the activity of such companies is strongly influenced by the evolution of prices on the mineral market. A study carried out by the Canadian Institute of Statistics mentions that between 1997 and 2000, approximately 45% of the junior companies have closed their activities.

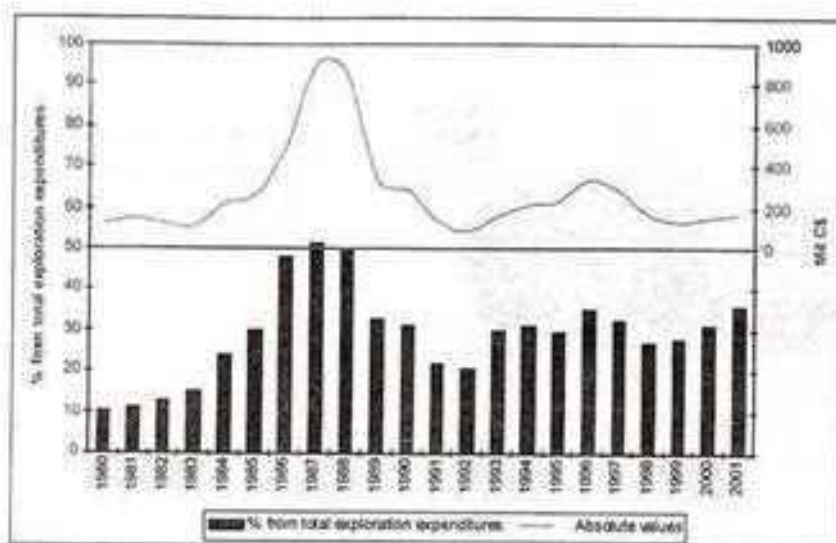


Fig.11. Exploration expenditures of the "junior" companies reported to the overall Canadian exploration expenditures (based on Statistics Canada data).

According to the data of the same Institute, only 27% of the exploration budgets are deployed for actual survey and exploration activities, the rest being used in the elaboration of technical and economic studies or in the development of mining infrastructure for the newly discovered ore deposits (Fig. 12).

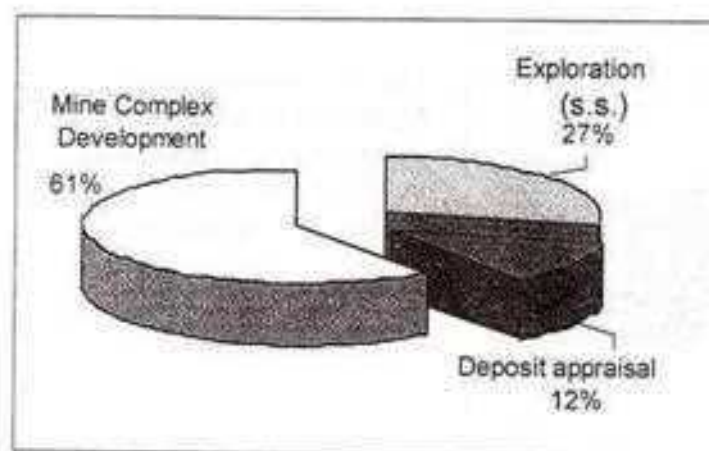


Fig. 12. Weight of different stages in the total exploration expenditures. Average values in Canada, between 1997-2001 (based on Statistics Canada data).

Although geophysical research methods are increasingly used in identifying favorable geological structures, their share in the total exploration expenditures (Figure 7) is still low (under 5%).

Geological mapping and geochemical sampling remain the main modalities to identify ore deposits. Such methods and activities are allotted with 20-30% of the exploration budgets (Fig.13).

Drilling is budgeted with approx. 40-50% of the exploration funds, with an increased use of cheaper reversed circulation methods, against more expensive classical methods involving continuous core-drilling.

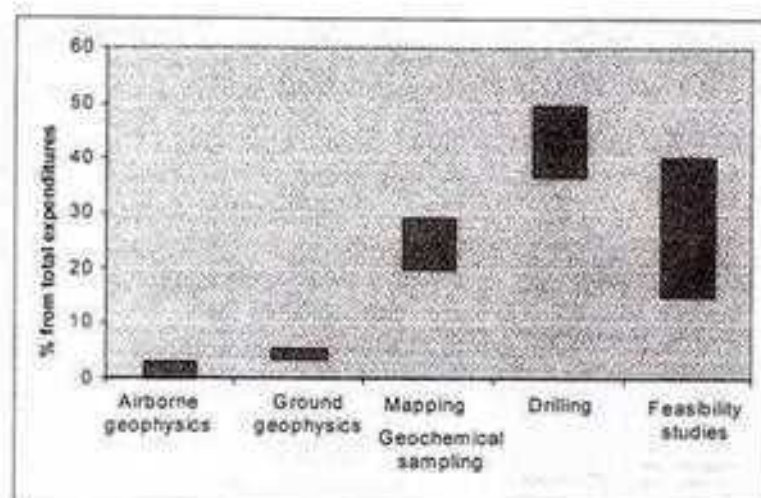


Fig. 13. Weight of different research methods in the total exploration expenditures. Average values in Canada, between 1980-1985 (based on Statistics Canada data).

The worldwide expenses for gold exploration in the last 30 years have oscillated between <1 billion USD and approx. 5 billion USD, with an annual rate of discovery of 1 to 12 significant ore deposits (Fig. 14).

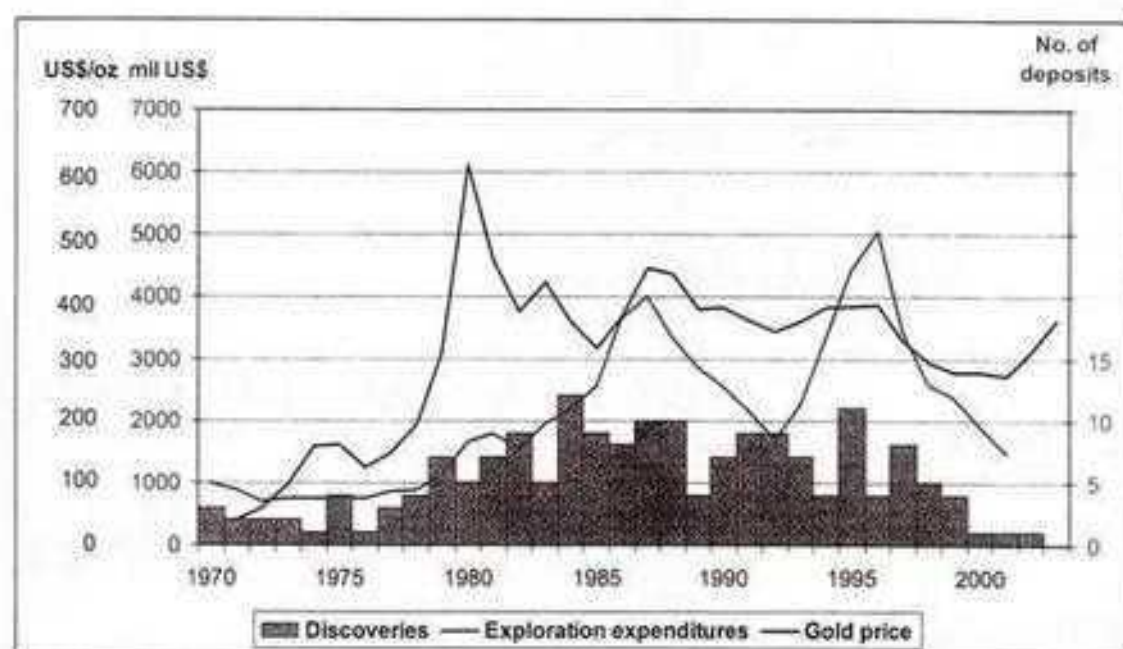


Fig. 14. The evolution of gold price, gold exploration expenditures and number of discovered ore deposits in the last 30 years. (source: Prospectors & Developers Association Canada, Blain 2000, Schodde, 2003).

In the last years, a continuous diminution, both in absolute and relative percentual values, of gold exploration budgets is conspicuous (Fig. 15).

A study carried out by Blain (2000) on the evolution of discoveries during the last 50 years, points out that geological interpretation and field surveys had a decisive role in the finding of most ore deposits. (Fig. 16). According to Blain, approximately 120 gold ore deposits have been

discovered during the last 50 years, most of them between 1980 and 1990 (Fig.17). In their majority the ore deposits consisted of gold-bearing quartz veins in green-schists areas, and least of them were of epithermal type. 33 of these deposits have resources exceeding 1 billion USD (Fig.18).

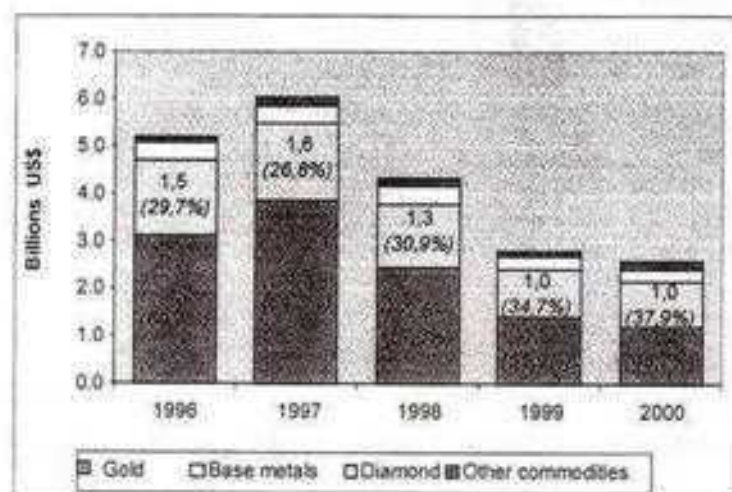


Fig. 15. Exploration expenditures for different commodities (based on data of Prospectors & Developers Association, Canada).

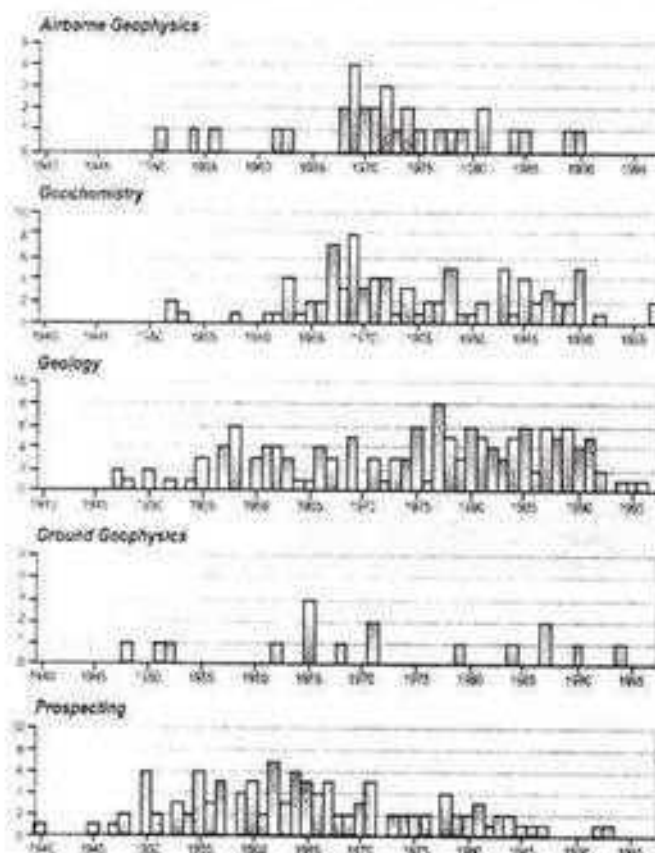


Fig. 16. Time trends in discoveries – primary discovery technique (Blain, 2000)

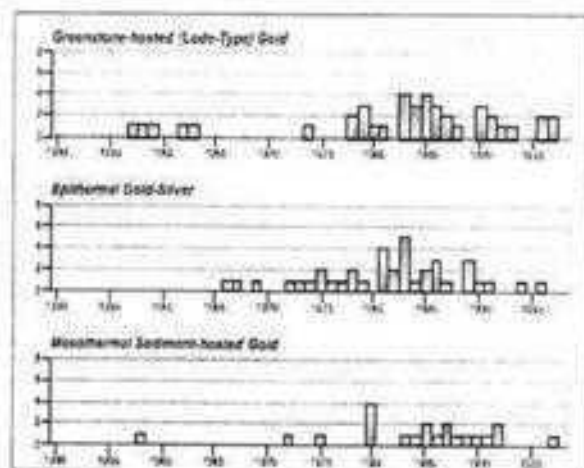


Fig. 17. Time trends in discovery by ore-type model (Blain, 2000).

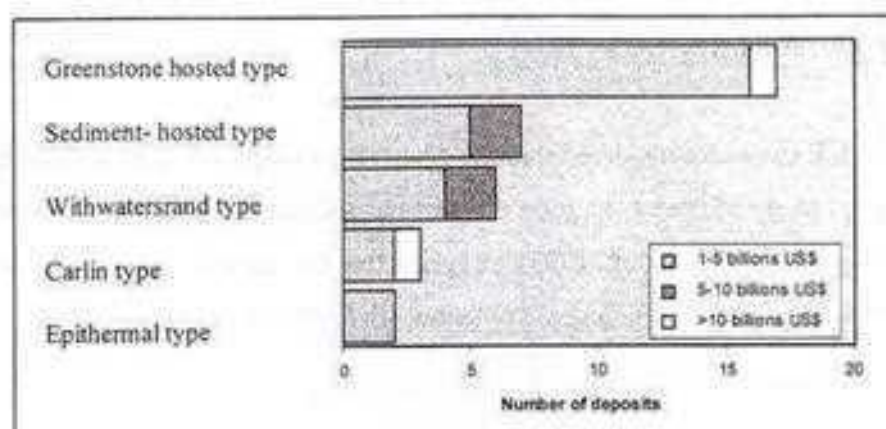


Fig. 18. In ground- values of the last 50 years discoveries grouped by ore-type models (based on Blain, 2000 data).

At present, the biggest ore deposits being developed are:

Ore deposit	Country	Reserves (mil oz)	Company
Target North & Sun	South Africa	72	Avgold
Sukhoi Log	Russia	46	Russian Government
Telfer	Australia	26	Newcrest
Pascua	Chile	24	Barrick
Donlin Creek	Alaska	23	Placer/Novagold
Cerro Casale	Chile	23	Placer/Bema
Boddington expansion	Australia	20	Newmont, AngloGold, Newcrest
Turquoise Hill	Mongolia	19	Ivanhoe Mines
Burnstone	South Africa	17	Great Basin Gold
Pueblo Viejo	Dominican Republic	17	Placer

Finally it should be stressed that many authors noticed a continuous increase of exploration and development expenditures during the last 20 years, sometimes to an alarming rate, as in the case of very large deposits (Fig.19).

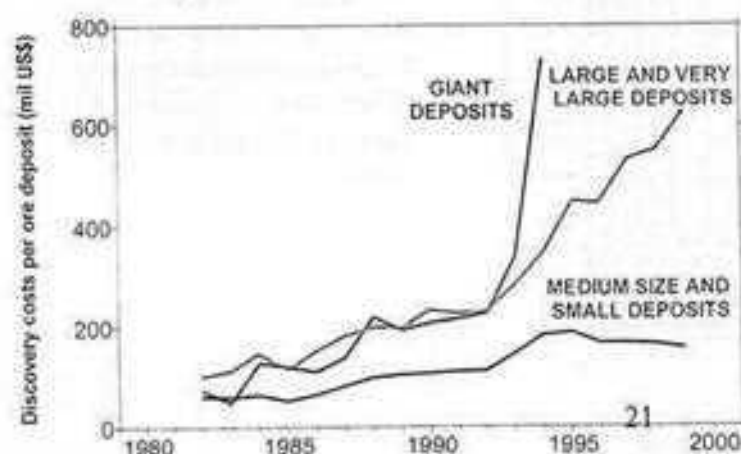


Fig. 19. Evolution of exploration and development costs per discovered ore deposit in the last 20 years (BHP Billiton).

Giant ore deposits: in situ value between 20 and 80 billion USD (6 examples)

Large and very large ore deposits: in situ value between 10 and 20 billion USD (12 examples)

Medium and small ore deposits: in situ value under 10 billion USD (252 examples).

Gold exploration strategies

In general, it may be considered that the chances for discovering an economically viable ore deposit are low. A study of the exploration projects carried out during 1980 and 1990 in the United States, Australia and Canada (Lacy, 1993), suggests that the success rate of exploration programs carried out in various areas of metallogenic potential was only 0.1-0.7% (Fig.20).

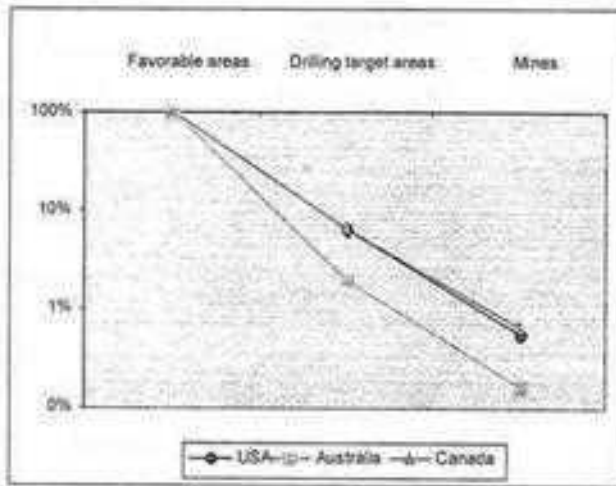


Fig. 20. Results of exploration programs carried out in the USA, Australia and Canada during 1970 - 1980 reported to the initial favourable areas (based on the Lacy's data, 1993).

Historic experience proved that the best place to look for an ore deposit is in the area where other ore deposits have been found (Parry, 2001). For instance, in the Laverton district of West Australia, economic ore deposits have been found on approximately 3% of the areas investigated during 1986 and 1999.

The plot of the ore deposits discovered in a given metallogenic district, on a diagram of resource distribution (Fig.21), shows which are the chances to discover an ore deposit of a certain resource volume in that district.

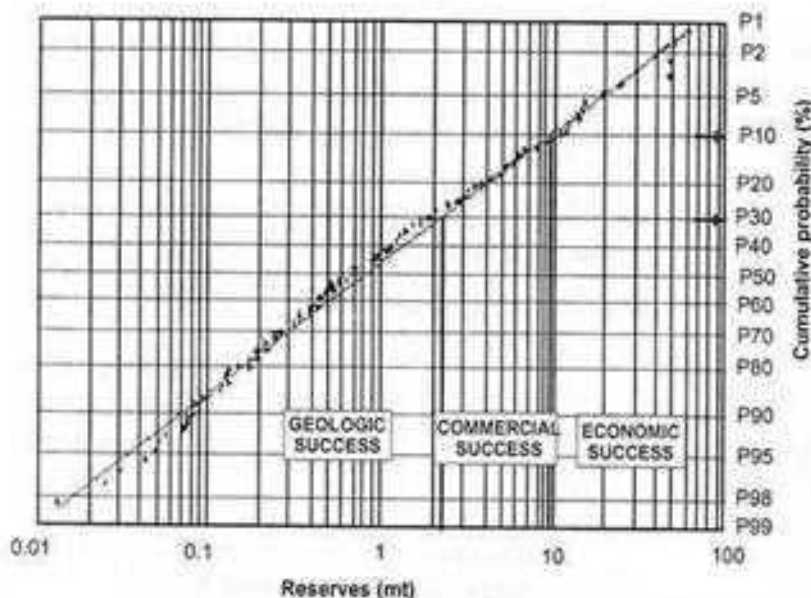


Fig. 21. Estimation of chances for an ore deposit of given size (tonnage) in the Abitibi green schists belt (Canada), using the statistic distribution of discovered deposits (Gouveia et al., 2003).

Both at regional and planetary scale, the distribution of ore deposits is strongly skewed; the largest part of resources is concentrated in a small number of ore deposits (Fig.22) (Light, 1996, Parry, 2001, Schodde, 2003, Hronsky, 2003).

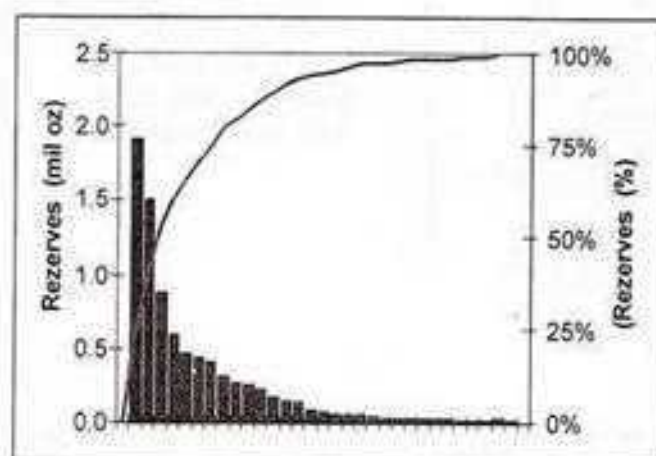


Fig. 22. Skewed distribution of gold reserves in a metallogenetic district. Example - In the St. Ives district, Australia, 65% of the reserves are concentrated within 5 deposits (Parry, 2001).

Due to this skewness, as a general rule, the most important ore deposits are discovered at the beginning of exploration history of a certain region (Fig.23). Another consequence is a decreasing rate of discoveries with an increased number of exploration programs in the area (that is, with the maturation of the district) (Light, 1996; Hronsky, 2003).

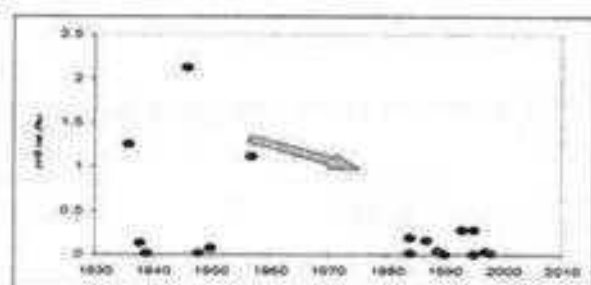


Fig. 23. The most important ore deposits of a district are generally discovered at the beginning of the exploration history. Example – the Norseman district, Australia (Schodde, 2003)

According Hronsky (2003) the success of a single project (P_s), depends on the number of projects previously carried out in the region (n) and on the success of these projects (P_d):

$$P_s = 1 - (1 - P_d)^n$$

Hronsky considers that three phases can be distinguished in the historic evolution of geological exploration for a certain district (Fig.24):

- The explosive phase, following up shortly after the discovery of the district, when the rate of discoveries is high, the size of the ore deposits is large and the discovery costs are low;
- The strategic phase, when the rate and size of discoveries diminishes, and the discovery expenditures exceed the worldwide average;
- The depreciation phase, when the discovery rate gets extremely low, the discovered ore bodies are small, and the exploration costs raise to a level of unprofitability.

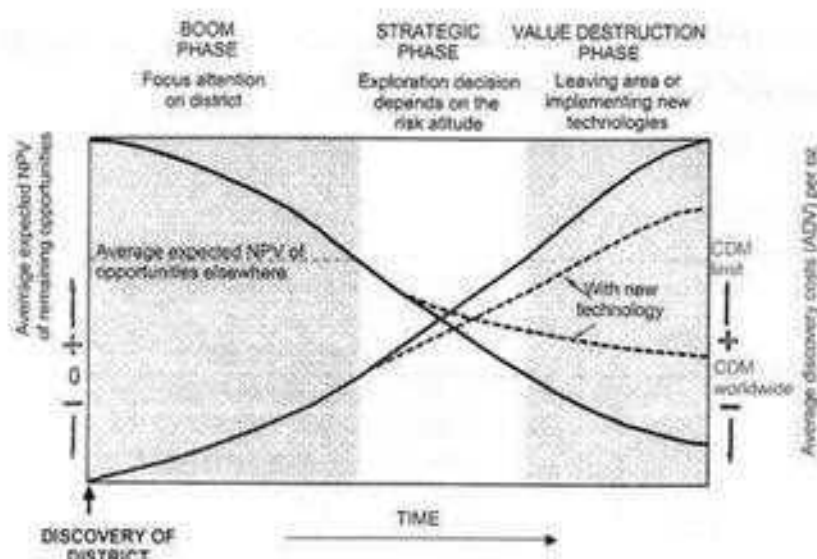


Fig. 24. Time trend of the exploration in a metallogenic district (after Hronsky, 2003 with completions).

Schodde (2003) considers that assessing the maturity of a metallogenic district can be done through the reviewing of the evolution of discovery expenditures per metal unit; at a certain moment, the exploration of ore deposits in a given district would become uneconomical.

Such methods may lead to an invigorated exploration of a given district, to higher discovery rates and lower costs. The same reinvigoration may be achieved with the introduction of new ore processing technologies which are less cost demanding.

In conclusion, the statistical analysis of the evolution of exploration in a mining district yields information on the probability to discover an ore deposit, of a certain size.

The aspects mentioned above have important implications in the strategy of defining the exploration objectives.

Two main types of strategies can be distinguished (Parry, 2001):

- missed opportunities in mature districts targeting strategy or elephant country targeting strategy;
- first mover targeting strategy.

The first strategy involves more reduced risks and has the advantage of a developed geological database which facilitates the selection of a potential target. Adopting this strategy implies in principle, new methods and techniques in the interpretation of available data concerning the ore exploration, mining or processing. Its disadvantage relates to the generally scarce probability of discovering large ore deposits. In "mature" districts (with prolonged and intense exploration) a risk exists only for overlooking ore deposits which are either uneconomical or at the limit of profitability.

The "first mover" strategy involves higher risks but may return significant discoveries. The possibility to acquire larger exploration licenses increases the chances to discover ore deposits. A larger number of smaller discoveries may become financially attractive if the production is directed

to a central processing plant. The success of such a strategy depends on how accurately previous exploration activities have been assessed (Parry, 2001).

The selection of either strategy depends on the company's policies concerning risk, diversification of activity (geographic diversification with regard to the types of ore deposits, mining and processing methods), expertise, financial background, technical capability and distribution of company's operations at the time of the decision (active mining operations, ongoing exploration projects).

The experience shows that the success of an exploration project depends largely on adopting the right strategy for defining the exploration objectives. There is no universal solution for that, but according to Schodde (2003), the key words are *"new areas, new ideas, new technologies"*.

World mining of gold

It is estimated that throughout human history, approximately 147,000 tones of gold have been extracted, of which approximately 60%, after 1950.

The world resources of gold known in year 2000 have estimated to approx. 102,500t. South Africa leads, with an estimated resource of 35,877t Au (fig. 25).

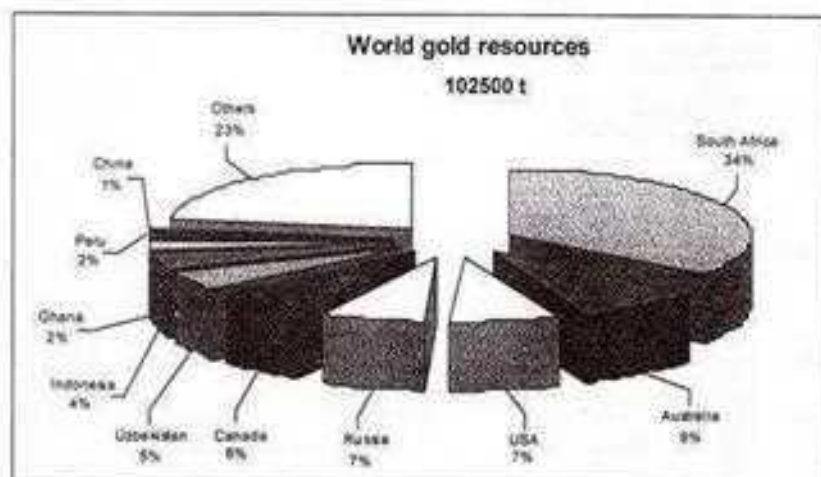


Fig. 25. World gold resources known in 2003 (based on U.S. Geological Survey data).

Over 90% of the world production of gold, sources from 20 countries (Fig.26, Table 2). The world leader in gold production is South Africa, with an annual production which ranging between 465 and 395 tones, in the last five years, and representing 16% of the global production. The United States of America (366t to 298t per year) and Australia (301 to 273t per year) follow in descending order.

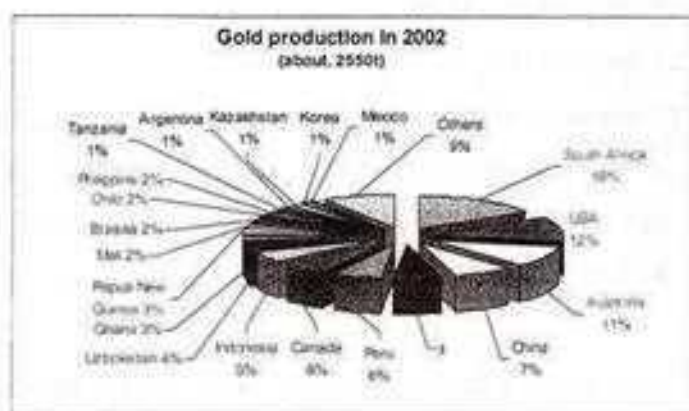


Fig. 26. The main gold producing countries (based on U.S. Geological Survey data)

The mining production of the last 20 years has raised by 2-4% annually. A slight decrease of production is noticeable since 2000 (Fig 27).

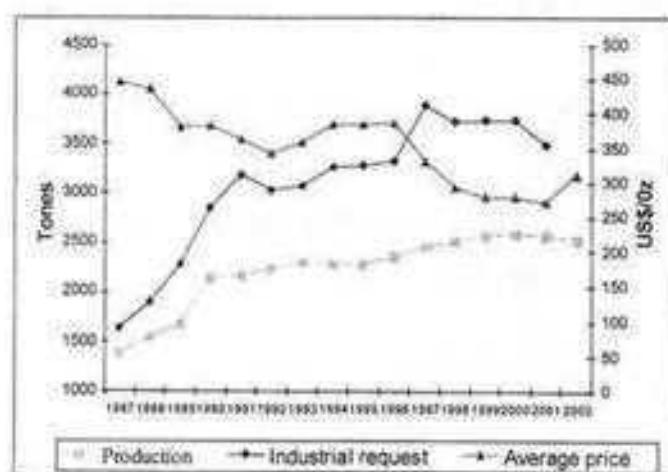


Fig. 27. Evolution of the mining production, industrial request and gold price (based on U.S. Geological Survey data)

Table 2. World production of gold (kg) (data after US Geological Survey).

Country	1998	1999	2000	2001	2002
South Africa	465100	451300	430800	394800	399234
Algeria	-	-	-	300	369
Saudi Arabia	5100	4570	3800	5000	5000
Argentina	20400	34515	25954	30630	32486
Armenia	350	400	600	1900	3200
Australia	310070	301070	296410	285030	273010
Belize	6	6	6	1	1
Benin	500	500	500	500	500
Bolivia	14444	11788	12001	12395	11256
Botswana	1	2	4	2	8

Brazil	49567	52634	50393	53207	50500
Bulgaria	1253	1034	1100	1000	1000
Burkina Faso	1091	886	1000	1000	1000
Burundi	-	-	-	415	420
Burma	334	267	250	200	200
Cameroon	1000	1000	1000	1000	1000
Canada	165599	157617	156207	158875	148860
Chile	44980	48069	54143	42673	40000
China	178000	173000	180000	185000	190000
Columbia	18810	43847	37018	21813	20799
Congo, Brazzaville	10	10	10	10	10
Congo, Kinshasa	151	207	52	50	50
Costa Rica	742	165	51	100	100
Ivory Coast	3400	2717	3154	3100	2000
North Korea	4500	2500	2500	2500	2500
Cuba	1000	1000	1000	1000	1000
Ecuador	3500	2026	2871	2297	2300
El Salvador	98	71	-	-	-
Eritrea	573	534	264	270	300
Ethiopia	2500	4905	5177	5200	5300
Fiji	3690	4428	3842	3858	3731
Philippines	34038	31031	36540	33840	40000
Finland	5000	5900	4951	5552	4600
France	3793	3600	2632	3000	2800
Gabon	70	70	70	70	70
Georgia	700	2000	2000	2000	2000
Ghana	72541	79946	72100	68700	69707
Guatemala	100	4449	4500	4500	4500
Guinea	7835	12001	13104	13000	13500
Equatorial Guinea	500	500	500	500	500
Guyana	12960	12905	13510	14183	12000
French Guyana	2673	2819	3469	3971	2971
Honduras	150	879	878	880	890
India	2383	2500	6200	3700	3800
Indonesia	124018	127184	124596	166091	135000
Solomon Islands	1565	3456	338	300	100
Iran	856	930	765	770	800
Italy	1100	700	709	503	500
Jamaica	-	-	-	214	214
Japan	8601	9405	8399	7815	8615
Kazakhstan	18100	20236	28171	27100	27000

Kenya	388	990	1243	1545	1600
Kyrgyzstan	22000	20000	22000	24000	17000
Liberia	800	1000	1000	1000	800
Madagascar	12	8	5	-	-
Malaysia	3394	3449	4026	3965	4289
Mali	20562	23688	28717	42288	57964
Mexico	25427	23755	26375	26300	20617
Mongolia	9531	10146	11808	13675	12097
Morocco	450	-	505	1190	2654
Mozambique	17	20	23	25	25
Namibia	1882	2005	2417	2851	2815
New Zealand	7544	8577	9880	9885	9770
Nicaragua	3834	4450	3672	3650	3660
Niger	1000	1000	1000	1000	1000
Nigeria	10	10	10	10	10
Oman	891	884	1029	1000	1000
Panama	1500	1500	1500	1500	1400
Papua - New Guinea	61641	65747	74540	67043	65200
Peru	94214	128486	132585	138022	157013
Poland	409	489	367	349	350
Central African Republic	50	41	12	20	20
Korea	22822	25730	22608	28595	26181
Dominican Republic	1424	651	-	-	-
Romania	4000	4000	4000	4000	4000
Russia	114900	125870	143000	152500	158000
Rwanda	17	10	10	10	10
Senegal	550	550	550	550	550
Serbia and Montenegro	2684	1260	1121	1100	1100
Sierra Leone	15	30	30	30	30
Slovakia	340	363	306	300	300
Spain	3295	5081	4310	3300	3600
United States	366000	341000	353000	335000	298000
Sudan	5671	5566	5774	5417	6000
Surinam	300	300	300	300	300
Sweden	5944	4400	3570	4986	4800
Taiwan	9	1	3	9	2
Tajikistan	3000	2700	2700	2700	2700
Tanzania	427	4767	15060	30088	36600
Turkey	1000	1200	500	2000	5000
Uganda	8	5	56	-	-
Uruguay	1985	2400	2177	2083	2100

Uzbekistan	80000	85000	85000	87000	90000
Venezuela	6740	5946	7332	9076	9000
Vietnam	1500	1500	2000	3000	3000
Zambia	765	700	600	130	150
Zimbabwe	25175	27666	22070	18050	15469
Total (tones)	2500	2570	2590	2600	2550

Against the trend of decreasing gold price and increasing production expenditures, the gold production of several countries such as South Africa, Australia, United States and Canada, has declined during the last years (Fig.28). Most affected country was South Africa where the very high costs of deep underground mining determined a gold production falloff of 35% during 1992 and 2002. Since 1997, after the deepening of the gold price crisis, the gold production in the United States and Canada has decreased in average with 3-4% per year.

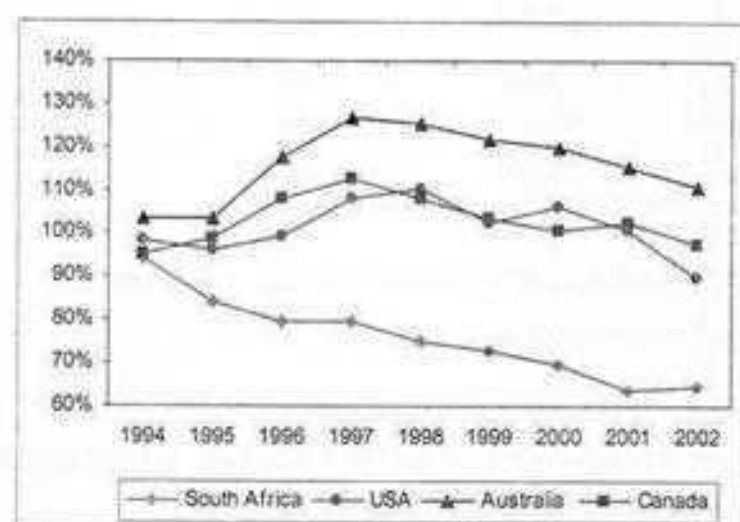


Fig. 28. Changes in gold production comparing with 1993 for the main gold producing countries (based on U.S. Geological Survey data).

In turn, gold production has recorded spectacular rates (Fig.29) in several countries of the South America (Peru, Argentina) and Africa (Mali, Tanzania).

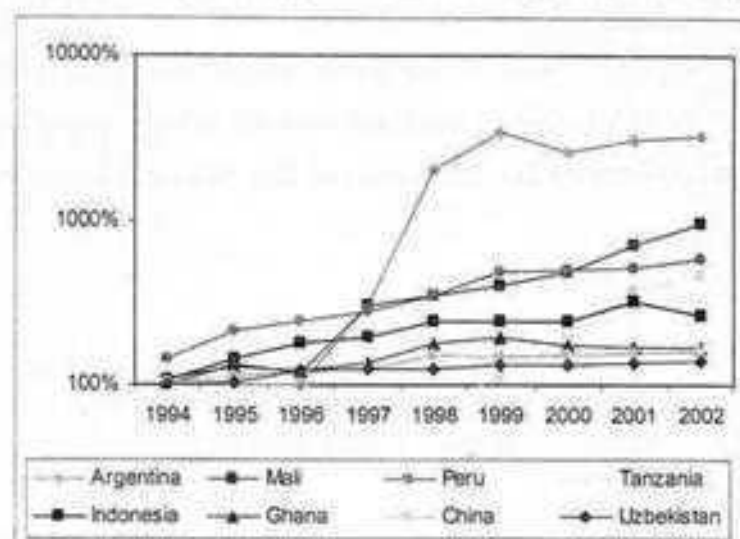


Fig. 29 Changes in gold production comparing with 1993 in some developing countries (based on U.S. Geological Survey data).

In Peru, gold production increased from 27 tones in 1993 to 157 tones in 2002, thus allowing the country to become the sixth world gold producer. From a production of 1t in 1993, Argentina has reached 32 t in 2002, thus entering the group of top 20 world producers.

Constant growths of gold production have been recorded in China, Indonesia, Uzbekistan and Ghana.

Russia had a severe gold production falloff during 1993 and 1998 which was followed by an ascending trend. Production in 2002 was roughly the same as in 1993.

As a result of the increasingly polarized industry, over 30% of the world production is obtained by 5 major international mining corporations. The mining reserves (proven and probable) controlled by these corporations exceed 9600 t Au (Table 3).

Company	Production (t Au)	Reserves (t Au)
Newmont	236,3828	2675
AngloGold	183,5077	2249
Barrick	177,2871	2706
Placer Dome	108,8605	1648
Kinross Gold	62,206	404

The largest part of the gold production (approx. 81%) is used in jewelry. About 10% are used in industry (especially for electronics) and stomatology.

At present, only 9% of the extracted gold is treasured in bank repertories. Central banks of various countries and private investors own very large stocks of gold in comparison with the annual production and consumption. According to some gold market experts (Christian 1996) the mining production represents only 30 to 40% of the marketed gold.

Experts believe that the evolution of the world production of gold in the next decade will depend on the price of this commodity (Fig.30). For a decrease of gold price down to 250USD/oz, the production might be reduced with up to 30%, whereas for a gold price around 300 USD/oz, the production will maintain relatively constant, with a possible slight decrease towards the end of the decade. For a gold price around 350\$/oz, experts predict an increase of the world production by approx. 25-30%.

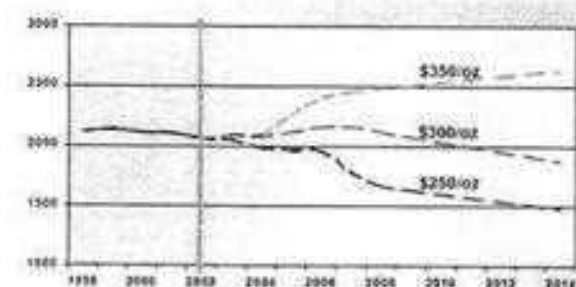


Fig. 30. Various scenarios for the future gold production function of the gold price evolution (Fellows, 2002)

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TIMING OF MIOCENE-QUATERNARY MAGMATISM AND METALLOGENY IN THE SOUTH APUSENI MOUNTAINS, ROMANIA

ROSU¹ Emilian, UDUBASA¹ Gheorghe, PÉCSKAY² Zoltan,

PANAOTU³ Cristian, PANAIOTU³ Cristina Emilia

¹Geological Institute of Romania, 1 Caransebes Street, RO-78344, Bucharest 32, Romania. E-mail: rosu@igr.ro; ²Institute of Nuclear Research of the Hungarian Academy of Sciences, P.O. Box 51, Bem ter 18/c, H-4001 Debrecen, Hungary; ³University of Bucharest, Paleomagnetism Laboratory, Bălcescu 1, 70111 Bucharest, Romania

In the South Apuseni Mountains (SAM), the Miocene-Quaternary volcanic activity evolved in three episodes. The first volcanic products are represented by poorly developed rhyodacite tuffs, hosted by Globigerina bearing marls (Langhian), followed by main and complicated magmatic activity in Kossovian-Pannonian. The last episode (Early Pleistocene) displays an alkaline character and occurs on a different geostructural context only in Uroi Hill (1.6 Ma), after a gap of about 2 Ma. At regional scale this areal display specific features with regard to space-time evolution of volcanic activity, association of elements, type of mineral deposits and age of deposits.

In this paper, we present the whole available data regarding the K-Ar ages included in our different papers (a few of them being re-analysed and corrected afterwards) and on this basis to estimate the age of main mineralizing processes in different areas according to spatial-temporal evolution of Neogene magmatism.

Based on detailed field observations combined with K-Ar ages, geochemical analyses, and paleomagnetic data the scenario for Neogene magmatic evolution of SAM is as follows: an early volcanogenic sedimentation in newly created pull-apart basins, followed by two magmatic activity events. The first event (calc-alkaline medium-K quartz andesites with amphibole, pyroxene ± biotite), between 14.8–11 Ma, is spatially restricted to Zarand-Barza-Zlatna-Rosia Montana-Bucium areas and shows a progressive clockwise rotation, around 70° between 14.5 Ma and 12 Ma. The second event, represented by calc-alkaline medium to high-K quartz andesites with amphiboles, biotite ± pyroxene, developed between 12.6–7.4 Ma, covers a larger areas in the Deva-Sacaramb-Hartagani and Baia de Aries-Rosia Montana zones, is free of paleomagnetic rotations, and the main products here are "adakite-like" calc-alkaline rocks. Small bodies (10.5 Ma) with alkaline features (trachyandesites, microdiorites)(Sacaramb-Hartagani area) and basaltic andesites (7.4 Ma) (Rosia Montana-Bucium area), with distinct geochemical signature, are the latest products in the respective districts.

The paleomagnetic data show also, that: (1) the clockwise rotation within Tisia block started after collision of the northern part of Alcapa block with the European continental margin at about 16 Ma (Panaiotu, 1998); (2) most of the Tertiary clockwise rotations were very fast: (around 70° between 14.5 Ma and 12 Ma) and (3) the Miocene volcanism from the Apuseni Mountains took place in a very dynamic rotational setting.

All the data regarding K-Ar ages for Neogene magmatic- Quaternary rocks in Apuseni Mountains are presented in Table 1.

Table 1 Sample location, rock type, lithology and K-Ar ages (whole rocks) for Neogene-Quaternary magmatic rocks in Apuseni Mountains.

Sample	Locality	Lithology	Rock type	K (%)	⁴⁰ Ar _{rad} (%)	⁴⁰ Ar _{rad} (ccSTP/g)	K-Ar ages	Source
ZARAND								
117	Tălagiu	α am px	neck	1.27	48.6	6.623x10 ⁻⁷	13.4±0.6	1
5186	Dieci	α am px	neck	1.01	16.2	5.293x10 ⁻⁷	13.4±1.2	1
1048	Camna	α px	lava flow	1.22	33.7	6.195x10 ⁻⁷	13.0±0.7	1
5199	Chișindia	α px	neck	1.18	43.3	5.897x10 ⁻⁷	12.8±0.6	1
6529	Vărfuri	α px	lava flow	0.94	24.0	4.559x10 ⁻⁷	12.43±0.79	3
1097	Minisulde Sus	α px	lava flow	1.3	28.3	6.144x10 ⁻⁷	12.4±0.7	1
BRAD								
2352	Curechi	α am px	sub-volcanic	1.18	12.2	6.757x10 ⁻⁷	14.7± 1.7	1
387	Cireșata	α q am bi+px	neck	1.05	14.6	5.236x10 ⁻⁷	12.81±1.27	3
193	Dl. Caraciu	α am px	neck	0.97	34.7	4.714x10 ⁻⁷	12.5± 0.6	1
4220	Barza	α am px	neck	1.44	14.4	6.977x10 ⁻⁷	12.4±1.2	1
393	Caracel	α px	neck	1.11	47.0	5.319x10 ⁻⁷	12.31± 0.53	3
593	Valea Arsului	α am px	neck	1.27	51.8	5.491x10 ⁻⁷	11.99± 0.50	3
404	Plesa-Brad	α q am bi	neck	1.65	26.7	7.298x10 ⁻⁷	11.34± 0.66	3
401	Brad -v. Steau	α q am bi+px	intrusive breccia?	1.35	62.7	5.813x10 ⁻⁷	11.04±0.44	3
4266	Bratisa	α q am bi+px	volcanoclastic rocks	1.22	54.4	5.096x10 ⁻⁷	10.7± 0.4	1
ZLATNA								
6922*	Trâmboiele	mō am px	sub-volcanic	1.75	64.7	8.621x10 ⁻⁷	12.6 ±0.5	2,
590	Stanija	α am px	neck	1.56	27.4	7.664x10 ⁻⁷	12.59±0.73	3
592	Stanija	α am px	neck	1.31	37.9	6.275x10 ⁻⁷	12.28±0.58	3
594	Almasu Mare	α am px	neck	1.61	27.6	6.948x10 ⁻⁷	11.07± 0.63	3
BUCIUM - ROSIA MONTANA								
6912	Bucium S	mō am px	sub-volcanic	0.94	33.3	5.401x10 ⁻⁷	14.87±0.82	2
6913	Bucium S	mō am px	sub-volcanic	1.14	29.2	6.618x10 ⁻⁷	14.7±0.8	3
2228	Bucium-Citera	α am px	neck	1.21	12.8	6.916x10 ⁻⁷	14.6±1.6	1
797*	Dl. Carnic	v	sub-volcanic	8.87	40.3	4.726x10 ⁻⁶	13.65± 0.63	*
795	Taul din Brazi	v	sub-volcanic	1.25	17.5	6.583x10 ⁻⁷	13.5± 1.1	1
4383	Dl. Contu	v	sub-volcanic	1.75	17.6	8.668x10 ⁻⁷	12.7± 1	*
84	Rotunda	α am px	lava flow	1.41	33.7	5.095x10 ⁻⁷	9.3±0.5	1
785	Geamăna W	α am px	sub-volcanic	1.27	55.8	3.883x10 ⁻⁷	7.8±0.3	2
788	Detunata	αβ	neck	1.30	37.3	3.602x10 ⁻⁷	7.4±0.3	1
BAIA DE ARIES								
801	Valea Lacului	α am bi	sub-volcanic	1.83	29.5	8.481x10 ⁻⁷	11.88±0.59	3
6908	Dl. Bulzu	α am px	neck	1.51	50.2	5.942x10 ⁻⁷	10.1± 0.4	2
362	Poenița	α q am bi	sub-volcanic	1.25	61.0	5.360x10 ⁻⁷	10.99±0.44	3
363	Poenița	α q am bi	sub-volcanic	1.17	51.4	4.245x10 ⁻⁷	9.31±0.39	3
799	Surligata	α am+px	sub-volcanic	1.20	12.3	3.533x10 ⁻⁷	7.6±0.9	2
SACARAMB - HARTAGANI								
388	Valea Draica	α am bi+px	blocks in bedded rocks	2.02	63.4	9.913x10 ⁻⁷	12.58± 0.50	3

567	Dealul Paua-N	α q am bi±px	neck	1.23	17.2	5.969×10^{-7}	12.40 ± 1.04	3
767	Cetras	α q am bi±px	neck	1.05	51.5	4.793×10^{-7}	11.7 ± 0.5	2
565	Voia	α am	neck	1.49	47.6	6.707×10^{-7}	11.54 ± 0.5	3
572	Dealul Padina	α q am bi±px	neck	1.91	30.1	8.532×10^{-7}	11.45 ± 0.62	*
192	Dl. Duba	α q am bi±px	neck	1.19	18.9	5.210×10^{-7}	11.2 ± 0.9	2
394	Gorunste	α q am bi±px	neck	1.40	47.6	6.109×10^{-7}	11.17 ± 0.48	3
389	Valea Draica	α q am bi±px	blocks in bedded rocks	1.09	23.6	4.753×10^{-7}	11.11 ± 0.72	3
390	Zuckerhut	α q am bi±px	neck	1.49	31.0	6.327×10^{-7}	10.89 ± 0.58	3
396	Hondol	α am	neck	1.31	26.1	5.449×10^{-7}	10.77 ± 0.64	3
395	Pr. lui Toader	mô am px±bi	sub-volcanic	1.72	42.1	7.113×10^{-7}	10.6 ± 0.48	3
776	Zămbrita	tr	neck	2.46	61.7	1.011×10^{-6}	10.5 ± 0.4	1
399	Hondol	α q am bi±px	neck	2.04	51.7	8.231×10^{-7}	10.35 ± 0.43	3
566	Dl. Paua S	α q am bi±px	neck	1.72	24.6	6.887×10^{-7}	10.27 ± 0.64	3
538	Faerag-Certej	α am	neck	0.96	23.1	5.333×10^{-7}	14.23 ± 0.93	*
DEVA								
6920	Serhediu	α am	sub-volcanic	1.14	56.9	5.671×10^{-7}	12.8 ± 0.5	2
400	Nocet	α am bi	sub-volcanic	1.40	71.0	6.482×10^{-7}	12.6 ± 0.49	3
6918*	Mina Deva	mô am bi	sub-volcanic	1.7	61.8	7.921×10^{-7}	12.1 ± 0.5	2
392	Cetate	α am bi	neck	2.09	58.6	9.645×10^{-7}	11.85 ± 0.48	3
UROI								
MM29	Uroi	tr	neck	3.38	21.0	2.099×10^{-7}	1.6 ± 0.1	1

Abbreviations: α =andesite, $\alpha\beta$ =basaltic andesite, tr=trachyandesite, mô=microdiorite, v=dacite, am=amphibole, bi=biotite, px=pyroxene, q=quartz. Sources of K-Ar ages are from: (1) Pécskay et al., 1995; (2) Roşu et al., 1997; (3), Roşu et al., 2001, 2004; new data (*); rocks hosting ore deposits (*).

The Neogene ore-deposits of the South Apuseni Mountains (SAM) are related to "normal" and "adakite-like" (or rather "high Sr" andesite) calc-alkaline intermediate magmatic complex structures generated under extensional and rotational regime in a non-subduction setting. A possible scenario, according to geotectonic, geochemical and paleomagnetic data, involves a transtensional tectonic regime directed by contemporaneous eastward translation and clockwise rotation of Tisia-Getia terrane, in area of South Apuseni Mts., on a relatively thin lithosphere. Expression of this are the deep-seated transtensional fault systems generating graben like-small pull-apart aligned basins, which represent the structural control for magma uprising. The mechanism of magmagenesis is considered to be related to decompressional melting of a heterogeneous source (subcontinental mantle affected by metasomatic process related to earlier subduction events and /or lower crust) situated at the crust-lithosphere mantle boundary. Mixing with asthenospheric melts generated during the extension-related attenuation of the lithosphere may also be implied (Rosu et al., 2001,2004). The Neogene ore-deposits of the SAM are represented by porphyry copper-gold deposits, base metal, world-class gold deposits and rich smaller deposits showing an uncommon density of ore bodies (Udubaşa et al., 2001). A detailed analysis of each zone shows that only some magmatic structures are productive, showing peculiar structural patterns. Despite of some mineralogical and geochemical differences existing between "normal" and "adakite-like" calc-alkaline andesites, the whole area of SAM is characterized by numerous porphyry copper systems (Cu ± Au, Mo) (although many of sub-economic class), base metal-gold and telluride epithermal ores: veins (low-sulfidation and sporadically high-sulfidation types), breccia pipes or replacement

bodies. Further on, there is a typical feature of many magmatic-metallogenetic structures: either porphyry systems enveloped by epithermal vein arrays (Bolcana-Troita, Valea Morii etc.) or productive subvolcanic bodies enveloped by barren volcanic structures (e.g. Sacaramb)(Rosu et al., 2003).

There are a few data regarding the timing of mineralization but based on these and on detailed field observations (pre-, host rocks, syn- and post mineralization), combined with K-Ar ages, geochemical analyses, and paleomagnetic data (Fig. 1) we can remark the following: the oldest mineralisation is the gold mineralization from Rosia Montana (13.6 Ma); in Zlatna area, the timing of mineralization developed between 12.6 Ma (porphyry copper) and probably 10.5 for epithermal ore deposits; the age of microdiorites with porphyry copper mineralization from Deva according with our data is 12.1 Ma. On the same criteria, we can estimate the intervals of mineralization processes from Sacaramb -Hondol-Voia area (porphyry and epithermal ore deposits) between 11-10 Ma, 12.5-11 Ma for porphyry and epithermal from Bucium Rosia Poieni area and 9.5-8.5Ma from Baia de Aries. In Barza area, the mineralized fragments of andesite-microdiorites are present in andesites from Ciresata Hill (12.81 ± 1.27 Ma); estimative interval of mineralization is between 12.8 (possible younger, cca 12.5 Ma) and 10 Ma, according to preliminary data obtained by A. Lips on the Valea Morii samples (personal communication)

Our data suggest three main time intervals for mineralization processes: the first, at the boundary Badenian/Sarmatian (13.6 Ma) in Rosia Montana area, the second, largely developed at regional scale between 12.5-10 Ma (Middle Sarmatian-Upper Pannonian) and the third, between 9.5-8.5 Ma at the Baia de Aries (Pannonian).

According to these data, with a few exceptions (e.g. Rosia Montana and probably Bucium Rodu), all the productive structures was emplaced after the cessation of the large clockwise rotation. This period, at regional scale and especially at the scale of complex magmatic structures ("volcano-plutonic structures") was favourable to intrusion and emplacement of shallow-columnar small sized subvolcanic bodies connected with deep sources rich in vapour-like fluid of low density and more saline liquid (brine) at this moment of evolution. This "shallow-columnar" subvolcanic bodies were the main "way" to transport this products and were in their upper part the place of segregation of ore-forming elements by separation of vapour and brine in accord with processes of crystallisation and physico-chemical parameters of magmatic-hydrothermal systems. In the SAM area, the porphyry copper mineralizations show a primary character, or with only local subsequent convective copper enrichment processes, being rich in fluid inclusions with very high salinity; in most the cases, the epithermal veins and/or breccias spatially related to porphyry copper or shallow subvolcanic bodies are rich in fluid inclusions with very high salinity, too (e.g. Brad area, Bocsa-Sacaramb, Hanes-Larga, Baia de Aries area)(Nedelcu et al., 1999, 2001)

The processes of mineralization were influenced by regional frame but as much important were the control at local scale, where this special moment of emplacement of shallow subvolcanic bodies connected with tectonically control and the permissive spaces created in the upper part in neighborhood of porphyry Cu $\pm$ Au, Mo, base metal and gold mineralization.

The spatial-time evolution and the distribution of complex magmatic structures ("volcano-plutonic structures") at regional scale, what usually are associated with mineralized structures is a good argument in sustaining this idea.

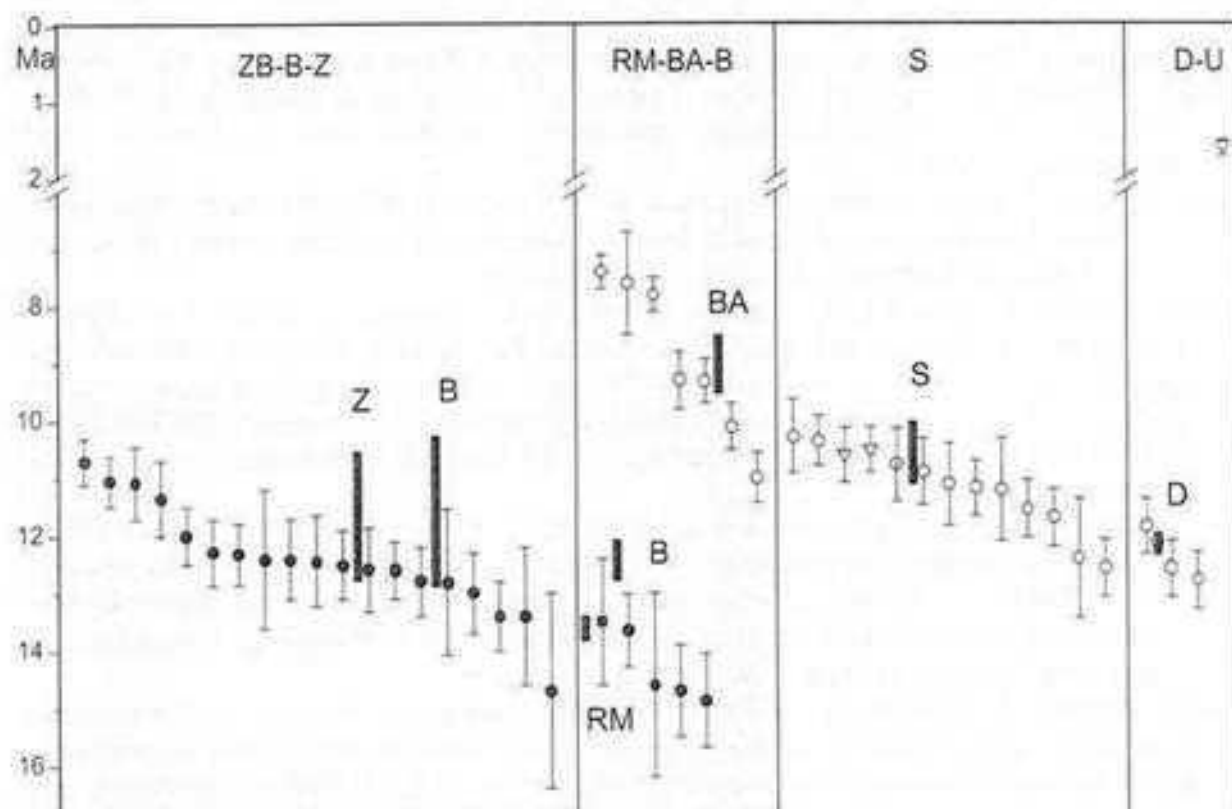


Fig. 1. Time evolution of volcanic and metallogenetic activity in the Southern Apuseni Mountains. For metallogenetic activity the time intervals are estimative. Symbols for rock types (black symbols are normal calc-alkaline rocks, open symbols are adakite-like calc-alkaline rocks): squares=dacites; circles=andesites; diamond=basalts andesites; triangle=alkaline rocks. Areas acronyms: ZB-B-Z = Zarand Basin – Brad – Zlatna; RM-BA-B = Roşia Montană – Baia de Arieş – Bucium; S = Săcărâmb; D-U = Deva – Uroi (see Table. 1 for their locations). K-Ar ages from Pécskay et al., 1995; Roşu et al., 1997, 2001, 2004 and this study. Time evolution of volcanic activity diagram after Roşu et al., 2004. Thick bars represent presumed age of mineralization for specific areas.

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Au-Ag TELLURIDE DEPOSITS IN THE METALIFERI MTS.: EFFECTS OF LOCAL GEOLOGY OR OF A "HYDROTHERMAL ICHOR"

UDUBASA¹ Gheorghe, UDUBASA² Sorin Silviu

¹Geological Institute of Romania, 1, Caransebes Str., Bucharest, Romania, E-mail: udubasa@igr.ro;

²Bucharest Univ., Fac. of Geology & Geophysics; 1, N. Balcescu Blvd., Bucharest, Romania, E-mail: udubasa@geo.edu.ro.

1. Introduction

The "Golden Quadrangle" (or Quadrilateral) (GQ) in the Metaliferi Mts. (MM), Romania, is well known worldwide especially due to the richness in Au-Ag tellurides (AAT) of several ore deposits in the area. In addition, the GQ is unique in the Carpathians both as a "gold spot" of prime importance in Europe and as occurrences with an unusual high frequency of AAT.

Attempts were made to explain this gold and AAT "anomaly" within the GQ, although the analytical proofs are not always available. Udubasa et al. (2001) pointed out to the peculiarities of the local geology and tectonic setting and invoked the role of the basement as a supplementary source of Au and Te. Alternately, Cook et al. (2003) "believe the answer lies in the evolution of individual hydrothermal systems, rather than in basement sources". What evolution is meant remains unknown and the arguments presented by Udubasa et al. are thus replaced by a "hydrothermal ichor".

2. Tectonic setting and some petrochemical features

The most striking feature of the magmatism in the MM is its generation in a transtensional regime, by adiabatic decompression and partial melting of the reactivating Upper Cretaceous – Paleogene enriched lithospheric mantle. The resulting graben structure was a consequence of eastward translation and clockwise rotation of the Tisia-Dacia or Tisia-Getia terrane (Seghedi et al., 1998). In this area the evidences of contemporaneous subduction are lacking, as opposite to the other segments of Neogene magmatism in the Carpathians. The same authors invoked a possible relation of the Neogene magma generation to an earlier subduction-related mantle metasomatism event (Late Cretaceous to Early Paleogene magmatism). Thus, the subduction signature of the Neogene magmatism in the MM is inherited from earlier events.

A further feature of the Neogene magmatites in the MM is their distribution along two "alignments" (roughly NW and SE) (Rosu et al., 2001). Between the two alignments is an angle of about 60-70°. Perhaps it is not a pure coincidence that the clockwise rotation of the MM during Eocene-Miocene was first of 20° and then of 60°.

The rotation started around 14 Ma and progressively diminished (28°) at 13 Ma and ceased at around 12 Ma (Rosu et al., 1998). It is perhaps not a pure coincidence that the age of the Sacaramb magmatites is "post-rotational", i.e. of 10-11 Ma.

A transition from normal calc-alkaline to calc-alkaline adakite-like magmas was depicted in some rocks of the MM (Sacaramb area included) and no significant contamination and fractional crystallisation of rapidly ascending magmas could be proved (Rosu et al., 2001). Formally, these facts seem to contradict any influence of the basement in featuring the MM magmatic and metallogenetic events/activity.

3. Historical and computation background

The Metaliferi Mts. (MM) in Romania, the historical "siebenbürgisches Erzgebirge", contain by far the richest gold deposits related to the Neogene magmatic activity in the whole Carpathians. The AAT ores represent also a unique feature of the area. The Sacaramb AAT ore deposit is situated in the southern part of the MM and is the largest among the AAT ore deposits. Its exploitation began some 250 years ago. The Sacaramb mine produced some 30 t Au, 55 t Ag and 60 t Te from veins located mostly in the volcanic (andesitic) structure. Five main mining horizons exist here, covering a vertical extent of about 450 m. The opening years and their altitude are given below.

Maria	1746 A.D.	784 m
Bernat	1757	723 m
Josephi (Ferdinand)	1765	637 m
Franz (Carol)	1824	494 m
Franz Joseph (Nicolae)	1898	335 m

The average content of gold was of about 90 g/t at the beginning and of about 3 g/t in the last 50 years, which roughly gives a general figure of 10 g/t Au. Ghitulescu & Socolescu (1941) gave a total output of Au+Ag of 85,000 kg, i.e. about 30,000 kg Au and 55,000 kg Ag. No data seem to exist concerning the Te content of the ores, which can be only estimated by assuming a Au:Te ratio of 1:2, as in the most important gold tellurides, i.e. nagyagite and sylvanite. From such estimations it results an average content of 20 g/t Te and about 60 t Te (only partly processed and used).

The "closely packed" vein array of Sacaramb shows a garland-like distribution within the volcanic structure. The veins have an average thickness of 0.3 m and a total length estimated at about 300 km (Udubasa et al., 1992).

The Sacaramb volcanic structure is of a moderate size, looking as an inverse cone some 1 km in length, 1 km in diameter at the upper part and less than 100 m at the lowest part known (160

m below the Nicolae horizon). The AAT ore-bearing andesite volume was thus probably of about 0.25 km^3 (eroded part included). The ore veins and the related altered host rocks make about 5 % of the volcano volume, i.e. 0.0125 km^3 , roughly 50 mil. t of "useful material".

By assuming that the volume of the magmatic chamber producing the Sacaramb volcano was 5 times larger than the volume of the volcanic rocks now exposed (underground and at surface), the volume of the magma and the related magmatic fluids can be estimated at about 1.25 km^3 . Taking into consideration the amount of 60 t of Te produced at Sacaramb an average content of 0.058 g/t Te in the magma and the related hydrothermal fluids can be computed. This figure is about 10 times larger than the average value of Te in the earth crust (0.006 g/t). If such an amount of Te can be accommodated by a normal andesitic magma is doubtful or at least should be proved.

4. Discussion; Origin of Tellurium

Due to the lack of data concerning the geochemistry of tellurium, the formation of the AAT ore deposits and especially of the Sacaramb deposit is hardly difficult to be convincingly explained. The Sacaramb deposit remains at least a big anomaly within the Carpathians volcanic chain of Neogene age.

First of all, the comparison of geochemistry of Neogene magmatites does not suggest major differences among the different segments of the Carpathian volcanic chain (Seghedi et al., 1998), except the adakite tendency of some andesites in the MM (Rosu et al., 2001). It is true, the Neogene magmatites in the MM have formed under special conditions, i.e. transtensional regime by adiabatic decompression and partial melting of the reactivating Upper Cretaceous – Paleogene enriched lithospheric mantle (Seghedi et al., 1998). This the first point to be highlighted: inheritance of an earlier subduction event.

Such peculiarities as concern the geochemistry and magma generation, are not sufficient to explain the huge concentration of Au and Te, at least at Sacaramb. Cook et al. (2003) suggest the evolution of hydrothermal system, without giving any data upon this special evolution. The recent review paper of Heinrich & Neubauer (2003) does not bring many novelties concerning the matter under discussion. Based on oxygen isotope analyses Alderton et al. (1998) and Alderton & Fallick (2000) suggest however a metasedimentary signature of the altered rocks. This is the second point in disturbing the role of a special hydrothermal "ichor" promoted by Cook et al. (2003).

Even if the contamination and fractional crystallisation processes cannot be traced from other isotopic data, e.g. Sr, at least for the younger magmatic stages (including the Sacaramb andesites) (Rosu et al., 2001, p. 17), contamination in shallow magma chambers cannot be excluded (the same authors, p. 19).

The role of the basement in the Te (and Au) enrichment cannot be totally ruled out, as there are several arguments, which should be "destroyed" prior to favoring a hydrothermal, undefined "ichor". The arguments are of different kinds:

- *General:*

1) As compared to the Baia Mare area (Pb Zn Cu dominated, with subordinate Au ores) the MM area is Au (Cu) dominated with a special Te signature. In the Baia Mare area there are only traces of basic rocks (scarcely developed Pienides, as a part of the Main Tethysian Suture, Sandulescu, 1984) whereas in the MM the ophiolitic basement is largely developed. In the Baia Mare area the adakite tendency has not been depicted (yet?).

2) No other parts of the Neogene volcanic chain in the Carpathians show such a varied basement as the MM has: Mesozoic ophiolites and sedimentary rocks, banatitic rocks and younger magmatic rocks of Eocene age, as well as sedimentary Mn ores.

- *Specific:*

3) Several magmatic events succeeded and spatially partly overlapped on a large area of the MM terrane:

- a) Ophiolites, ~140 Ma
- b) Lower Cretaceous granitoids, ~80 Ma
- c) Upper Cretaceous - Paleogene banatites, 60 Ma
- d) Acidic rocks (scarcely developed), ~40 Ma
- e) Neogene andesites, 15-8 Ma
- f) Basaltic and shoshonitic rocks, 1.6 Ma

Fluid circulation can be traced in every of the above mentioned events, suggesting a repeated heating and cooling of a large area, as well as circulation of fluids of different composition and temperature (Udubasa et al., 2001) and also mixing of fluids of different ages, which could have brought leachates from different sources, some of them uncommonly rich in Te (and Au and Mn).

4) The geochemical triad Au-Te-Mn is very typical, especially for the Sacaramb ores, a feature not encountered in other parts of the Carpathian Neogene chain. However, Popescu (1978) advocated the role of the stratiform Mn ores from Preluca Mts. in explaining the abundance of rhodochrosite at Cavnic, Baia Mare area.

- *Particular:*

5) In a pure Pb-Zn-Au ore deposit (Coranda Hondol) AAT were found exclusively within altered ophiolites (and Cretaceous sedimentary rocks).

6) The Sacaramb AAT ore deposit is situated near the Major Tethysian Suture (see Fig. 1) and at the same time at the "intersection" of the two alignments with Neogene magmatites (Fig. 2), representing thus the "pivot" of the Miocene rotation (?).

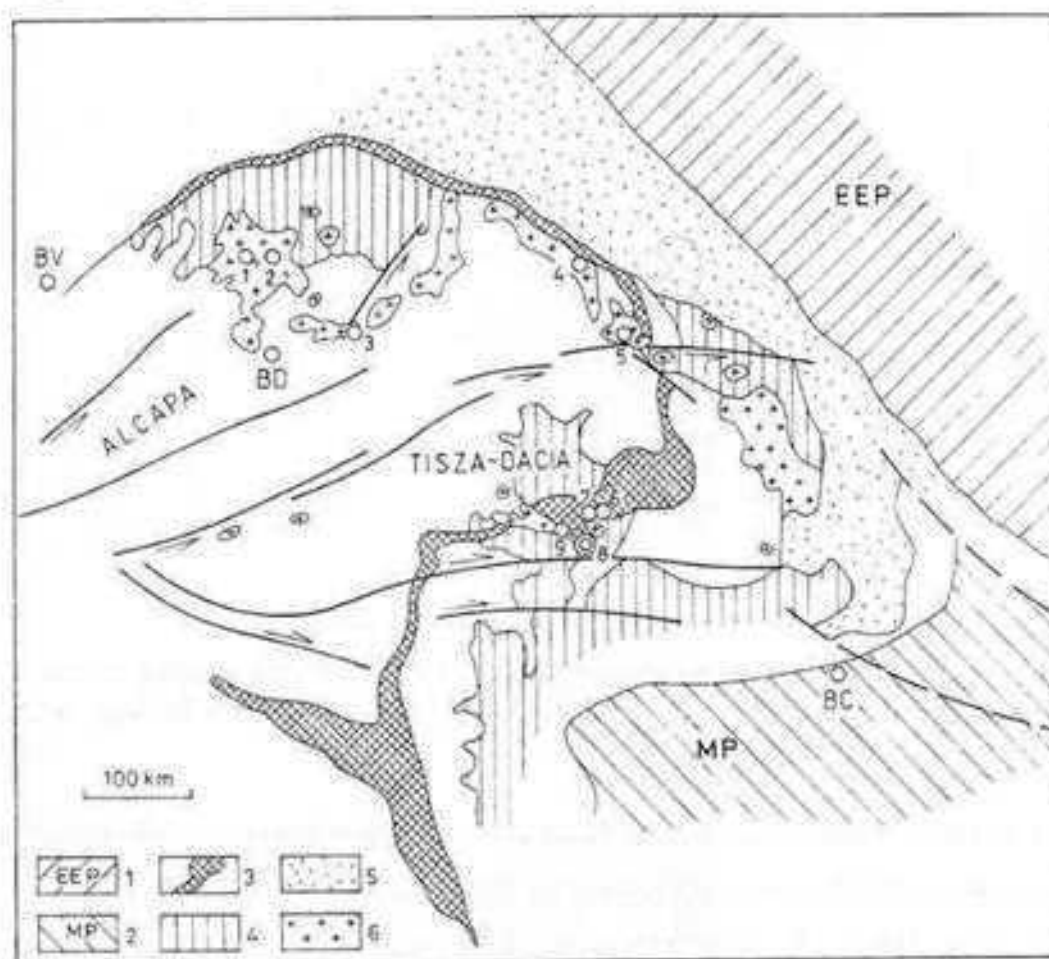


Fig.1-Structural sketch of the Carpathians (simplified, acc. To Sandulescu, 1984; Seghedi et al., 1998; Hippolyte et al., 1999) showing the distribution the Tertiary volcanic rocks and the location of the 9 major ore deposits related to them (1. Kremnitsa (Au), 2. Banska Stiavnica (PbZnCu); 3. Reesk (Cu); 4. Vyshkovo (Hg); 5. Baia Sprie (PbZnCu); 6. Rosia Poieni (6); 7. Rosia Montana (Au); 8. Sacaramb (AuAgTe); 9. Brad (Au). EEP (1)-East European plate; MP (2) Moesian Plate; 3-Major Tethysian Suture; 4-Pre-Neogene rocks; 5. Carpathian Flysch Belt; 6- Tertiary calc-alkaline and alkaline volcanics. The Miocene kinematics (simplified) acc to Royden et al.(1982), Csontos et al. (1991) and Fodor et al.(1996) – from Hippolyte et al.(1999). Abbreviations: BV-Bratislava; BD-Budapest; BC-Bucuresti.

• Computational:

7) The magmatic chamber producing the Sacaramb volcanic structure should have contained ten times more Te (0.058 ppm) than the average content in the earth crust (0.006 ppm). This figure was computed in order to obtain the amount of Te (about 60 t) produced by the Sacaramb mine. If an andesitic magma with related fluids can accommodate such large amounts of Te (and Au: 30 t and Ag: 55 t) remains to be proved.

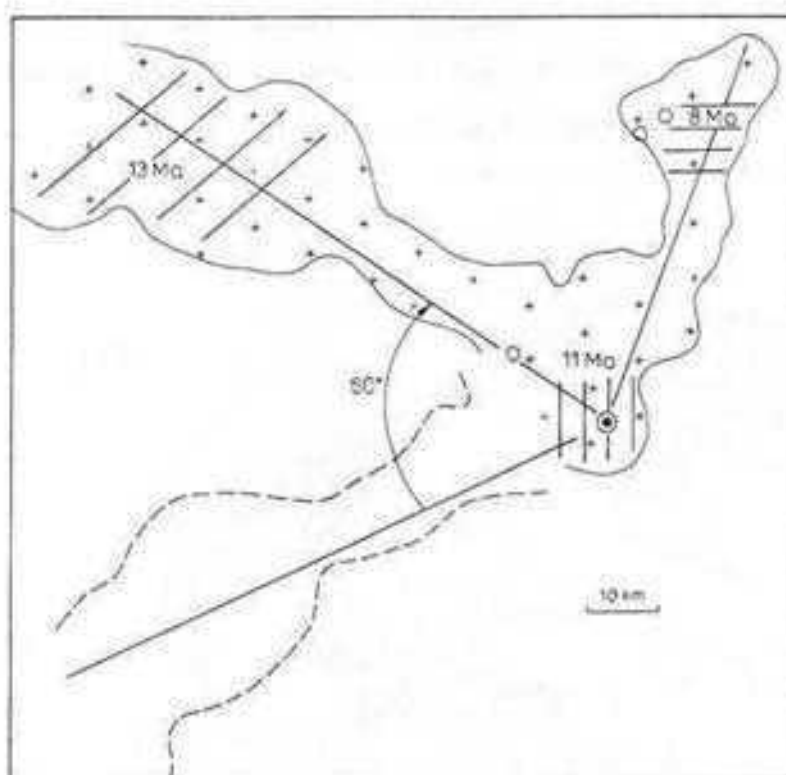


Fig. 2. Cartoon showing the position of the western alignment with Neogene magmatites (crosses) before the rotation (14-12 Ma). The Sacrament AAT ore deposit might be regarded as a "spindle" of the two alignments.

8) The so far highest Te contents in terrestrial materials were determined in some limestones and shales (Beatty & Manuel, 1973). Amazingly enough, the cosmic abundance of Te and its abundance in biosphere is higher than in the lithospheric materials (Cohen, 1981). The average content in meteorites is of about 1 ppm (Greenland, 1967).

Final conclusion

Instead of promoting a hydrothermal "ichor" (a special evolution of hydrothermal systems) it would be more realistic to take into consideration the above mentioned arguments, most of them not obvious at the first glance and not easily to be overlooked.

In addition, one conclusion released by Afifi et al. (1988) from their experimental study of telluride stabilities is as follows: "The deposition of tellurides in ore deposits is due to a short-lived increase in Te fugacity, probably reflecting a finite supply or an abbreviated release mechanism for tellurium at the source" (p. 402). No further comments are needed. Just remember: "short-lived increase in Te fugacity" and "finite supply ... for tellurium" should be accommodated to a hydrothermal model before the effects of local geology will be totally refuted.

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Appendix

1. Some data on geochemistry of Te (average values, ppm)

Crustal abundance	0.005	(Cohen, 1984)
Earth crust	0.006	(Rosler & Lange, 1972)
Meteorites	0.1	(Goldschmidt, 1937)
	1.02	(Greenland, 1967)
Rocks	0.0018	(Goldschmidt, 1937)
Igneous rocks	0.0082	(Beaty & Manuel, 1973)
Carbonates rocks	1-2	(Beaty & Manuel, 1973)
Human body	560mg	(Beaty & Manuel, 1973)

2. Enrichment factors for Sacaramb ores

Te	3,333x (20ppm, av.ores : 0.006)
Au	2,500x (10ppm, av.ores : 0.004)

3. Computation of the total amount of Te produced by Sacaramb mine (Te content of the ore never measured) by using three different methods:

I. By assuming a double amount of Te as compared to Au (30t)	60t
II. By considering 200 Km of mining workings on veins (1.8Mil.t)	52t
III. By considering the waste dumps (about 40 Mil.t) and giving about five per cent therefrom for the ores extracted	60t

SOME THOUGHTS ON THE DACIAN GOLD

JUDE Radu,

University of Bucharest, Department of Mineralogy, 1, Blvd. N. Balcescu.

The opinion concerning the richness in gold of the Dacia, contained in some ancient writings was still expressed until today. So, the Greek historian Herodot (V century B.C.) said that Agathyrshy, a population of Scythian affinity from the Mureş valley was had numerous gold objects and jewels. Ioannes Lydus related about the treasures of gold captured by Emperor Traian after conquest of the Dacia by Romans. Criton had mentioned a fabulous quantity, of about five millions pounds of gold (2,5 Mil.kg Au) and a double quantity of silver (Drăgan, 1976, pg 20). More plausible estimation gives J. Carcopino, of 165500 kg gold and 331000 kg of silver (Drâmba, 1985, vol. I, pg 788).

According to Herodot, the Dacians as well as Gethyans are ancient peoples of Thracian kingship.

New archaeological discovery, posterior to the 2-th World War and radiocarbon dating with ^{14}C method allowed a more exactly outline of the development of civilizations in the Carpatho-Danubian space and its surroundings, beginning of Prehistory times. Ghimbutas (1989) promoted the concept of 'Old European Civilization' comprising the Neolithic and Chalcolithic Cultures (7000-3500 B.C.) for the Carpatho-Danubian area, including also the Adriatica, Aegean region and the south part of Italya, contemporaneous with the Mesopotamian and Anatolian Civilizations. This Old Civilization was created by indigenous populations of shepherds and farmers-hands (agriculturist), which know three aceramic and five – ceramic stages, before of infiltration of Indo-European populations, during the 4-th and 3-rd millennia B.C., so named 'The Kurgan Cultures' by Gimbutas. These earlys populations discovered the utilization of the metals – the native copper and gold: copper beginning with 5500 B.C. – the Starcevo Culture (Serbia) and Criş – and gold, around 4000 B.C. – Vinča, Turdash and Tisza Cultures.

The production of the bronze and its utilization seem to be of Transcaucasian influence, carried here by Indo-Europeans. The Bronze Ages (Epoch) cover the time interval from 3500 to 2000 B.C. The spectral analysis reveals that the majority of the bronze objects have the composition of a Cu-As alloy; only few of Cu-Sn composition. This is an interesting and realistic discovery, if we call in mind the scarcity of the Sn-mineralizations in this geographic space, except those of the late-Paleozoic granitoids of Bohemian District. But then, the As is a natural constituent of some ore minerals and may be present as trace element in of the ore minerals. As example may be mentioned

the Bor (Serbia), Moldova Nouă, Ocna de Fier, Sasca, Oravița (Banat - Romania) related to the Iaromic granitoids; at Moldova Nouă the As-sulphides may be found even as distinct occurrences. The Neogene epithermal Cu-Au-As mineralization of Bucium-Arama ore deposits (South Apuseni Mts) is another example of the Cu-As geochemical association.

The Sources of Gold of the Dacians. Two important types of occurrences of gold may be postulated as possible sources for Daco-Gethyan populations beginning with Pre-Roman colonization of the Dacia, until Middle Ages. First, as free gold occurrence in outcrops of epithermal mineralizations: veins, veinlets, mineralized breccias a.s.o. related to the Neogene magmatism. Characteristic are the Cetate and Cărnic from Roșia Montană, Bucium, Băița-Brad, Caraci-Tebea, Stănița, Almaș in S-Apuseni Mts. More rarely, in there are other kind of mineral occurrences; for example the gold-quartz ore in metamorphic terranes (Someșul Rece-Gilău, Bozovici, Sebeș and Lotru Massifs).

The second important source was the the occurrence of gold grains and nuggets in detritic sedimentary deposits, especially as gold alluvial placers, as those from Crișul Alb, Arieș, Ampoi, Someș, Pianul de Sus, Sebeș, Nera, Olt river a.s.o. (Bârlea, Bârlea, 1963; Berbeleac et al. 1998).

Near Gemenea (Dâmbovița river) the archaeological data mention a pre-Roman Gethyc site (IV century B.C.) with an activity of extraction of gold from the Dâmbovița alluvial sands (Pârvar, 1967, pg 95) and possibly from Pleistocene Căndești gravels. The nearest source of gold for Agathyrshy-populations from the Mureș Valley, mentioned by Herodot was, probably, the alluvial placers from the Pianu Valley and vicinities: Sibișel, Cioara, Geoagiu, Ampoi.

The Transilvanian gold, after Pârvar (1967, pg 53) has an yellow-whitish color because its content of silver. This is true only for the 'electrum' variety of native gold, usually associated with silver minerals, as in the 'Silver Veins', a group of veins in the southern part of the Cărnic dacitic massif (Roșia Montană), in which the fineness of the gold diminish down to 500 ‰. In other veins from Roșia Montană the fineness may be exceed 800 ‰. The fineness of the gold is an expression of geochemical feature of the ore deposits. Frequently, the fineness of the gold in alluvial placers is more elevated than that of the native gold of primary – 'in situ' mineralizations (Bârlea, Bârlea, 1963, pg 24). The high fineness of the gold grains within alluvial sands may result by loss of the silver as a secondary effect during exogenous processes of the alluvial gold deposits.

Mode of recovery. The archaeological evidences and chemical analysis prove that 'the earliest gold objects of ancient civilizations where fashioned directly from natural gold' (Boyle, 1979). The available sources of gold at these times come from the alluvial gold placers. The interest of the ancients for discovery the sources of gold is reflected by the Greek mythology about the Argonauts expedition in the Colchida Country to find the Golden Fleece.

The method of recovery of the gold is recorded by Strabo, the Greek geographer which wrote that the gold carried by mountain torrents 'is catch in a troughs perforated with holes and in fleecy skins' (Boyle 1979, pg 2). This seem to be 'Hurca' used by the peasants for extraction of gold from Dacian antiquity, until the Middle Ages and latter. The handicrafts mans from Apuseni Country was sculpted 'Şaitrocul'. Very probable this wooden tool originate from Dacians tradition of hydraulic pick-out of the native gold. These operations are illustrated by Agricola in his 'De Re Metallica' from 1556 (Fig. 1).



Figure 1 – Ancient method of gold recovery, after Agricola (1156), in "De Re Metallica"

The process of 'parting' gold and silver was probably know in 6-th Century B.C. So, in the Latène Culture (400-300 B.C.) the Daco-Gethyan populations produced both gold and silver jewels. At these times prevailed the silver jewels: rings, necklaces, carrings and spiraled bracelets with snake-shape heads, kept in the Collections of antiquities (Fig. 2).

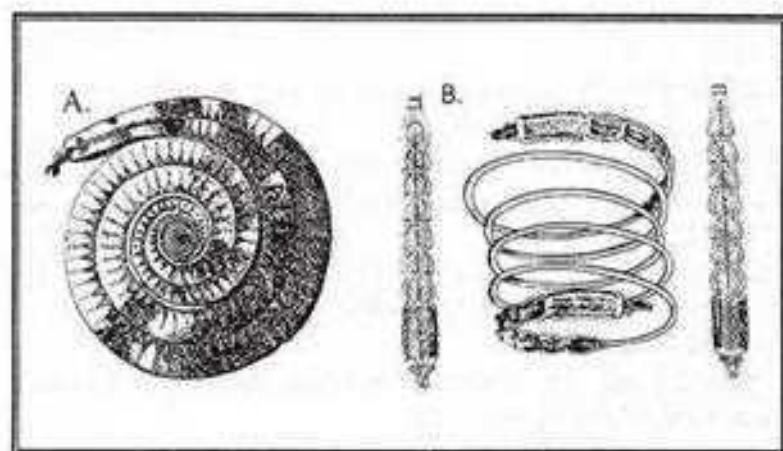


Figure 2. A. – Golden Jewel from Sărasău – Maramureş . B. - Silver bracelet of Dacian Style from Transilvania (in Părvan, 1967).

The mining method of extractions and metallurgical processing of gold (associated with sulphide and silver minerals) according to Părvan (1967) was, probably of Celtic influence. New data of mining archaeology with ^{14}C method, reported by Cauuet (2000 in Tămaş PhD. Thesis, 2002 Cluj Napoca Univ.) prove that the beginning of extraction of gold in Apuseni Mts. preceded

with more than a century the Roman colonization of Dacia (50 B.C. – 80 A.C.). Somehow, these date confirm the anterior supposition made by Szábo (1876, in Haiduc, 1940) that the mining extraction from Roşia Montană preceded with 150 years the Romans colonization of the Dacia.

For a systematic extraction of gold and silver ore the Romans used mining specialists from Dalmatia (Pyrustae). The Roman step-galleries (ladder gallery) allowed to descend at deeper levels of the mines, as may be seen at Țarina (Roşia Montană) and 'Treptele Romane' from the Ruda Valley (Brad).

The 'Waxen-plates' found in Cetate and Cărnic Golden Mines tell us about the relations of private and state property as well as the mining organization in Alburnus Major (Roşia Montană), Alburnus Minor (Abrud) for Bucium extraction and in Apellum (Zlatna), an administrative Centre during the interval 158-180 A.C. (Popa, 1999).

The whole quantity of gold and silver produced in Dacia until the Middle Ages (396 year) estimated by Haiduc (1940) was around 730000 kg Au and 1345000 kg Ag.

In North Transilvania, according to Helke (1938) the free gold in the Neogene ore deposits was scarce, but the silver minerals are more frequently than in the Apuseni Mts. In these territories the extractions of gold and silver as well as of the base metals become actively from the Middle Ages, as at Mons Medius (Baia Sprie), Dealul Crucii, Băița, Valea Borcutului a.s.o. ore deposits.

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THE STRUCTURAL SETTING OF THE ROSIA MONTANA GOLD DEPOSIT, ALBA, ROMANIA

G. V. O'Connor¹, Dr. C.R. Nash², C. Szentesy¹

¹SC Rosia Montana Gold Corporation SA, Alba, Romania

²Colin Nash & Associates Pty Ltd, Brisbane, Australia

Abstract: The Rosia Montana gold deposit is located within the Southern Apuseni Mountains in western Romania. The deposit is a low-sulphidation style epithermal mineralized system, hosted in a Tertiary age dacitic intrusion and phreato-magmatic diatreme breccias. The stratigraphy of the area is dominated by Early Cretaceous flysch sequences, an arenite-rich basal unit, overlain by a shale-dominated unit. Neogene structures are related to Tertiary dextral motion on the Zlatna strike-slip fault in the extreme south of area, which was locally the principal focus of deformation associated with eastward extrusion of the Tisza-Dacia block. A conjugate set of NNW-SSE and NE-SW structures developed concurrently and these appear to be the major controls of Middle and Late Miocene volcanism and porphyry intrusion.

1. Tectonic Setting

The Rosia Montana area is located in the Southern Apuseni Mountains (SAM) region of the western Carpathian mountain belt. Pre-Neogene rocks of the SAM area consist of (i) a metamorphic basement intruded by Hercynian anatectic granitoids, (ii) Early Cretaceous flysch and (iii) a Tethyan ophiolitic suite (Triassic to Early Jurassic pillow lavas and sheeted dykes; Jurassic calc-alkaline volcanics). The Carpathian belt of Romania is interpreted as the site of continental collision between the African and European Plates in Late Cretaceous times, with closure of the Mesozoic Tethyan Ocean that separated the continents.

During final stages of Tethyan closure a N-S oriented belt of acid to intermediate calc-alkaline intrusive rocks, including porphyry Cu deposits, was formed in the west of the SAM (Ciobanu et al., 2002). This stage of tectonic evolution was also accompanied by Maastrichtian-Paleocene molasse deposition, some of which may be preserved in the Rosia Montana area.

The Cenozoic evolution of the SAM is extremely relevant in the context of the present study. A useful visualization of the tectonic setting of the region has recently been proposed by Grancea et al., (2002), and is shown in Fig. 1. The arcuate 'S' shaped Carpathian belt is thought to include two continental blocks or micro-continents, (Alcápa and Tisza-Dacia Blocks) which may have undergone opposite rotations during the Cenozoic. It is probable that the Tisza-Dacia block was extruded toward the east as indicated in Fig. 1.

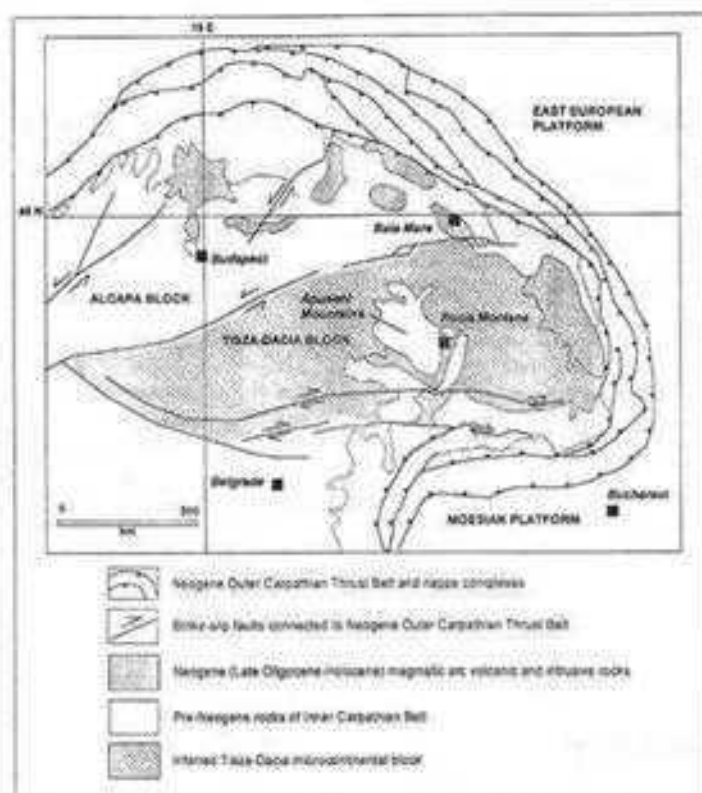


Fig. 1. Tectonic setting of Apuseni Mountains (after Grancea et al., 2002).

The cause of Neogene magmatic arc volcanism in the Apuseni Mountains and elsewhere in the region is debatable. Whatever the mechanism, oceanic crust had been consumed by the end of the Miocene, and continent-continent collision took place between the Alcápa/Tisza-Dacia microcontinent and the East European Plate. This collision was accompanied by calc-alkaline magmatism and the formation of a major east-vergent thrust belt. The Pannonian Basin behind the arc was controlled by a conjugate system of strike-slip faults connected to zones of coeval shortening within the thrust belt.

Calc-alkaline to alkaline magmatism took place in the Inner Carpathians from Oligocene to Recent times (Heinrich and Neubauer, 2002). In the 'Golden Quadrilateral' region of the Apuseni Mountains, a cluster of large, low-sulfidation epithermal Au-Te deposits, including Rosia Montana and Sacarimb were formed. These are spatially and

temporally associated with Cu (Au) porphyry style deposits in calc-alkaline intrusive centers. The emplacement of intrusive stocks was probably controlled by extensional accommodation of the major strike-slip faulting described above. The Neogene intrusions are mainly located in a NW-SE oriented intramontane basin (Rosu et al., 2001), located some 200 km behind the main Carpathian arc (Fig.1)

According to Ivascanu et al., (2002), Neogene brittle strain in the southern Apuseni Mountains region is represented by 'mosaic block faulting and shear-related strike-slip and pull-apart structures'. Paleomagnetic and geochronologic data suggest that the Apuseni Mountains underwent clockwise rotation from 15-12 Ma.

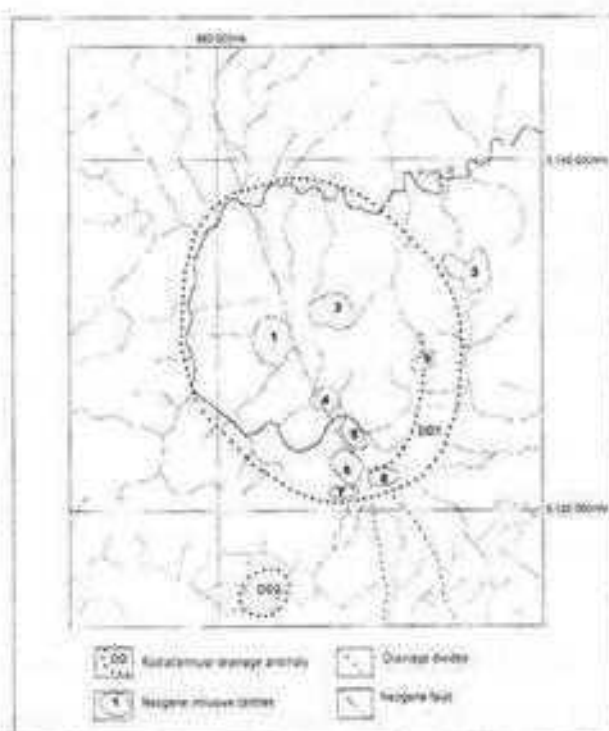


Fig. 2. Drainage patterns and mineralized systems in the Rosia Montana area.

2. Neogene Structures of the Rosia Montana Area

Geomorphology

Since the mineralized intrusives are very young (middle to late Miocene), it follows that landforms associated with intrusion and volcanism are likely to be preserved. There is also generally a close link between younger structure and geomorphology, hence it is to be expected that important structures active in the Neogene will have landform expressions.

Drainage patterns in the area (Fig. 2) suggest the presence of a large subcircular structure that circumscribes all but one of the known Neogene intrusive centres. This structure is defined by the annular shape of the Abrud/Aries River drainages. This conforms with the NW-SE oriented intra-montane basin as described by Rosu et al., 2001. It is also a major radial drainage anomaly, with the centre of the radiating streams located between Rosia Montana and Rosia Poieni intrusive centres. It is bisected by a major NNW-SSE Neogene fault system mapped, which appears to continue to the south as one or more linear drainage divides.

In satellite imagery of the Rosia Montana area, curvilinear, inferred caldera-margin faults around the southern part a circular drainage anomaly can be seen. The presence of higher ground to the south and east of the circular feature would suggest that the latter is relatively down-faulted. It is noteworthy that remnants of the regional quaternary sediment erosional surface all occur at the same elevation, and all are outside the inferred caldera. Both ASTER imagery and the ASTER DEM suggest the presence of concentric faults in the SE segment of the circular structure. The belt of high ground in this segment contains the Valcoi-Botes and Corabia deposits and continues towards the east. This belt is characterized by preservation of the Quaternary sediments at surface. The Baia de Aries mineralized centre is also on this structural segment and at a similar elevation.

Mapped Structures

Figure 3. is a structural overview map based upon the results of airphoto and ASTER interpretation. The most prominent structures visible in the study area are, (1) Poorly-developed E-W structures affecting the Early Cretaceous flysch that may be related to Cretaceous closure of the Tethyan ocean. (2) Possible flat-lying transported thrust sheets in the west of the area that are of probable Tertiary age. (3) An inferred dextral shear zone (Zlatna Fault Zone) in the extreme south of the study area, along which slivers of ophiolite or tectonic mélange occur. (4) Late-stage NNW-SSE and NE-SW faults passing through the Rosia Montana-Rosia Poieni area that appear to have a vertical component that post-dates the Rosia Poieni andesites (9.3 Ma).

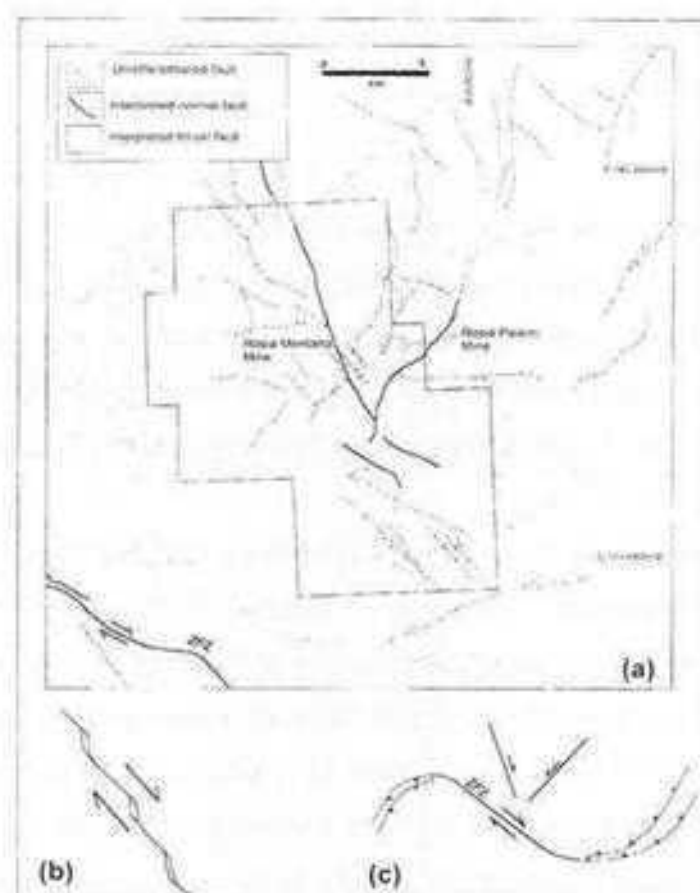


Fig. 3. Photogeologically interpreted structure of Rosia Montana area.

A suggested interpretation of the mapped Neogene structures is shown in Figure 3. It is suggested that the NW-SE Zlatna dextral fault zone (ZfZ) is a major feature along which Tertiary strain was accommodated during the eastward extrusion of the Tisza-Dacia crustal block. The western end of the shear zone is accommodated by a system of W-vergent thrust in Mesozoic seafloor rocks, while a mirror-image system of E-vergent Neogene thrusts that forms the eastern accommodation of the ZfZ shear is clearly visible on regional maps and satellite images in the area to the east of the present study.

It is probable that the system of NNW-SSE and NE-SW conjugate faults in the Rosia Montana and Rosia Poieni areas was formed initially as a set of Riedel 'R' and R'' (synthetic and antithetic) shears in association with the ZfZ. We would therefore infer early dextral motion along the NNW-SSE fault that bounds the Rosia Montana dacite body to the east. This would explain the pattern of N-S trending sigmoidal veins found in the Rosia Montana and Bucium mineralized areas.

The final motions on the NNW-SSE and NE-SW conjugate faults were vertical. The block containing Rosia Poieni porphyry mine has been uplifted and unroofed (probably by 1-

2 km) relative to the block to the west, where andesite flows are still preserved on the hilltops north of Rosia Montana.

3. Conclusions

With regard to regional geology, the stratigraphy of the Rosia Montana area is dominated by Early Cretaceous flysch sequences that outcrop very poorly. A basal unit with a relatively high proportion of arenite has been identified in contact with Paleozoic basement rocks in the NE of the study area, overlain by a very poorly outcropping, shale-dominated unit. In the south of the area, rugged forest-covered hills are thought to reflect sandstone-dominated flysch.

It is suspected that on the tops of the highest hills the Early Cretaceous flysch may be capped by a post-tectonic Paleocene (?) molasse. To the west of the Abrud River, in the vicinity of Campeni, we suspect the presence of flat-lying Tertiary thrust sheets composed of mobile Cretaceous material overlain by remnants of massive limestone and crystalline marble. The ASTER DEM images also reveal the presence of remnants of a regional Neogene planation surface in the extreme north and south of the study area.

Neogene volcanic and intrusive rocks in the study area have strong photogeological signatures. This is caused by the local control that these bodies exert upon geomorphology and drainage patterns, as well upon vegetation. Intrusive bodies, including the Rosia Montana and Bucium dacite bodies as well as the Rosia Poieni, Tarnita and Baie de Aries andesite intrusions typically form topographically prominent features with old-growth or plantation forest.

The principal objective of the study has been identification of structural controls of magmatism and mineralisation. Structures identified on images are related to Tertiary dextral motion on Zlatna strike-slip fault in the extreme south of area, which was locally the principal focus of deformation associated with eastward extrusion of Tisza-Dacia block. A conjugate set of NNW-SSE and NE-SW structures developed concurrently and these appear to be the major controls of Middle and Late Miocene volcanism and porphyry intrusion. An 18 km long NNW-SSE structure passing to the east of Rosia Montana dacite body has been recognized on imagery. This structure probably behaved as a dextral Riedel shear during the early phases of volcanic activity at Rosia Montana, which would explain the observed pattern of N-S dilational veins. Later vertical movements on the NNW-SSE and conjugate NE-SW faults caused relative uplift and un-roofing of the Rosia Poieni porphyry system to the east of Rosia Montana.

Acknowledgements

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EXTENDED ABSTRACTS

CU (AU) MINERALIZATION IN THE KUHE-ZAR AREA, NE OF IRAN

ABEDI, A.¹, ZIAI, M.¹

¹Mining Faculty, Birjand University, Birjand, IRAN, goharkavir@yahoo.com

The Cu (Au) porphyry mineralization of Kuhe-Zar is located 41 km west of Torbate-Heydaruh, in the west Khorasan province NE Iran. Mineralogical observation of the upper levels of the Kuhe-Zar deposit revealed the following pre-ore hydrothermal alteration within the intrusive, volcanic and volcanoclastic formation of younger age: propylitic (chloritization), silicification and argilization. Mineralization occurs in quartz-specularite-pyrite-chalcopryrite veins and veinlets. Several mineral assemblages representative of low-sulphidation style and quartz-hematite type were established in the upper levels of Kuhe-Zar deposit. These include specularite (Cu-V-Mo assemblage), pyrite, chalcopryrite, (Ag-PGE assemblage), annivite (Se-Zn-Cd assemblage) tetrahedrite (tennantite) (Bi-Se-Zn-Cd-Sb assemblage), acanthite (Fe-Cu-Te-As assemblage), native gold, electrum, covellite (Cu-Fe-As assemblage), digenite and supergene minerals such as goethite, hydrogoethite, Cu-Fe oxides and malachite.

In the investigated ores, gold is observed, as well as in the altered volcanic tuffs and in the granitoid rocks. Gold is present as fine inclusions of electrum (50-61% Ag, 3 wt% Hg) and as native gold (12-19% Ag, 0.1-0.6 wt% Cu, 0.1-0.4 % Hg) with quartz-hematite-chalcopryrite-tennantite assemblage.

Annivite (Bi-tennantite) is observed in close accretions with chalcopryrite as fine-grained aggregates, up to 30 microns. EPMA data indicates Cu: 42.60, As: 21.14, Sb: 4.53, Bi: 10.46, S: 28.52 wt%, with impurities of Se, Zn and Cd.

Acanthite is observed as a relic mineral in association with covellite, Cu-Fe oxides and quartz. EPMA data reveals the following main elements: Ag: 83.17, S: 15.8 with impurities of Cu: 5.89 and Te: 0.34%.

Stream sediment and rock chip sampling resulted in the recognition of several moderate to strong anomalies of Au, Cu, Pb-Zn, pointing mainly to the Kuhe-Zar ridge. The Au values ranged up to 8 ppm, whereas Ag, Bi, Cu and Pb-Zn were high, with maxima of 750 ppm Ag, 2000 ppm Bi and 1-3% Pb-Zn and Cu.

The copper mineralization in Kuhe-Zar area is characterized by a metal assemblage with Au, Ag, Bi, Pb-Zn and Cu. Despite observation of the above elements as relic minerals in polished sections, it is assumed that the mineralization had a polymetallic character at deeper levels.

Thermobarogeochemical investigations of quartz allowed the determination of the formation temperature interval: 195-274°C.

The growth of quartz occurred from solutions of two types: low-saline solutions, with mainly NaCl, and medium saline with prevailing CaCl₂.

Given the above results, it is suggested that medium temperature fluids with low mineralizing potential were responsible for the metal deposits in this area.

Gold mineralization is present in stringer stockwork veinlets and silica-quartz hydrobreccia, where it is associated with abundant specular hematite and siderite.

Most ore mineralization is represented by stringer stockwork of veinlets with zonal-banding and crustiform and breccia texture. Veinlets are combined with quartz-specularite, and the central part is represented by colorless or white quartz and amethyst. Stringer stockwork veinlets are characterized mainly by fine to medium-grained quartz with crustiform texture, and with Cu (Au) mineralization.

The ore mineralogy and geological conditions of Kuhe-Zar ore deposit are particularly complex compared to other deposits. The early quartz-magnetite-hematite (specularite) assemblage, which is typical to other porphyry copper deposits in the region, suggests that deposits in the studied region may be of similar origin with the Kyh-Dom and Anarak in Central Iran (Romanko, 1986) or the Chile type Cu (Au)-porphyry deposits (Sillitoe, 1991).

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GEOCHEMICAL CONSIDERATIONS ON THE TOURMALINE FROM THE CONȚU-NEGOVANU PEGMATITES (LOTRU-CIBIN MTS.)

ANDRONE, D. A-M.¹, BUZGAR, N.¹, KASPER, H. U.², SCHOENBECK, T.²

¹University „Al.I.Cuza” Iași, 20A Carol I Blv., 700507 Iași, România), dandrone@gemma.geo.uaic.ro; nbuzgar@uaic.ro; ²Geological Institute of the University of Köln, Zulpicher Str. 49A, D-50674 Köln, Germany), hu.kasper@uni-koeln.de

The Conțu-Negovanu granitic pegmatites are hosted by the metamorphic rocks belonging to the Sebeș-Lotru Group, represented mainly by biotite paragneisses, quartz paragneisses and garnet, kyanite and staurolite-bearing micaschists. The pegmatites display two distinct mineral assemblages, assigned to two different types of pegmatites: feldspar ± muscovite pegmatites and albite – spodumene pegmatites. Tourmaline is commonly present in the feldspar pegmatites as an accessory mineral, in concentrations near contact zones. In transmitted light, it displays green-khaki shades and has no colour zoning. The absence of significant colour zoning correlates with the nearly constant chemical composition, as shown by X_{Mg} (calculated as $Mg/(Mg+Fe_{Tot})$) which varies by only 0.03.

The X-ray powder diffraction data show the presence of schorl-dravite {2.581(1); 2.964(1); 4.000(0.77)}, foitite {6.340(0.8)} and uvite {2.043(0.95)}. Unit-cell parameters calculated from X-ray powder diffraction patterns are $a = 16.017 \text{ \AA}$ and $c = 7.188 \text{ \AA}$.

The chemical composition of the investigated tourmaline samples (Table 1) falls broadly within the dravite-schorl solid solution series, with a slightly dominant magnesian term (X_{Mg} varies between 0.57 and 0.60). The very high X_{Na} (calculated as $Na/(Na+Ca)$) indicates a lesser participation of the Ca end-members, which is consistent with the structural data. The SiO_2 and Al_2O_3 contents are respectively similar to those of other tourmalines from Roumanian pegmatites. Considering X_{Mg} and X_{Na} parameters, a great similarity between the tourmaline from the feldspar pegmatites and the one from the surrounding metamorphics can be observed. Using the same parameters when compared to the tourmaline from the Gilău Mts. pegmatites (Stumbea, 2001) and from the Preluca pegmatitic area (Buzgar & Rădășanu, 2001), the tourmaline from the Conțu-Negovanu feldspar pegmatites shows higher X_{Mg} (magnesian dominant) and lesser X_{Na} (fig.1.). These compositional differences do not necessarily involve distinct crystallisation stages, but most likely represent the effect of the chemical control of the metamorphic environment over the pegmatitic fluids generated by partial anatexis. Thus, the micaschists and the biotite paragneisses from the Conțu-Negovanu area appear to have higher MgO and CaO contents (shale protolith of dominant montmorillonitic composition), comparatively to the metamorphic rocks belonging to the

Someş group and Baia de Arieş group (the Valea Cavnicului formation). The latter contain also leptonite and quartz-feldspar intercalations which indicate an other kind of metasedimentary material (arenaceous-silty-clayey protolith). Of particular interest is the tourmaline from the albite-spodumene pegmatites from the Conţu-Negovanu area (fig.1.), which represents a geochemically evolved pegmatitic stage (Murariu, 2001), where the tourmaline crystallisation involves large amounts of FeO_{Tot} and Na_2O .

Table 1. Chemical composition (wt.%) of the tourmalines from Conţu-Negovanu pegmatites and metamorphics (Androne, 2004).

	T-12 ¹	T-141 ²	T-142 ³	T-143 ³	T-144 ³	T-35 ⁴	T-21 ¹	T-22 ¹
SiO_2	36.73	36.05	36.7	36.63	36.3	35.65	36.65	36.42
TiO_2	0.90	1.04	0.946	1.087	1.052	0.75	1.19	1.56
Al_2O_3	35.01	32.58	32.92	33.27	33.31	34.48	33.48	32.62
Fe_2O_3	8.67 [*]	-	-	-	-	2.65	9.62 [*]	10.35 [*]
FeO	-	7.91 [*]	7.82 [*]	7.56 [*]	7.88 [*]	8.95	-	-
MnO	0.04	0.054	0	0.066	0.018	0.12	0.04	0.05
MgO	5.86	6.13	6.49	5.94	5.79	0.77	5.51	5.42
CaO	0.73	0.593	0.676	0.522	0.517	2.08	0.58	0.54
Na_2O	2.05	2.41	2.13	2.09	2.27	1.40	2.06	2.11
K_2O	0.06	0	0.008	0	0.02	0.11	0.06	0.21
P_2O_5	0.02	0.041	0	0	0	-	0.02	0.08
Li_2O	0.007	-	-	-	-	-	0.012	0.009
B_2O_3	10.72 ^{**}	10.63 ^{**}	10.77 ^{**}	10.73 ^{**}	10.70 ^{**}	10.06	10.80 ^{**}	10.73 ^{**}
H_2O	-	-	-	-	-	2.18	-	-
Unit formulae on the basis of 29 (O,OH,F)								
Si	5.95	5.89	5.92	5.92	5.89	6.03	5.89	5.89
^{IV} Al	0.05	0.11	0.08	0.08	0.11	0.00	0.11	0.11
T	6	6	6	6	6	6	6	6
^{VI} Al	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00
Z	6	6	6	6	6	6	6	6
Fe^{2+}	1.06	1.08	1.05	1.02	1.07	1.27	1.16	1.26
Fe^{3+}	-	-	-	-	-	0.46	-	-
Mg	1.41	1.49	1.56	1.43	1.40	0.19	1.32	1.31
Mn	0.01	0.01	0.00	0.01	0.00	0.02	0.01	0.01
Ti	0.11	0.13	0.11	0.13	0.13	0.10	0.14	0.19
Al	0.25	0.16	0.17	0.26	0.26	0.88	0.23	0.11
Li	0.00 [*]	0.00 [*]	0.00 [*]	0.00 [*]	0.00 [*]	-	0.01	0.01
F	2.84	2.87	2.89	2.85	2.86	2.92	2.87	2.89
Ca	0.13	0.10	0.12	0.09	0.09	0.38	0.10	0.09
Na	0.64	0.76	0.67	0.66	0.71	0.46	0.64	0.66
K	0.01	-	0.00	-	0.00	0.02	0.01	0.04
	0.22	0.14	0.21	0.25	0.20	0.14	0.25	0.21
X	1	1	1	1	1	1	1	1
B	3	3	3	3	3	2.94	3	3
OH						2.46		
X_{Fe}	0.57	0.58	0.60	0.58	0.57	0.10	0.53	0.51

- not determined; ¹ XRF analysis; ² EMPA analysis; ³ chemical analysis; ⁴ FeO or Fe_2O_3 as Fe_{Tot} ; ^{*} stoichiometric values; ^{**} values lower than 0.005; (T-12)- tourmaline associated with quartz and feldspars within feldspar pegmatite; (T-141)-(T-144)- tourmaline associated with quartz, albite, microcline and apatite within feldspar pegmatite; (T-35)- tourmaline from albite-spodumene pegmatite (Murariu, 1990); (T-21)- tourmaline from micaschist; (T-22)- tourmaline associated with quartz and micas in metamorphic vein.

The tourmaline from the Conţu-Negovanu feldspar pegmatites has also a very high TiO_2 content (1.005% TiO_2 average), which matches that of the surrounding metamorphics, showing a genetic relationship between these rocks. This fact is also supported by similar MgO , CaO , Na_2O and Li_2O contents in both rock types. Another characteristic feature of the tourmaline from the

feldspar pegmatites is the extremely low Li_2O content (max. $55 \mu\text{g}\cdot\text{g}^{-1}$), typical for the Mg-rich metapelitic tourmaline (Henry & Dutrow, 1996).

The normative composition of the pegmatitic and metamorphic tourmaline has been calculated considering both the X-ray powder diffraction data and the absence of the Li end-members. Thus, the sequence of normalization was: foitite (Ft) $\rightarrow$ uvite (Ut) $\rightarrow$ olenite (Ot) $\rightarrow$ dravite (Dt) $\rightarrow$ schorl (Sch) and the average normative composition is:

- pegmatitic tourmaline: **Dt_{31.2} Sch₂₆ Ft_{20.4} Ut_{10.6} Ot₄**;
- metamorphic tourmaline: **Dt_{36.5} Sch_{29.3} Ft₂₃ Ut_{9.5} Ot_{1.5}**.

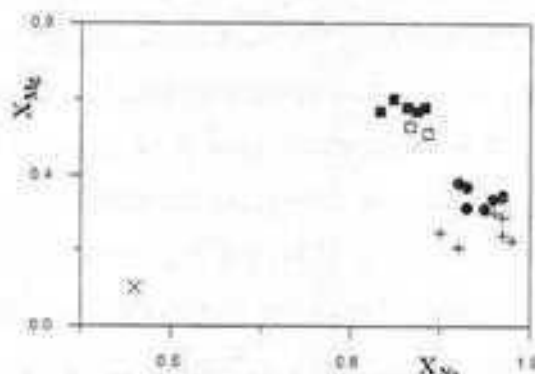


Fig. 1. Tourmaline samples plotted in the X_{Na} vs X_{Mg} diagram (black square – Conju-Negovanu feldspar pegmatites; white square – Conju-Negovanu metamorphics; x – Conju-Negovanu albite-spodumene pegmatites; black circle – Preluca pegmatites; + – Gilău pegmatites).

Normalization of the formula unit was made on the basis of 29 (O, OH, F), including Li_2O content. Unit formulae are given in Table 1.

In the *T* site, Al^{3+} substitutes for Si^{4+} in low amounts, typically for the tourmalines from medium degree metapelites (Henry & Dutrow, 1993). This kind of substitution is part of the Tschermak substitution, which is one of the few effective in the investigated tourmalines (fig.2a).

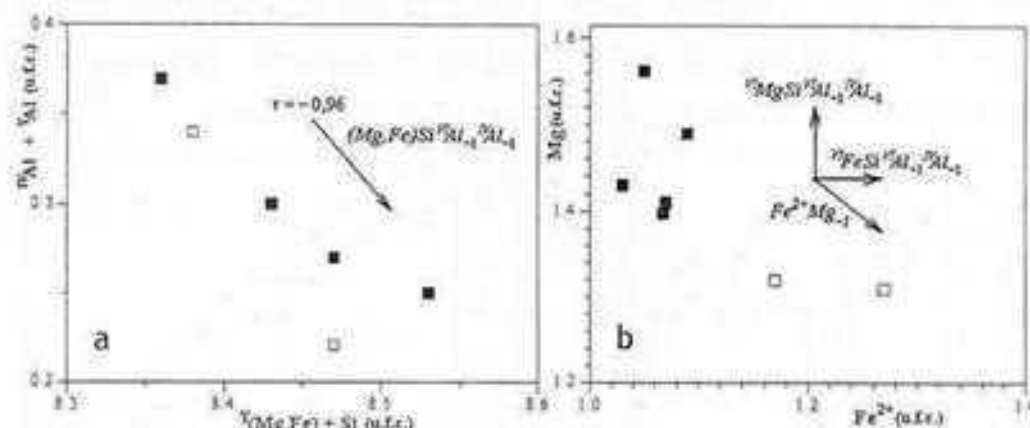


Fig. 2. Effective substitutions in the tourmaline from the Conju-Negovanu pegmatites and metamorphics.

The *Z* site is fully occupied by Al^{3+} (by stoichiometrical constraint), showing the peraluminous character of the feldspar pegmatite tourmalines. The Al excess is found in the *Y* site

and the substitutions involved can be described by the $\text{AlOMg}_1(\text{OH})_1$ and $\square\text{AlNa}_1\text{Mg}_1$ exchange vectors (Henry & Dutrow, 1993). The *Y* octahedral site is dominantly occupied by Mg^{2+} followed by Fe^{2+} . The second effective substitution is a simple one, described by the $\text{Fe}^{2+}\text{Mg}_1$ exchange vector (fig.2b.). This substitution affects the tourmaline on a sample group basis and between the two groups the Tschermak substitution is effective. In the *Y* site, Al^{3+} ($\pm\text{Fe}^{3+}$) also substitutes for Fe^{2+} and Mg^{2+} by a deprotonation mechanism which involves a coupled substitution described by the ${}^{\text{V}}\text{AlO}(\text{Mg}, \text{Fe})_1(\text{OH})_1$ exchange vector. This type of substitution is also an effective one in the tourmalines from the feldspar pegmatites, establishing the variation of the (dravite, schorl)/olenite ratio. It is less effective in the metamorphic tourmalines. The *X* site is dominantly occupied by Na^+ , displaying high X_{Na} (over 0.83) which reflects in fact the X_{Na} of the feldspars. They are both established by the X_{Na} either of the pegmatitic fluid or of the protolith.

The trace element distribution within the tourmaline from the feldspar pegmatites shows rather high concentrations of vanadium ($290 \mu\text{g}\cdot\text{g}^{-1}\text{V}$), strontium ($238 \mu\text{g}\cdot\text{g}^{-1}\text{Sr}$) and zinc ($147 \mu\text{g}\cdot\text{g}^{-1}\text{Zn}$). A similar concentration level of the same elements in the metamorphic tourmaline emphasizes once again the geochemical resemblances between the feldspar pegmatites and the surrounding metamorphics. The low Zr, Y and Hf concentrations (fig.3A) in the pegmatitic tourmaline is due to the usual accumulation of these elements in the anatexis restite. A particular case is that of Nb, Ta, Th and U which concentrate in the pegmatitic fluid, being afterwards included in the late-stage crystallised mineral phases. The REE from the metamorphic tourmaline display the highest concentrations, particularly for LREE: $21.66\text{--}55 \mu\text{g}\cdot\text{g}^{-1}\text{La}$, $44\text{--}107 \mu\text{g}\cdot\text{g}^{-1}\text{Ce}$, $18.11\text{--}46 \mu\text{g}\cdot\text{g}^{-1}\text{Nd}$ and $3.093\text{--}7.608 \mu\text{g}\cdot\text{g}^{-1}\text{Sm}$. Comparatively, the pegmatitic tourmaline shows much lower REE contents: $2.823 \mu\text{g}\cdot\text{g}^{-1}\text{La}$, $4.739 \mu\text{g}\cdot\text{g}^{-1}\text{Ce}$ and $1.819 \mu\text{g}\cdot\text{g}^{-1}\text{Nd}$. The latter indicate a low degree of melting of the protolith, but developed at equilibrium conditions at least for the LREE, as an obvious parallelism exists between the REE pattern of both pegmatitic and metamorphic tourmalines (fig.3B). The Eu positive anomaly displayed only by the pegmatitic tourmaline stands for the reducing environmental conditions during the crystallisation of this mineral.

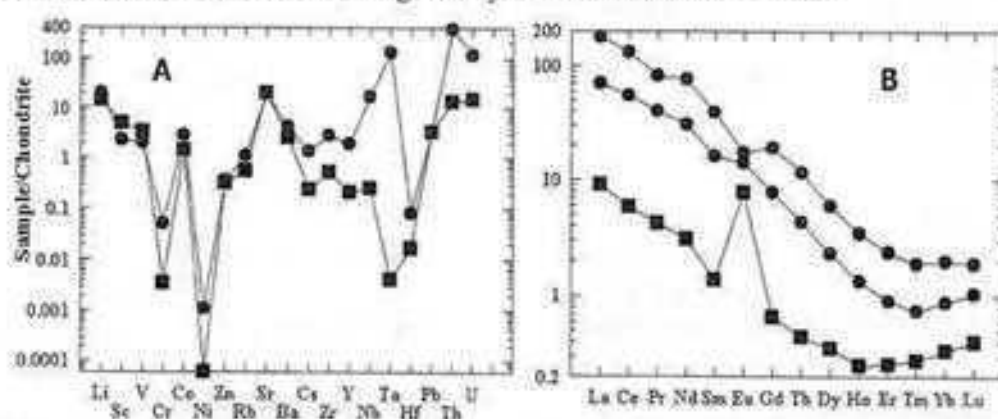


Fig. 3. Trace element (A) and REE (B) concentrations normalized to the chondrite composition (Thompson, 1982; Boynton, 1984).

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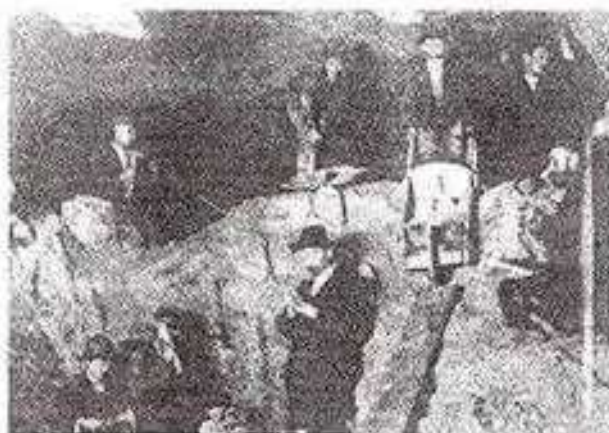
APUSENI MINING AND THE ENVIRONMENT: MUST THEY BE ENEMIES ?

John ASTON¹, Horea AVRAM²

¹ Environmental Manager, Roşia Montană Gold Corporation, Alba Iulia, Romania

² Environmental Officer, Roşia Montană Gold Corporation, Alba Iulia, Romania

The Roşia Montană gold and silver ore deposit is situated towards the top of the Roşia Montană valley in the Apuseni Mountains in west-central Romania. The Roşia Montană deposit has been mined for over 2000 years. This was a jewel in the crown of both the Roman and the Austrian-Hungarian Empires, and the most important gold-producing region of Europe throughout these ages. More recently the site has gone through over 40 years of state-owned underground and open-pit mining. These historical activities, conducted with few environmental controls, have created a network of more than 140 kilometres of underground workings, and have become an extensive regional source of Acid Rock Drainage (ARD - acidic water with heavy metal content). The name "Roşia Montană" meaning "Red Mountain" is largely attributed to the red streams flowing down its valleys. Streams in the region have pH as low as 2.5, and existing water chemistry pollution over 70 times the Romanian legal limits.



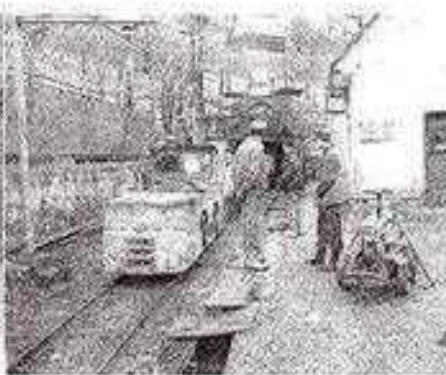
The Roşia Montană gold deposit has been mined for over 2000 years.



The existing non-environmentally friendly Roşia Montană open pit.



ARD from existing galleries flows straight into local water courses.



A train leaves Roşia Montană's underground galleries - ARD water runs alongside.

For some time now, the existing operation in Roşia Montană has been heavily subsidised by the state due to large financial losses (~3 million US\$ per year). This period of economically and environmentally non-sustainable operation is scheduled to close under Romanian government

restructuring plans resulting in significant job losses in this already improvised area. The new Roşia Montană Project provides an option to rebuild the social and economic fabric of the area. The Roşia Montană Project is based upon the commercial redevelopment of the gold and silver resource in Roşia Montană using state-of-the-industry internationally accepted mining and treatment practice. The new mine is faced with an environmental legacy. Operation of the new Project faces the environmental challenge of rectifying two thousand years of aquatic pollution and complying with Romanian, EU and World Bank standards.

The Roşia Montană Project is, however, more than just a mine. It includes cultural property preservation (archaeological surveys, assessments, cataloguing and preservation of significant artefacts, and the creation of a museum and tourist circuit), community resettlement linked to the creation of a new village with associated institutional buildings, clinics and schools, rectification of negative historical environmental impacts, and support for development of the local communities.

The Project began in 1997 with planning and exploration activities. Construction will commence after all planning and permitting is completed and will lead to an initial capital investment of more than 500 million US dollars in Roşia Montană, with a further in-country running cost of more than 1.4 billion USD over the currently planned mine life.

In addition to local, regional and national benefits, the Project will provide investors with an acceptable rate of return on investment, hence securing the financial backing for the Project. The Project's activities are interdependent. For the environment, it is through the finance raised from the development of the new mine that the environmental clean-up becomes financially possible. This clean-up involves three steps. The first is to identify the current pollution sources. The second is to identify the pathways through which this pollution enters the downstream environmental system. The third and final step is the isolation and/or removal and treatment of the pollution and the beginning of biodiversity rehabilitation. Once the old mine is stabilised, the new mine will have to be operated so as to minimise environmental risks.

A reality of such a development is that there is the introduction of the environmental risks of cyanide and a large tailings dam. The associated facts are as follows. A dilute solution of cyanide, as is the case for the recovery of almost all of the world's gold production, is an integral part of future operating plans of the new Roşia Montană mine. To manage this properly, cyanide management for the Project will follow the UNEP facilitated International Cyanide Management Code. Cyanide will be transported to site in its solid form. Following treatment, the tailings will be subject to cyanide detoxification and stored in an engineered rock tailings dam. The dam will be designed and built to meet all Romanian and international safety standards. To ensure that the Project has the administrative structure to deliver on its commitments, associated management plans are being developed to implement international best practice (e.g. ISO 14001).

This initiative faces a modern challenge. Some view the combination of international finance, mining, cyanide use, and community resettlement as an environmental and social evil. This has lead certain NGO's to mount a campaign to oppose the Project. Given the standards that the developers have committed to respect, this project will lead to sustainable development in this impoverished region of Romania. If the Project does not go ahead then the existing environmental and social degradation of the region will continue.

The Roşia Montană Project has the potential to be a success story of private capital and enterprise working with local and national authorities and other stakeholders to resolve the legacy of years of environmentally unfriendly and non-sustainable mining and create a platform for future sustainable development.



APUSENI GOLD AND SUSTAINABLE DEVELOPMENT: THE CASE OF ROȘIA MONTANĂ

John Aston¹, John Knight²

¹ Environmental Manager, Roșia Montană Gold Corporation, Alba Iulia, Romania

² Environmental Permitting Manager, Roșia Montană Gold Corporation, Alba Iulia, Romania

Today's world requires the promotion and integration of economic activity with environmental integrity and social concerns, with the twin aims of improving human well-being and of sustaining these improvements over time. These concepts are central to Romania's sustainable development and form a challenging framework for change.

The Roșia Montană Project, started in 1997 in the valley of Roșia Montană in the Apuseni Mountains, faces this challenge. The Project, currently in its planning, land acquisition, and pre-approval stage, recognises that this challenge is made more difficult by past and present environmentally unsustainable mining which resulted in the generation of Acid Rock Drainage (ARD), and significant biodiversity degradation and risk to human health. The International Commission for the Protection of the Danube River (ICPDR) has identified the area as a high-risk industrial "hot spot" in a study it published in 2000. A further complication in the development of the Roșia Montană Project is the extremely negative image of gold mining developed after the cyanide spill from Baia Mare.

In order to manage this legacy, the Project's planned development will employ both Romanian and international experience using the world's best available technologies to re-develop the existing Roșia Montană mine – which, in its current state, is both economically and environmentally unsustainable.

The challenges confronted by the Roșia Montană Project in achieving its goal of creating a successful Romanian mining operation include:

- ❖ project development in accordance with EU and international standards and policies,
- ❖ the management of the new mine to internationally recognised environmental and management standards,
- ❖ the management of the new mine to address centuries of ARD pollution and biodiversity degradation,
- ❖ the management of the future use of cyanide as a reagent,

- ❖ the operation of a large dam for tailings storage,
- ❖ developing and operating the mine in such as will help the initiation of sustainable social, environmental, and economic regional renewal, and
- ❖ future mine closure issues.

One dominant conclusion of this paper is that the Roşia Montană Project has enormous potential to reverse the current levels of environmental, economic and social degradation in this region, and to initiate a new era for Romanian mining, that will contribute to Romania's efforts to achieve a robust and realistic sustainable development.

SOME ASPECTS OF PLANAR FLOW BANDING AND FLOW FOLIATION IN NEOGENE ANDESITE FROM VOIA AREA, METALIFERI MOUNTAINS, ROMANIA

I. BERBELEAC¹, D. ZUGRAVESCU¹, L-M. NUTU¹

¹ Institute of Geodynamics, 19-21 Jean-Louis Calderon Street, Bucharest-37, Romania, R-70201, E-mail: dorezugr@geodin.ro

In Metaliferi Mountains the flow foliations are common in Neogene andesite coherent lava flows, domes and dikes. These forms of lava flows are the result of planar and laminar flowage.

This paper is focused to describe ones of the most expressive planar flow bandings and lava flow foliations from Voia Valley (Fig. 1). Other near similar Neogene flow foliations in andesites is known in Porcurea, Cordurea and Draica areas (Berbeleac, 1975).

Andesite lava flow from Voia appears on about 3 km along the upper part of Voia Valley. It is delimited by the volcanic products of Buha and Cetras, at north, Momeasa and Geamana, at west and Macris at south (Fig.1).

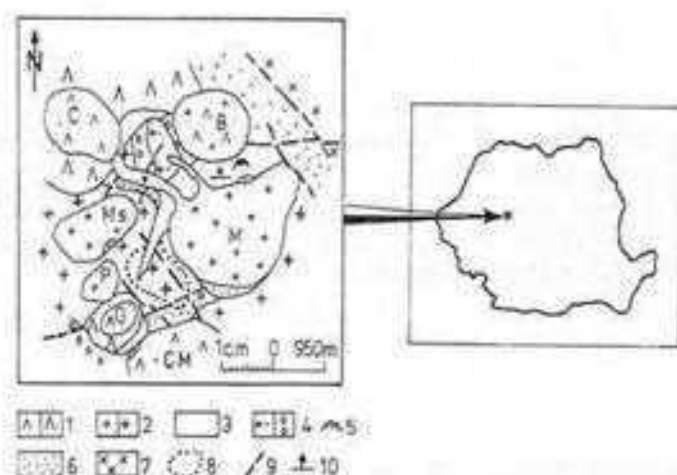


Fig. 1. Geological sketch map of Voia area (in medallion Voia area). 1. Hornblende, biotite and quartz ± pyroxene andesite (Cetras type): intrusions (a) and lava (b); 2. Hornblende, biotite and quartz ± pyroxene andesite (Sacaramb type): intrusions (a) and lava (b); 3. Andesitic flow with bandings and laminations; 4. Hornblende andesite: lava (a) and pyroclastics ± volcano-sedimentary deposits; 5. Upper Cretaceous-Lower Miocene molasse; 6. Jurassic ophiolites; 7. Andesite - diorite subvolcanic body (projected); 8. Fault; 9. Strike of banding; 10. Quarry. B-Buha; C-Cetras; Ms-Momeasa; P- Paua; G-Geamana; Cm-Coasta Mare; M-Macris.

In this area it seems to be the oldest volcanic product, probable Lower Sarmatian in age. It covers Upper Cretaceous-Lower Miocene sedimentary and volcano-sedimentary deposits (Badenian) of Brad-Sacaramb molasse and it is covered or penetrated by younger hornblende, biotite and quartz ± pyroxene andesites from Macris (11.5 Ma), Buha and Cetras (10.5 Ma, Rosu et al., 2001), Momeasa and Geamana volcanoes. Its eastern contact with molasse deposits is made by two near vertical faults, E-NW and NW-SE in strike (Fig.1.). The thickness of this lava flow with

its volcanoclastic and volcanogenic sedimentary sequences ranges between 150-300 m (Berbeleac et al., 2003, unpublished data).

Mesoscopic lava flow from Voia shows a planar flow banding and flow lamination and different degrees of devitrification, hydrothermal alteration and tectonic deformations. Noticeably are: 1) towards west of Cetras Brook and north-west of Lazului Brook, the dominant propylitic alteration from the eastern front of lava flow, usually, pass gradually to intermediate and intense hydrothermal types of alterations (argillic, silicic, quartz-allunitic etc, Berbeleac et al, 1978) and 2) lava flow from Voia Valley had suffered a strong ductile and brittle tectonic deformation (fracturing, shearing, fissuring etc) due to particular position, namely its penetration by younger andesite sub-volcanic bodies related to Sarmatian –Pannonian volcanic activity.

The most expressive planar flow lamination and lava flow foliation from Voia Valley appear

nearly to the front of lava flow, in a small quarry (25-30/5-15m) situated on northern slope of Voia Valley (Fig.1). Here, the flow bands accommodate the prominent siliceous bounding- like structures are probably the results of nodular devitrification and overprinting siliceous alteration. Planar flow lamination comprises white siliceous that alternate with pale green domains (Fig.2 a, b).

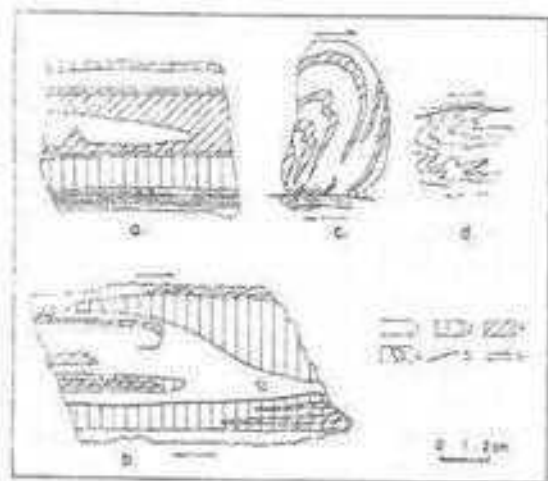


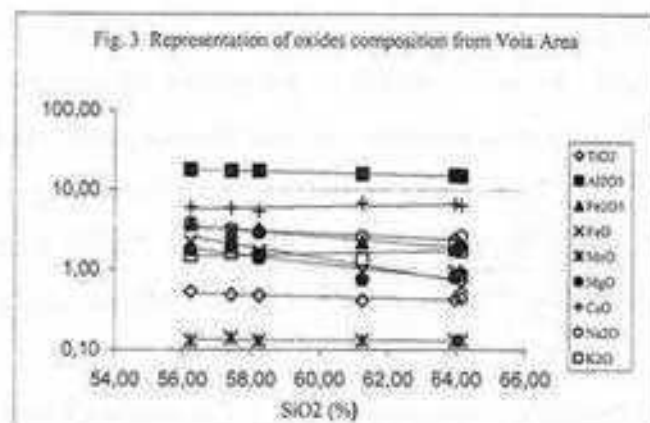
Fig. 2. Alternating chloritic and siliceous layers (flow laminae), flow banding-flow foliations (a-c) and antiform and synform folds in andesitic lava from Voia Quarry. 1.Silica white band with near fresh biotite ; 2. Chloritic band (propylitised); 3. Transition Zone; 4. Biotite (not at scale); 5.Detachment surface; 6. Detachment strike

Dark green or pink phyllosilicate stringers transect the flow foliation and overprint any pre-existing flow laminae; dextral detached synforms and antiforms are also presents (Fig. 2 c, d). Planar, laterally continuous flow banding is particularly well-developed (mm-tens m), evenly porphyritic texture in a hornblende, biotite, feldspar and quartz andesite. Phenocrysts of feldspar and biotite are partially preserved and partial chloritised; hornblende is total chloritised. The groundmass consists of spherulitic bands and lithophysae (quartzfeldspathic devitrified), chlorite, carbonates, albite, apatite, opaque minerals. Sometime, the flow banding is locally accentuated by hematite alterations.

With small exceptions, the millimeter, rarely meters, flow folds may be present. The axial planes of these lie sub-parallel to the foliation plane, and fold axes are perpendicular to the direction

of flow. Within the flow the "rolling" directions of foreign rocks, or porphyry minerals and fold vergence preserve the local direction of flowage. Due to these foreign bodies the fold axes show a considerable scatter. In the spite of enough measurements unevenly distributed, the mean fold axe orientations (N-S) have been used to estimate the present direction of flowage. This seams to vary around E-W directions.

Other aspect of flow foliation and banding is the variation in chemical - mineralogical composition. The white bands (Tab.1, 375-1-D, C.V, Fig. 2 a-c, Fig. 3) are richer in SiO_2 , CaO , K_2O and CO_2 and poor in Al_2O_3 , FeO , MgO and Na_2O , while green bands (propylitised andesites, Tab.1, 376-1-D, D.V, 2A, Fig. 2 a-c, Fig. 3) are richer in Al_2O_3 , Fe_2O_3 , MgO , Na_2O and H_2O .



Intermediate compositions above mentioned values show the transition zones (Tab. 1.1A, Fig. 2 a-c, Fig. 3), where the paleosome are partially substituted by neosome.

Tab. 1 Chemical analysis (%) of some adesites from Voia Quarry.

Crt. No	Sample	SiO_2	TiO_2	Al_2O_3	Fe_2O_3	FeO	MnO	MgO	CaO	Na_2O	K_2O	P_2O_5	CO_2	H_2O
1	375-1-D	63.96	0.42	15.26	1.82	0.93	0.13	0.80	6.61	2.24	1.95	0.16	3.44	2.29
2	376-1-D	57.43	0.48	17.29	2.87	2.97	0.14	1.93	5.86	3.08	1.60	0.19	3.01	3.11
3	C.V	64.14	0.44	14.86	2.01	0.61	0.13	0.87	6.30	2.59	1.74	0.18	3.82	2.38
4	D.V	56.24	0.53	17.80	3.70	2.19	0.13	1.75	6.02	3.70	1.50	0.22	3.24	2.99
5	1A	61.25	0.41	15.81	2.21	0.94	0.13	0.75	6.83	2.56	1.33	0.1	3.26	2.55
6	2A	58.23	0.47	17.38	3.15	1.66	0.13	1.38	5.40	2.89	1.48	0.11	2.1	3.36

Samples: no. 1-4 chem. M. David (Berbelec et al., 1976, unpublished data); no. 5-6 chem. S. Puiu, T. Minciulescu, P. Gheorghiu.

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THE STRUCTURE OF VOIA NEOGENE SUBVOLCANIC BODY AND RELATED ALTERATION-MINERALIZATION IN THE LIGHT OF THE DRILLING EXPLORATION AND MTS DATA, ROMANIA

I. BERBELEAC¹⁾, D. ZUGRAVESCU¹⁾, V. RADULESCU¹⁾, D. STANICA¹⁾, M-L NUTU¹⁾

¹⁾ Institutul de Geodinamica "S.Stefanescu", Str. Louis Calderon, 19-21, Bucuresti, Romania, E-mail: ionberbeleac@geodin.ro

The Voia Neogene sub-volcanic body and related alteration-mineralization products are situated in the central part of Metaliferi Mountains - an active continental margin of a back-arc area characterized by extension periods (17-15 Ma) and intense volcanic and metallogenic activity (14-11 Ma, Rosu et al., 2001). It has been recognized by field observations (partially outcrops, Fig. 1), and the studies of the 18 drillings exploration (100x100m; 450-1200 m the depths; 15.000 m the total length) and the 31 MTS data (three profiles; 60-175m the distance between stations; 2800m the total length; 5.30 h the measurement time; 5 km the investigation depth).

The main features of this sub-volcanic body are followings: 1) the $\sim 45^\circ$ S dipping, Fig. 2; 2) the form as shallow andesite-microdiorite stock (~ 12.7 Ma) with poly-stage evolution and composed by at least three type of andesites: hornblende quartz andesite, hornblende, biotite, quartz $\pm$ pyroxenes andesites and younger hornblende quartz andesite; 3) the position in a local ductile environment of the Sacaramb- Hondol- Gura Barza strike-slip duplex fault (Drew & Berger, 2001); 4) towards the depth, the body's form and size (depth m / diameter m) and his resistivity (Ohm) and the adjacent formations roughly change, such as: the cycle ($\theta=500$ m) $\rightarrow$ the ellipse - like (500-200m / 650-850m) $\rightarrow$ the cycle (1500- 2500m / 500-400m; 3500m / 300m; 5000m / 200m); 0-900m/150-180Ohm.m 55-180Ohm.m within Neogene formations; 900-1600m /55Ohm.m/25-70Ohm.m in Mesozoic-Lower Neogene formations; 1600-3500m /190-260Ohm.m/180-200Ohm.m for Mesozoic ophiolite and 3500-5000m/>3000Ohm.m for probably, crystalline basement; 5) a great diversity of mineralizations are related with it: the Ca-Mg- py (Au) skarns on Upper Jurassic-Lower Cretaceous and Sarmatian limestone, the porphyry Cu-Au (Mo) stockwork ($\sim 300/250$ m), the quartz-pyrite-Cu-Au and quartz-carbonates-Pb-Zn-Cu-Au-Ag epi-mesothermal veins, the quartz-Cu-Au-As veins and anhydrite (gypsum)-pyrite-marcasite (Pb, Zn) HS veins, the quartz-anhydrite (gypsum)-pyrite (Pb, Zn, Au) IS, pyrite $\pm$ Au; Pb-Zn (Au, Ag) and Pb -Zn-Cu-Au-Ag epithermal LS veins; 6) at surface, except HS, the other mineralization types, do not appear; 7) towards the

depth, the quartz-alunite and intermediate- intense argillic alterations gradually pass and superpose to/on (phyllic) , feldspathic and propylitic alterations.

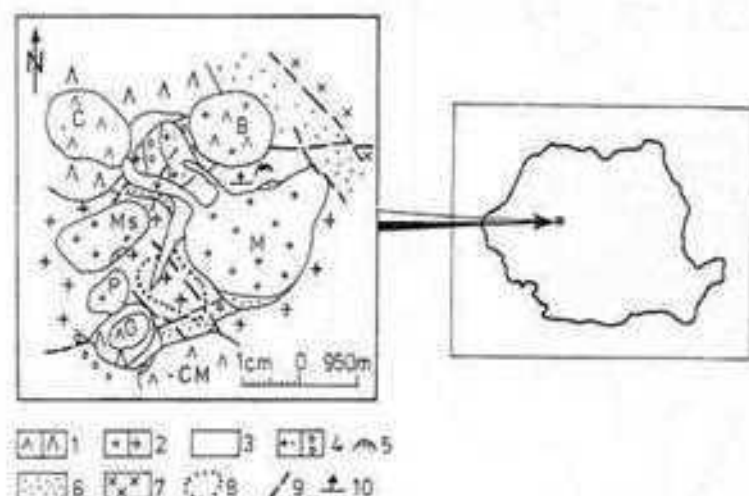


Fig. 1. Geological sketch map of Voia area (in medallion Voia area). 1. Hornblende, biotite and quartz $\pm$ pyroxene andesite (Cetras type): intrusions (a) and lava (b); 2. Hornblende, biotite and quartz $\pm$ pyroxene andesite (Sacaramb type): intrusions (a) and lava (b); 3. Andesitic flow with bandings and laminations; 4. Hornblende andesite: lava (a) and pyroclastics $\pm$ volcano-sedimentary deposits; 5. Upper Cretaceous-Lower Miocene molasse; 6. Jurassic ophiolites; 7. Andesite - diorite sub-volcanic body (projected); 8. Fault; 9. Strike of banding; 10. Quarry. B-Buha; C-Cetras; Ms-Momeasa; P- Paua; G- Geamana; CM-Coasta Mare; M-Macris.

According to the variation of rock resistivity values and in relationship to lithology, the grade of alteration and the rock depth (depth m/Ohm.m fresh/alterd rocks) from the surface: towards the depth, the sub-volcanic body relationship with surrounding formations is underline by followings: 1) the Tertiary molasse as sedimentary, volcanic-sedimentary and volcanic rocks (~14-12Ma, Fig.2) are cut by the this body; 2) round of it at the surface and 200-300m to depth a large area with advanced argillic and quartz-alunitic alteration usual, with HS and IS alteration (quartz, alunite, clay minerals, anhydrite, gypsum etc) and mineralization type (pyrite-marcasite-anhydrite or gypsum veins and disseminations, etc) is present and remarked by low resistivity (40-100 Ohmm); 3) Upper Cretaceous-Paleocene and Lower Cretaceous flysch, that round the intrusion is transformed to middle -high resistivity hornfels with Cu (Au)- pyrite disseminations and Upper Jurassic-Lower Cretaceous limestone are metamorphosed in pyrite (Au)-Ca-Mg skarns and marble (~170 Ohm.m) and 4) between -1600 and -3300m the fractured ophiolite rocks with low resistivities (190-260 Ohm.m), seam to form a un-homogeneous layer, probably in nappe structure, overlap the Precambrian- Paleozoic crystalline formations and 5) probable the Pre-Cambrian- Paleozoic crystalline basement (>3000 Ohm.m). The andesitic-microdioritic sub-volcanic body comprise HS, IS and LS alterations and mineralizations (quartz-carbonates-pyrite- Au and quartz-carbonates -Au-Pb-Zn veins, etc) and between + 400 m and - 600 m below the surface the porphyry Cu-Au (Mo) (Berbeleac et al., 1978).

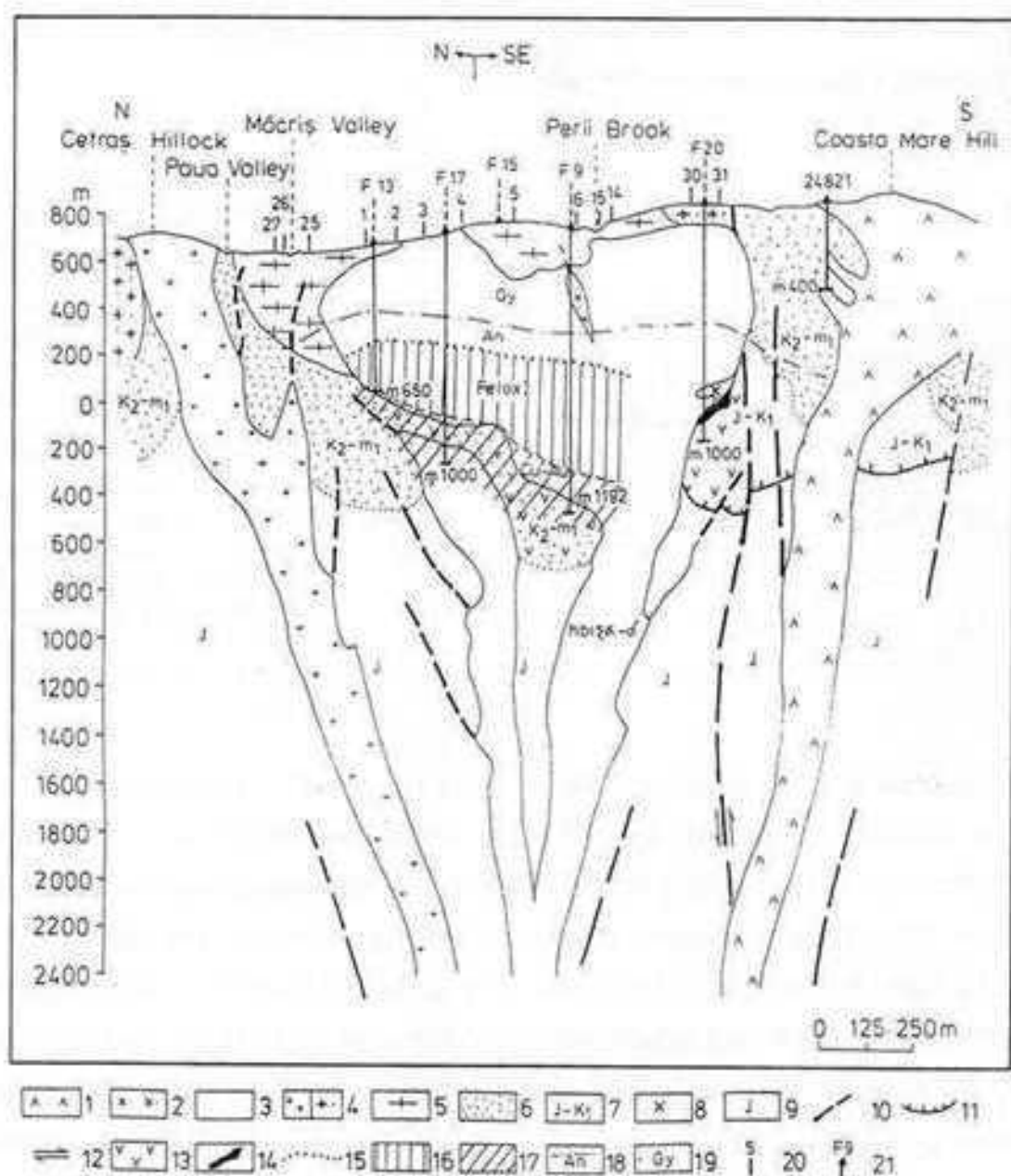


Fig 2. Geological cross-section through Voia sub-volcanic body (Acc. Berbelec et al., 2003, with modifications, unpublished data) Neogene volcanic rocks: 1. Hornblende, biotite quartz $\pm$ pyroxene andesite (Cetras type); 2. Hornblende, quartz andesite; 3. Andesite-microdiorite subvolcanic body (hbiq α - δ); 4. Hornblende, biotite and quartz $\pm$ pyroxene andesite (Sacaramb type); intrusions (a) and lava (b); 5. Older hornblende, biotite and quartz andesite (lavas, pyroclastics with sedimentary sequences); 6. Upper Cretaceous-Lower Miocene molasse deposits (k_2-m_1) (sedimentary, volcanic-sedimentary deposits); 7. Upper Jurassic-Lower Cretaceous limestones; 8. Upper Jurassic diorite (?) body; 9. Jurassic ophiolites; 10. Fault; 11. Nappe; 12. Sense of block movement; 13. hornfels; 14. Skarn body; 15. Upper limit of porphyry system; 16. Fe oxide zone; 17. Cu-Au zone; 18. Approximate boundary of anhydrite zone; 19. Gypsum zone; 20. Electromagnetic station; 21. Borehole.

The post-magmatic product distribution show some particularities, such as: 1) the alteration and mineralization took place during tow main stages: early, proper to porphyry Cu-Au system and late, proper to epithermal HS, IS and LS systems. The environment conditions for early stage of mineralization and alteration was defined by: dominantly magmatic and fluids

(hypersaline), brittle rocks, high O_2 , $T > 400^\circ\text{C}$ and $P \sim 1\text{-}2\text{kb}$. The acid environment is characterized by the zonal distribution of mineralization/alteration (simplified, from surface to depth, Fig. 2): a) pyrite-marcasite-argillic minerals-gypsum $\pm$ anhydrite-base metal (Au) (veins and disseminations $\pm$ breccia bodies) zone; b) magnetite-hematite-(pyrite)-(chalcopyrite)-argillic minerals-anhydrite (gypsum) $\pm$ base metal (Au) (veins and disseminations $\pm$ breccia bodies) zone, and 2) porphyry Cu-Au (stockwork) zone. According Fournier (1999) in porphyry copper the brittle to plastic transition occurs at about $370\text{-}400^\circ\text{C}$. In the late stage episodic and temporary breaching allows magmatic fluid, to escape into the overlying hydrothermal system and mixed with meteoric water it become a fluid with dilute to moderate salinity, neutral to alkaline pH. In this subsequent stage, fluid temperatures decreased across the structure to less 200°C . Pressures were 250 to 300 bar in a hydrothermal regime, during boiling relating to HS, IS and LS epithermal systems. These conditions proper to epithermal LS gold and base metal-gold mineralizations seem to be installed in the depth structure where rich Au-Pb-Zn (Cu) veins are known (Berbeleac et al., 1988).

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A COMPLEX, UNCONVENTIONAL UP-TO-DATE VALORIZATION MODEL OF THE TAILINGS DEPOSITS RESULTED FROM GOLD ORE MINING IN METALIFERI MOUNTAINS

D. Viorel BRANDA¹, Gabriela POPESCU¹, Norocel Al. MERCUS¹, Dan MERCUS¹,
N. FRATILA¹, Gr. VERDES², Gh. CETERCHI¹, A. CEGU¹

¹- BUCHAREST UNIVERSITY, Dept. of Studies, Research, Implementation and Microproduction, e-mail:
<dscim@go.ro>; ² - CNACF Deva, BRADMIN SA.

Mining of the gold-bearing ores in Metaliferi Mountains generated huge volumes of minerals and rocks stockpiled and considered as "sterile deposits". At present market conditions of our country, reported to european and worldwide conditions we tried to make a quantity and quality evaluation as potential accumulations of useful mineral substances ores, by the synthesis of a complex, interdisciplinary research. This is an issue of capital interest and importance for the Romanian industry, a proposal of Implementation of the results of scientific, technologic and economic research of the tailings deposits resulted from to various economic agents from different technical fields, by means of an *elaborated model of reasonable industrial valorization* that leads to the *diminution of the environmental risk* raised by the presence of these deposits.

The fact that these stockpiled deposits still contain gold and silver mineralizations almost as much as the effective percentage extracted from underground ore are the proof that the technologies were old, not optimized and unsuited to ore conditions.

The main clue and the original point of view of the presented work was to put into relief the importance of non-metaliferous minerals composition of the deposit, that would be evacuated, overpassing 96 to 98% of the tailings entered in the technological flow, in the case that all of the resource volume would be prepared and valorized to obtain gold. The idea is obviously not to give birth to a new mineral debris pile, but to integrally valorize and promote in unconventional production flows a large and expanded variety of mineral nonmetalliferous substances ready to use in many technical domains. That is to say, our aim is to elaborate a schematic model for the use of the *bulk stored tailings material (metalliferous and especially non-metalliferous minerals and rocks, as well)*, from three sites in Brad region, Hunedoara county. Quantitative and qualitative evaluation and research intended to establish the opportunity - in the effective market conditions in Romania - which these deposits could be, classified as mineral raw materials resources.

We consider that these deposits are the best examples of recyclable tailings ("technogene") deposits meant to change old approaches of partially valorizing of an ore, through which for the extraction of a very small quantity of precious metal, huge volumes of hardly brought

at the surface materials – expensively and complicated, high energy costs to be regarded as simple, value-free tailings.

Approximately 4% of the bulk stockpile material quantity that processing plants are fed with is spent to gain gold and gold-bearing pyrite concentrates, the rest of 96% being represented by the slam or “sterile” as it was considered, so its destiny would be to be pumped into another dam, practically moving one deposit to another.

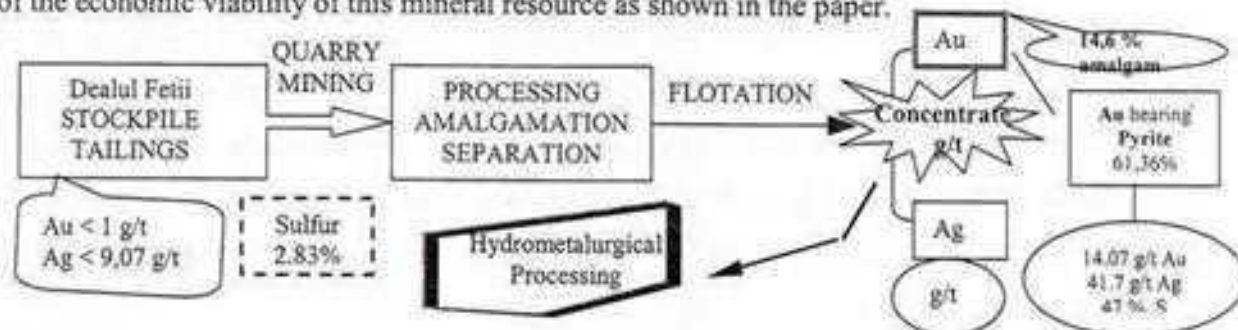
Our attention was concentrated on the up-to-date detailed evaluation of three main deposits from Barza mining perimeter, especially regarding an alternative technological promoting: Dealul Fetii stockpile; Valea Blojului stockpile and Rovina dam (tailings basin).

As a case study, we present the research results applied on “Dealul Fetii” stockpile. Dealul Fetii stockpile, measuring a 60000 sq.metres surface on the territory of Luncoiul de Jos village, 7 Kms SE from Brad town, Hunedoara county, being the most developed tailings deposit in the Barza region, with its thickness of 15 to 20 meters and a 70% percentage of the bulk material volume resulted from underground mining of gold – silver bearing ores.

The work was done on two main directions:

- A) Quantitative and qualitative determination of the gold –silver resources and reserves, evaluated according to UN international classification.
- B) Geological, experimental and technological study of the rocks and nonmetalliferous minerals which compose the tailings material.

The quality evaluation of the deposit for precious metals resources has been previously made by the industrial processing of 147600 tons of material, that made possible the evaluation of the economic viability of this mineral resource as shown in the paper.



Quality evaluation schedule of the deposit for precious metals

In order to classify this resource according to U.N. system, a detailed economic evaluation has been made (mining – metalurgy whole chain). Calculated global technical – economical parameters reflect the situation shown in the presented schedules in the oral communication.

According to the degree of determination knowledge, resources can be classified as 331. The economic evaluation made on the basis of the effective technical and economical parameters in

industrial conditions could be assimilated to a mining study. In such conditions, resources of Dealul Fetei stockpile may be considered as conjunctural resources (211 category).

B) Analytical and experimental research of the non-metalliferous minerals and rocks composing the tailings for a complex and profitable valorisation in many industrial fields

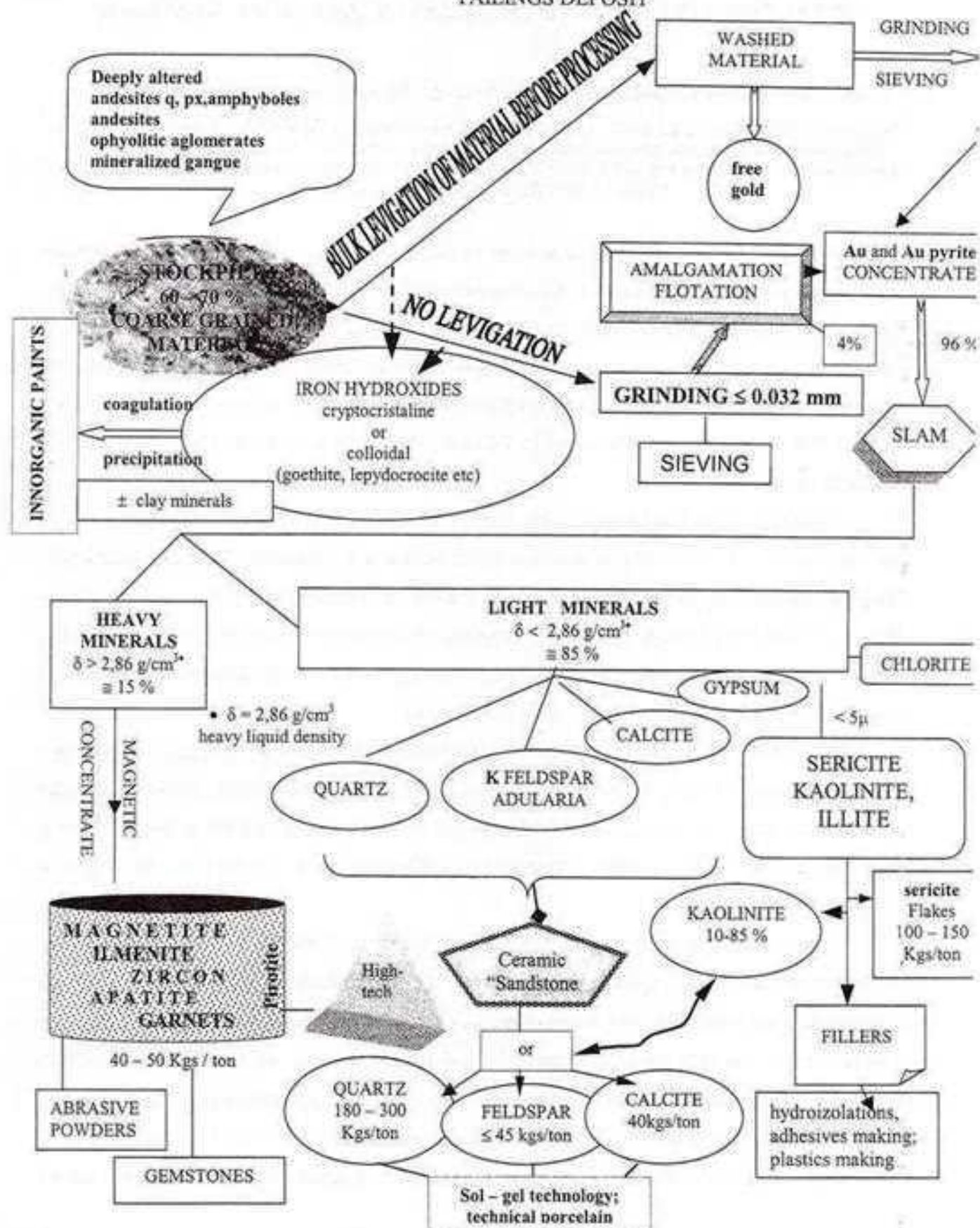
Effusive rocks that constitute Barza mining perimeter form the most extended hydrothermal aureole of the Metaliferi Mountains, adularisation being the specific phenomenon. The aging of the stockpile during the past 30 years since the activity ceased, determined that over the hydrothermal alteration a superficial alteration made by the weather agents overlay. That is why the real nature of the rocks and minerals fragments is very difficult to establish, the smaller the grains, the more powerful changes occurring, that affect it entirely. Most of the centimetric or decimetric grains are covered by a yellow – brownish to brown – reddish limonitic crust having the aspect of some rust leakage. Most of the examined fragments show the presence of andesites and quartz andesites with pyroxenes and amphyboles, deeply hidrothermally altered. In many cases, alteration worked so deeply that the porphyric initial structures were completely erased. In the situation of a rock fragment, neoformation minerals belonging to a couple of hydrothermal alteration phenomena could be observed. Adularisation affected the plagioclase phenocrysts and the matrix as well. Sometimes, the hydrotrothermallized rock fragments include mineralisations, especially dispersed pyrite, as fine grain aggregates to lens or millimetrical veins. More rarely, sphalerite, chalcopryite, chalcocite, bornite and covelite were met. In spite of all efforts, *free gold* could not be observed as in the case of minute grains material. Ophiolites fragments are also met, being altered by albitization, chloritization, leucogenization, calcitization processes.

On the basis of mineralogical and petrographical compositions of the deposit and their resource volume, on our firm opinion there is a solution to overpass the negative conjuncture conditions of valorizing of the gold – silver mineralizations. These deposits, as those came from their processing for gold and gold-bearing pyrites extraction must not be considered as sterile tailings, anymore, in the future, namely having no value, no utilization means and domains (see the *schedule* on the next page.).

The most widespread light fraction minerals are: quartz, potassium feldspar (especially adular), plagioclase, sericite, chlorite, illite and Kaolinite.

A large variety of products could be obtained since the deposits are exploited individually or mixed to those from Rovina dam. This complex valorization mechanism once put into technological flows could make possible statement and development of processing units or renew profiling of the traditional plants, i. e. commercial societies to make competitive products, whose value overpass the value obtained from the precious metals valorizing only, making profitable the recuperation of these metals, of gold-bearing pyrites and silver-bearing sulfides.

**SCHEDULE – COMPLEX VALORIZING MODEL OF “DEALUL FETEF” GOLD ORE
TAILINGS DEPOSIT**



GYPSUM AND BASSANITE IN THE BAT GUANO DEPOSIT FROM THE "DRY" CIOCLOVINA CAVE (SUREANU MOUNTAINS, ROMANIA)

DUMITRAȘ Delia-Georgeta¹, HATERT Frédéric², BILAL Essaïd³, MARINCEA Ștefan¹

¹ Department RIMTI, Geological Institute of Romania, 1 Caransebeș Str., RO-012271, Bucharest, Romania; ² Laboratoire de Minéralogie, Université de Liège, Sart-Tilman, Bâtiment B 18, B-4000 Liège, Belgium; ³ Département GÉNERIC, Centre SPIN, Ecole Nationale Supérieure des Mines de Saint-Etienne, 158, Cours Fauriel, 42023, Saint-Etienne, Cedex 2, France.

The "dry" Cioclovina Cave is located in the southern part of the Sureanu Mountains (Southern Carpathians), at about 16 km east-southeast of Hațeg, on Luncanilor Valley. The cave, known since 1873 and famous as the type locality for ardealite (Schadler, 1932), was extensively exploited for phosphates because the huge bat guano deposit inside. The mined part of the cave consists in a nearby sub-horizontal gallery with some short divergent passages, measuring on their all about 900 m. The cave is developed in Tithonic - Neocomian algal micritic limestones with calacrenite levels.

Phosphates from this famous guano deposit were subjected to minute investigation (*e.g.*, Constantinescu *et al.*, 1999; Marincea *et al.*, 2002; Marincea & Dumitraș, 2003; Dumitraș *et al.*, 2004) and are the best documented from the 29 mineral species described in the cave. As a note, Onac *et al.* (2002) and Onac & White (2003) reported the presence of some exotic mineral species, such as berlinite, burbankite, churchite, chlorellestadite, foggite, paratacamite, collinsite and sampleite, but their occurrence is not enough substantiated.

During recent investigations, two Ca sulfates were also identified in the deposit: gypsum and bassanite. In Sample D 115, the two species occur as finely intergrown phases, with the dominant mineral being bassanite. Many other samples consist in pure gypsum. As far as the authors are aware, this is only the third report of bassanite in a Romanian cave and the first submitted to a minute mineralogical study.

The present paper aims to report new physical, chemical, X-ray and infrared absorption data on the two sulfate species, gypsum and bassanite. The information herein is based on scanning electron microscopy coupled with energy-dispersive scans, X-ray powder diffraction (Cu K α , λ = 1.54056 Å) and Fourier-transform infrared absorption spectrometry. All the analytical facilities, procedures and experimental details are similar to those described by Dumitraș *et al.* (2004).

Gypsum is one of the most common sulfates in the bat guano deposits from the caves (*e.g.*, Hill & Forti, 1997). At Cioclovina, the mineral generally forms parallel aggregates of minute bladed

crystals up to 100 μm in length. It occurs as tiny individuals, flattened on {010} and elongated toward [001]. Stacking aggregates of crystals grown subparallel or parallel to (010) are common.

The unit-cell parameters determined for representative samples after "n" cycles of least-squares refinement based on "N" well-resolved X-ray powder diffraction lines are given in Table 1. The refinements were carried out accepting the monoclinic symmetry, space group $I2/c$, of the mineral (Cole & Lancucki, 1974).

Table 1. Unit-cell parameters of selected samples of gypsum from the "dry" Cioclovina Cave

Sample	<i>a</i> (Å)	<i>b</i> (Å)	<i>c</i> (Å)	<i>V</i> (Å ³)	β (°)	<i>n</i>	<i>N</i>
D 25 II	6.513(3)	15.185(7)	5.684(2)	494.71(3)	118.37(2)	8	49
D 31 A	6.518(7)	15.184(1)	5.669(4)	494.77(7)	118.15(5)	3	24
D 32 A	6.519(3)	15.190(7)	5.678(3)	495.48(3)	118.21(2)	3	47
D 37 A	6.507(1)	15.221(3)	5.683(7)	495.78(1)	118.25(1)	6	28
D 38 A	6.513(2)	15.187(5)	5.672(2)	493.87(2)	118.33(2)	10	32
D 68 A	6.521(4)	15.202(9)	5.675(3)	494.53(3)	118.46(1)	7	83
D 81	6.523(8)	15.202(2)	5.679(7)	495.09(7)	118.46(1)	7	71
D 115	6.513(3)	15.152(9)	5.675(3)	493.20(3)	118.30(3)	7	51

The calculated density of a selected sample of gypsum from Cioclovina (sample D 115) with the ideal formula $(\text{Ca}_{0.998}\text{K}_{0.001}\text{Na}_{0.003})(\text{SO}_4) \cdot 2\text{H}_2\text{O}$ (see below), is, for $Z = 4$, $D_x = 2.318 \text{ g/cm}^3$. This value is in good agreement with the density of the "light" fraction obtained by heavy liquid separation, measured by suspension in methylene iodide diluted with toluene, which is $D = 2.32(1) \text{ g/cm}^3$ for a mean refraction index $n = 1.52(1)$. Calculations from the chemical data and the physical parameters (n and D_x), using the Gladstone-Dale constants of Mandarino (1981), gave "superior" compatibility (compatibility index = - 0.0112).

Bassanite occurs as pseudomorphs after gypsum, whose perfect cleavage parallel to {010} is always observable. The SEM study shows that bassanite occurs as clustered acicular crystals that parallels the [001] axis of gypsum. They currently show parallel growth along the longest axis. Crystals are of the order of no more than 5 μm in length and often much less than this.

The gypsum + bassanite association occurs as decimeter-sized, white nodules of earthy or chalky appearance, included by the guano mass. No fluorescence has been observed for these nodules under either short-wave (254 nm) or long-wave (366 nm) ultraviolet radiation. The analyzed sample (D 115) was taken off from an excavation that parallels the northern wall of a passage preceding the Bivouac Room. Restricted to this sample, associated minerals include brushite, minor quartz and illite 2M1. In order to avoid supplementary gypsum dehydration, samples were stored after collection in sealed plastic bags, at room temperature. As a result of the finely intergrown nature of the aggregates, it was not possible to obtain pure mineral separates.

A wet-chemical analysis of a composite aggregate (sample D 115) gave (in wt.%): $\text{CaO} = 35.05$, $\text{MgO} = 0.01$, $\text{K}_2\text{O} = 0.04$, $\text{Na}_2\text{O} = 0.06$, $\text{P}_2\text{O}_5 = 4.55$, $\text{SO}_3 = 45.02$, $\text{H}_2\text{O}^+ = 14.49$, total =

99.22. The corresponding chemical-structural formula, calculated on the basis of 1 (P + S) per formula unit (*pfu*), is: $(\text{Ca}_{0.998}\text{K}_{0.001}\text{Na}_{0.003})(\text{SO}_4)_{0.898}(\text{HPO}_4)_{0.102} \cdot 1.233\text{H}_2\text{O}$. Accepting that all the sulfate ions are included in the formula of gypsum and bassanite and all the protonated phosphate pertain to the formula of brushite, the formula above corresponds to a mixture of 45.53 wt.% bassanite, 44.27 wt.% gypsum and 10.20 wt.% brushite. Supposing that the alkali cations are uniformly distributed within the three mineral species, which respect the stoichiometry as concerning the molecular water, the formula of bassanite is $(\text{Ca}_{0.998}\text{K}_{0.001}\text{Na}_{0.003})(\text{SO}_4) \cdot 0.5\text{H}_2\text{O}$.

Its unit-cell parameters, calculated after 6 cycles of least-squares refinement from 32 X-ray powder reflections attributable to bassanite in the sample, are: $a = 12.027(12) \text{ \AA}$, $b = 6.906(7) \text{ \AA}$, $c = 12.657(17) \text{ \AA}$ and $\beta = 90.27(6)^\circ$. They were refined in the space group *I*2, accepted for the mineral by Ballirano *et al.* (2001).

With $Z = 12$ (Ballirano *et al.*, 2001), the calculated density for the formula given before is $D_c = 2.751 \text{ g/cm}^3$, which is close enough to the value measured for the "heavy" fraction in Sample D 115 by sink-float in methylene iodide diluted with toluene [$D = 2.74(1) \text{ g/cm}^3$]. A mean index of refraction measured in Cargille oils for the same fraction, that apparently consists mainly in bassanite, is $n = 1.56(1)$. Calculation of the Gladstone-Dale relationship using the calculated density and the constants of Mandarino (1981) yields superior compatibility (compatibility index = -0.0186).

An infrared spectrum recorded for the "heavy" fraction in Sample D 115 gave bands that are assumable to both gypsum + bassanite (gyp + bas) and brushite (brs). An attempt to assume these bands to specific vibrational modes of the structural groups in the three mineral species is given in Table 2, being largely based on data in literature. These assumptions ignore the tendency to overlap of the infrared bands and must be taken with caution.

Table 2. Positions and ideal assumptions of the infrared absorption bands of Sample D 115

Structural group	Vibrational mode	Wavenumber (cm ⁻¹)	Character, intensity ⁽¹⁾	Mineral species
H ₂ O	ν_3 antisymmetric stretching	3617	s, sh	bas
H ₂ O	ν_3 antisymmetric stretching	3561	s, sh	gyp, bas, brs
H ₂ O	ν_3' antisymmetric stretching	3431	s, b	gyp, bas, brs
H ₂ O	ν_1 symmetric stretching	3250	s, shd	gyp, bas, brs
(HPO ₄) ²⁻	(P)O-H stretching	2935	s, shd	brs
H ₂ O	ν_4 in-plane H-O-H bending	1621	m, b	gyp, bas, brs
(SO ₄) ²⁻	ν_3 antisymmetric stretching O-S-O	1158	vs, sh	bas
(SO ₄) ²⁻ , (PO ₄) ³⁻	ν_3 antisymmetric stretching	1142	vs, sh	gyp, brs
(SO ₄) ²⁻ , (PO ₄) ³⁻	ν_3' antisymmetric stretching	1138	vs, sh	gyp, bas, brs
(SO ₄) ²⁻	ν_1 symmetric stretching O-S-O	1117	vs, sh	gyp, bas
(SO ₄) ²⁻	ν_1 symmetric stretching	1011	m, sh	bas
(SO ₄) ²⁻ , (PO ₄) ³⁻	ν_1 symmetric stretching	1007	m, sh	gyp, brs
(HPO ₄) ²⁻	P-O(H) symmetric stretching	865	w, b	brs
(HPO ₄) ²⁻	P-O-H out-of-plane bending	778	w, b	brs

$\text{H}_2\text{O}, (\text{SO}_4)^{2-}$	ν_2 H-O-H; ν_4 in-plane bending (O-S-O)	667	s, sh	brs; gyp, bas
$(\text{SO}_4)^{2-}$	ν_4' in-plane bending (O-S-O)	632	m, sh	gyp, bas
$(\text{SO}_4)^{2-}$	ν_4'' in-plane bending (O-S-O)	605	s, sh	gyp, bas
$(\text{PO}_4)^{3-}$	ν_4 in-plane bending (O-P-O)	576	w, sh	brs
$(\text{PO}_4)^{3-}$	ν_4' in-plane bending (O-P-O)	526	w, sh	brs
$(\text{SO}_4)^{2-}$	ν_2 out-of-plane bending (O-S-O)	492	w, sh	gyp, (bas)
$(\text{SO}_4)^{2-}$	ν_2' out-of-plane bending (O-S-O)	420	w, sh	gyp, bas
$(\text{PO}_4)^{3-}$	ν_2 out-of-plane bending (O-P-O)	410	w, shd	brs

(1) s = strong; m = medium; w = weak; vs = very strong; sh = sharp; b = broad; shd = shoulder.

The presence of $(\text{SO}_4)^{2-}$ in solution is clearly critical to the formation of gypsum at Cioclovina. The sulfate ions in the leaching waters, that may be strongly acidic, may derive both from the oxidation of the up-welling pyrite-bearing schists and from the oxidation of the organic matter in the guano itself. Bassanite formed during a later diagenetic stage, typical for the "dry" karst systems, and was found in the driest part of the cave.

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BRECCIA AND VEIN STRUCTURES IN CĂRNIC MASSIF, ROȘIA MONTANĂ ORE DEPOSIT, APUSENI MOUNTAINS, ROMANIA

Nicoleta FEIER¹, Nuțu GROZA¹, Călin G. TĂMAȘ²

¹Roșia Montană Gold Corporation, 321, Piața str., Roșia Montană, Alba County, Romania;
ngroza@rmgc.ro

²Babeș-Bolyai University, Mineralogy chair, 1, M. Kogălniceanu str., Cluj-Napoca, Romania.

Roșia Montană has been considered a low-sulphidation epithermal ore deposit (Mărza et al. 1997, Tămaș and Bailly 1998; 1999, Tămaș 2002) spatially and genetically related to a Neogene dacite intrusion. Various types of ore bodies occur at Roșia Montană (veins, stockworks, breccias, impregnations, and placers). This study is focused on breccia and vein structures from Cărniciu massif as well as on their relationships. Even if the breccia structures presented here are smaller and less important in respect to the better known and widely studied Cetate breccia body from Cetate massif, they provide additional evidences concerning the genesis and the controls of precious metal mineralisation from Roșia Montană.

The Corhure breccia pipe, located in Cărniciu massif, has been exploited both in a coranda (underground unsupported stope, tens of meters wide both horizontally and vertically), and a rooms and pillars zone. The room and pillars mining area has an elliptical shape, its size being approximately 125x110m. The access to this mining area is possible by a rib gallery on the 958m level.

Underground detailed mapping of the Corhure breccia pipe structure (+958m mining level) allowed us to separate several types of breccias (descriptive): clast-supported breccias, open-space breccias, mosaic breccias, and matrix-supported breccias with coarse and fine matrix.

The mapping of the Corhure breccia took into account several peculiarities of the main components of the breccias: rock fragments (lithology, shape, dimension, participation), matrix (composition, participation), and open spaces (dimension, filling, frequency). The key genetic descriptive features have been pointed out and consequently

two types of genetic breccias have been separated: phreatomagmatic and phreatic. The phreatomagmatic breccias have a greater spatial development covering almost entirely the rooms and pillars exploitation zone, while the phreatic breccias, which in fact reworked the pre-existent phreatomagmatic breccias, are developed predominantly along the contact of the phreatomagmatic breccia body with the dacite host rock.

The phreatic brecciation event delineated within the Corhuri breccia body post-dates the phreatomagmatic brecciation stage. The subsequent phreatic brecciation can be recognized both in the phreatomagmatic breccia body and in the host rock, too. The effects of the hydrothermal activity are reflected by the occurrence of superposed phreatic breccias onto phreatomagmatic structure, by the presence of phreatic breccia dykes and pockets in the dacite host rock, but also by the vein structures superposed on the phreatomagmatic breccia body.

The Cărnăc II breccia is a phreatomagmatic breccia structure. This breccia body has been partially reworked by a later phreatic brecciation (Tămaş, 2002). The phreatic manifestations are reflected in different ways within the pre-existent breccia body and the host rock. A phreatic rebrecciation has been produced along the northern contact of the phreatomagmatic breccia, while in the dacite host rock a vein structure has been emplaced (the so-called "Fortis vein"; Cauuet et al., 2002). This tabular mineralized structure represents a breccia dyke structure close to Cărnăc II breccia pipe body, then it became a classic vein structure, and further on the vein is branching becoming a stockwork.

The mineralized structure mined in the Cărnăc V Ancient mining site (Cauuet et al., 2002) is a branching zone of a vertical vein. The vein is mainly composed of quartz but microbreccia sequences (*chingă*) also occur. The dacite host rock is highly silicified only 40 – 50cm both sides outwards the vein and further on the dacite is free of silicification. Another structure mapped in the Cărnăc V Ancient mining site is a 20cm-width barren breccia dyke. The contact of the dyke with the host rock is sharp. Its features proved the phreatomagmatic origin of this breccia body. Crosscutting relationships among the breccia dyke and the vein structures certify that the vein is younger.

Generally speaking, our researches carried out in Cărnic massif, Roşia Montană confirmed that irrespective of the size of phreatomagmatic breccias, this early stage of brecciation could be considered a "ground preparation" for the ore deposition. Later hydrothermal fluid flow has been focused mainly along the contacts of the phreatomagmatic breccias and through the coarse matrix zones.

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REHABILITATION EXPERIENCE OF THE JIU VALLEY – ROMANIA MINING ZONE

Mircea GEORGESCU

University of Petrosani, 20, University Str., Petrosani

Abstract: The coal basin of the Jiu Valley (JV), placed in the south-western part of Romania, represents a strong town-planning zone, which is, almost exclusively, related to the activity of pit coal output and dressing. The reorganization of this zone become difficult to be accomplished because of coal output decreased below 50% in comparison to 1989 and also because of the mono-industrialization of the zone. Even if the process of rehabilitation of the Jiu Valley started late and develops hard, it is a necessary one. This process has to be accepted and developed in time by following some successive steps that are able to avoid, as much as possible, the start of some major social conflicts.

In the present paper are shown, as much is allowed by the restricted space reserved for it, the stages of the zone reorganization process, the economic and social effects of this process and also a strategic zone development program, integrated in a larger one – a regional one.

1. Introduction

The mining zone called Jiu Valley (JV), also known as Petrosani Intra-mountain Depression, is placed in the south-western part of Romania and represents a complex surface as an asymmetric triangular shaped synclinal which has a 46.5 km length, 9.6 km width in the East and 2 km width in the West and a total area of 137.6 km². It is surrounded by Soth Carpathians. The absolute altitudes of the relief vary between 535m and 1034.5m. The climate is rough, cool and humid with annual average temperature of 7.5°C and about 716mm multi-annual rainfalls. The hydrographical network is dominated by the two branches – headwaters of Jiu: East Jiu (Transylvanian) and West Jiu (Wallachian) that confluence near to Petrosani town.

The population of the Jiu Valley, initially composed by rural communities of small dimensions, counts today around 165,000 inhabitants that are grouped in urban communities concentrated in 6 towns from which the largest and which is considered a municipal one is Petrosani that has 50,000 inhabitants. Here, there is, for almost 50 years, a University that has a the biggest Mining Faculty from Romania.

The subsoil of the Jiu Valley contains the largest pit coal deposit from Romania, with minable reserves estimated at around 1 billions of tons and supposed to be enough for the next 80-110 years if the present extraction rhythm is kept.

The Jiu Valley coal basin has 21 coal beds, but economic importance (with thickness bigger than 1m, larger and more uniform occurrence area) have only 13 beds, but the third one represents around 48% from the pit coal reserves volume of the whole coal basin.

In time, the whole deposit was extracted through more mining fields, thus in the 80's were 15. Today remained only 10 because during 90's 5 of the mines were closed. Today, in the whole basin, Only 6 beds are not extracted.

The geological-mining conditions of the deposit are difficult: complex tectonic, extracting depths between 300m and 900m, high concentration of ash (35-40%), presence of the methane both in coal beds and in surrounding rocks (more than 15m³/t/day), make these mines being fiery ones and the coal having a pronounced tendency of self-ignition.

At the beginning of 1990, the Jiu Valley could be characterized as a strong urbanized zone, almost exclusively related to the activity of coal output and dressing (more than 60,000 from the inhabitants work directly or indirectly in mining field).

II. The reorganization necessity of the mining from the Jiu valley

Mining industry from Romania strongly developed after The Second World War as a result of the decision of political factors of those times.

In Romania, 1989 was the year of the highest mining production existing in that period, 278 functional mines, where were working 10% from the total of active population.

In the mining basin of the Jiu Valley 12 million tone of energetic pit coal for coke were annually extracted and the employees number of the Jiu Valley Integrated Coal Work (CMVJ – as it was called at that time the administrative structure of the whole mining activity from the area) was of 60,679.

The system planned by state, a closed and inflexible one, inside of which was functioning national economy before 1989, couldn't allow and may be it wasn't wanted a real evaluation of this economy.

Afterwards there were created the condition for a market economy it was observed that not only from the quality point of view but also from the economic point of view the Romanian industry, generally speaking, and extractive industry, in particular, was uncompetitive.

And so, the mining activity from the Jiu Valley could not be an exception.

Thus, the prime costs per whole basin were 13-20 USD/Gcal or 50-77 USD/t while on world market these were somewhere around 9 USD/Gcal, respectively 37-42 USD/t.

Besides, the competition and the non-profitability of many electrical energy-consuming companies severely diminished the demand of pit coal on internal market. Because of the reasons mentioned above the access on the international market was impossible, so the board of the CMVJ,

in order to keep "alive" the extraction industry, had to choose between one of the following decisions:

- to produce the quantity of pit coal demanded by the internal market using the existing personnel, but this option implies an unacceptable increase of prime cost per tone of pit coal that could determine the lost even of the internal market;
- to produce the market demanded quantity of pit coal on the competitive prices, but this option implied an inevitable reduction of personnel.

It was obvious that the second option was the best. But, how can it be done if:

- there was a strong pressure from the trade union, which wanted an increase of the salaries and no employee to become unemployed;
- the investments were almost totally missing ;
- the geological-mining conditions were harder and harder ;
- the technologies and especially the work technique were old;
- the opened and prepared reserves of pit coal, in some mining perimeters, were in course of working-out, existing no financial possibilities to develop them in a superior category;
- it was inherited the shortest weekly working schedule in the world (30 hours/week);
- the higher and higher prime costs (these exceed the selling prices of the pit coal over four times) couldn't be state aided from the budget;
- there was a state control of the coal selling prices (and not only of the coal) because it was believed that in this way, the inflation rate could be slowed down;
- there were auxiliary and connective activities that determine a complex and expensive personnel structure, which was also hard to be administrated.

Furthermore, it was the problem of engaging the miners, especially those from the Jiu Valley, into political games that generated so called "mineriade" (violent miners' revolts) that brought the opprobrium of a part of country population and even of some politicians at those times. All these, placed in the context of an erroneous economic politic based on populism and incoherence of central decisions, affected the image of Romania, which in these days, is considered among the last countries from Europe regarding the mining reorganization.

III. Romanian legislation regarding mining reorganization

World economic recession, after 1990, strongly affected Romania, which has, as almost all the other countries from the former communist camp, a particular situation: it was passing from a planned economy to a market one. Of course, this had effect upon mining activity.

Romanian needed to solve a problem, which unfortunately wasn't entirely solved even during 2002: to disappear or to be restructured with a view to be efficient. There were many governors that preferred the first choice and they even acted consequently, as it can be observed in legislation until 1997. Fortunately, the trade unions pressure – positive from this point of view – and the impossibility of the state budget to cover the expenses necessary to buy the mineral raw materials from outside the country, changed the state attitude regarding this branch of Romanian economy.

Studying the Romanian legislation regarding economy reorganization and in particular that regarding mining, it can be made the following observations.

Until 1997, the laws, resolutions and government orders wanted to obtain only a "cosmetic" change of mining: the old structures were changed to autonomous administrations and then into national companies that can be managed buy-out; the detachment of auxiliary and appendant activities from these structures and their transformation into state capital concerns; closing/reorganization of some less importance divisions from Pit Coal Autonomous Administration – Jiu Valley.

The effect of these decisions was: an insignificant decrease of employees (it was not a real one – retirement and employees transfer to those concerns); economic ratios (extract net production, output per man-shift, prime cost and production costs) decreased; in conclusion the effect was not the wanted one.

After 1997 the legislation focused, especially, on the reorganization through dismissing the employees from all economy fields, but there were issued orders regarding only the mining branch and that of geological exploitation. In that period appeared the conception of "mass dismissing" with compensatory payments for the dismissed personnel. These dismissing were made in more stages, with different stipulations, that caused inequities and a significant decrease of employees' professional quality. Thus, during the first stage, the dismissed employees from all the branches of Romanian economy got 6, 9 or even 12 economy minimum wages, depending on their length of service, after that it was issued an order, just for the mining branch, which stipulated the fact that the dismissed employees from this branch will get 12, 15 or 20 economy minimum wages that could be given at one instalment. After that a new order made some correction to the previous one but not with positive effects.

However, it is mentioned that the legislation applied after 1997 contained "active measures against unemployment" (professional orientation, setting up consultant and business development centres, enterprising and professional training, financial support to create new jobs, etc.) as well as "reorganisation programmes" (ensemble of organisational, technological, management and financial measures meant to decrease and stop the losses and the back payments through state).

To offer facilities for the investors with a view to create alternative jobs, it was issued an order according to which Jiu Valley was declared "under-privileged zone". The main support offered to the investors in these underprivileged zones the financial facilities: profits tax relief, relief/refund of customs duties, value-added tax relief (VAT) and so on for a certain period of time.

A deed normative, which preceded the reorganisation program, at that moment, but in time it proved to be disastrous, stipulated the retirement conditions for age limit and length of service of the mining employees to 45 years old for all those who have 20 years length of service in underground conditions.

IV. The effects of legislation upon mining activity from Jiu valley

Even if the mining legislation has shortcomings, ambiguities and inconsequence, generated also by the fact that we all Romanians, implicit the decision agents, were submitted to some unprecedented provocations for this generation, the effects of the decisions upon the the Jiu Valley mining basin determined and will determine continuity conditions for pit coal extractive activity because there is a real internal market to sell the mining products of the Company; there are still important reserves of coal pit; there were allocated funds for reorganization of existing infrastructures that was materialized in technological lines for pit coal output and dressing; there was elaborated a strategy with a view to decrease the state-aided and the budgetary allocations.

There was a continuous decrease of the employed personnel of the Company, attaining today a number of employees three times lower than in 1989.

There were changes also in the structure of the employed personnel. Thus, if during 1990, from the total number of employees, 88.9% were workers, 3.1% were deputies, 8.0% administration and services personnel, and today this structure has the following composition: 91.9% workers, 3.0% deputies and 5.1% administration and services personnel. A significant change is the percent of the pitmen and that of the above-ground personnel. In 1990, 49.7% from the employees worked underground and 50.3% above-ground. Today, this proportion is: 67.7% underground and 32.3% above-ground.

With the view to concentrate the production and to have a better management of the subunits activity the reorganization was concentrated upon the number of mining grounds, which was reduced with 33.3%, that of the extraction zone was reduced with 41.6%, the number of the productive departments decrease with 20% that of the investment departments with 27.5% and finally, the auxiliary departments was reduced with 33.2%.

The large number of personnel dismissals between 1996 and 1998 caused big activity problems inside the Company, due to the impossibility the appropriate placement of the employees to the coal faces. The immediate negative effect was the abrupt decline of production. To solve this

problem the employees had to work in gangs, from which two of them were productive ones and the other one is used for technical revision and repairs. Also, some categories of auxiliary personnel were directed to coal faces with "on line" training.

In time these measures proved to be viable because the base economic ratios improved.

If the measures taken for mining industry from Jiu Valley proved to be useful, in being obtained some stability and even efficiency increase, for the rest of the population from this mono-industrialized zone these mining reorganizations had strong negative effects. The companies from the Jiu Valley that focused their activity on repairs and designs of mining equipments, had to reorient also to other products, and the two mining research and design institutes had to reduce their activity. Even the University of Petrosani and especially its Mining Faculty, which has before 1989 over 2500 students at mining specializations, has today only 300.

The other state corporations from this zone (buildings, transports, public foods, services) had suffered also because of the abrupt decrease of the mining activity from this zone.

Analysing the evolution of the incomes obtained by the unemployed and the way that the compensatory payments were used, it results that the incomes are somewhere among 20 and 60 USD/month, lesser than average wage of 120-150USD/month got by an employee, and that money were banked by around 39% from the unemployed, around 34% of these spent them to long time commodities and only 6% from the unemployed started their own business, proves that the idea of these compensatory payments (even in one block) was not a realistic one. All these happened because, on the one hand, there were no alternatives in the area and, on the other hand, because the people didn't have the appropriate education to start their own business. A statistic shows that 68% from the unemployed did not find a place to work, around 6% work occasionally, 6% work on their own account and only 20% have a full time job.

These are the reasons why the rate of unemployment in the Jiu Valley was, at one moment, around four times higher than the medium on the country.

Because in the Jiu Valley a family has medium 4.8 persons and almost 80% from the unemployed were the only persons in the family that had an income, it can be observed a drastic decrease of living standard of the population from this zone.

Unemployment and lower living standard determine other negative effects: zone depopulation, population ageing, increase of the criminality and the number of social conflicts, increase the number of welfare recipients, amplification of corruption, increase the number of children that give up school and illiteracy, worsen live conditions and so on.

But, it has to be mentioned the positive effects derived from the legislative measures.

Besides, there were created premises needed to perpetuate the main activity from this zone – mining – by increasing the technical-economic ratios, as it is presented above, it can be established

another successes: decrease the number of individual and collective work accidents; decrease the number of occupational diseases, modification of the employee mentality regarding their working efficiency, development of the contractor spirit in this zone and of some utilities, increase the educational level by taking part of professional re-qualification programs and so on.

V. The strategy of the future reorganization of the Jiu valley mining zone

It appears, from what we mentioned above, that it was necessary a new approach for economic and social reorganization of the Jiu Valley, being unjustified the measures taken till now, which, generally, were adopted from other regions.

The future strategy for socio-economic development of the mining basin of the Jiu Valley resulted after there were consulted and asked to participate all the interested agents from the zone, outside of it and even from outside the country (European Community and World Bank).

There were identified, in the first time, the main problems of Jiu Valley: dependence upon coal mining, absence of important extra-mining activities, inadequate state of the infrastructure, environment pollution.

The main objective on which was founded the development strategy of the JV is represented by the *reorganization of the JV economy, replacing its dependence upon the mining industry, as a result to the new variety of fields, businesses and qualifications that were created.*

Starting to this objective, it was elaborated from JV a 10 years-forecast, which, shortly, included the following:

- a rate of unemployment at least equally to the average for this zone;
- a strong touring branch;
- a cleanest environment;
- a local base of small and medium sized firms from manufacturing, trading and services industry;
- appropriate houses;
- an enterprising community more ambitious.

To achieve this purpose it will be necessary new substantial resources, appropriate programmes and incorporated actions and also a high quality implementation of them.

In the following, without detailing the means used to attain these development strategic objectives of JV (because of space restriction), the most significant of them, without commenting them will be enumerated:

- to transform the towns from JV mining basin into zones favourable to development of private sector;

- to set up a touring branch capable to stimulate the economic increase and a decrease of unemployment;
- to improve the living standards by increase the living fund and that of local public utilities services;
- to increase the quality of environment and infrastructures by public utilities programmes;
- professional training of manpower corresponding to economic demands that are in transition;
- to exploit local resources from the agricultural, forest and piscicultural branches;
- offer to young generation viable alternatives that are able to determine them to continue to live and work in JV;
- to promote a positive image of this zone, to attract investments and to improve the community trust;
- to re-launch the mining activities from JV by: closing the unprofitable mines, modernizing and improving the technology of mines and dressing firms that are still working, continuously improving the technical-economic ratios.

To achieve all these objectives, obviously, considerable financial sources. should exist. Besides those obtained from Romanian state for JV as credits, unsettled loans, subventions for jobs, an important funds source will be that supported by International Financial Institutions. Thus, some of the funds allocated for Romania by the European Community will be used in JV by the following programmes:

1. Programme of economic and social cohesion
2. RICOP Programme (Firms Reorganization and Manpower Conversion)
3. ISPA Programme (Instrument for Structural Politics of Pre-Adherence)
4. SAPARD Programme (Supporting Program of Agriculture and Rural Development)
5. Programmes of financial support focused on small and medium size firms.

As a result of measures implementation contained by the long-term development strategy of JV, it is estimated to be create a total number of extra-mining jobs (on long and short term) between 18,000 and 28,000. Of course, these changes also will determine other significant effects.

The following aspects can be anticipated very precisely, as a perspective for year 2010:

- ❖ The Jiu Valley will still be highly depended, upon mining activity for a significant period of time;
- ❖ The process of mining activity reorganization will be carried on at the same time with the development of some private branches that will be capable to takeover, by transfer, a part of the unemployed from the mining activity.

VI. Conclusions

The mining resources from this zone and also the geographic conditions had a strong effect upon the socio-economic development of JV, turning it in a mono-industrial zone with mining specific.

The reorganization of mining activity, beginning especially after 1997 and till now, influenced significantly the social and economic development of this zone, the impact being observed both at social level and at level of connected economic activities from the area.

The alternatives offered to the unemployed personnel, respectively to the other categories of unemployed people and graduates, were reduced and caused an abrupt decrease of living standards in this zone.

All these determined, as being necessary, a new approach of economic and social rehabilitation specific for JV, being insufficient to borrow the solutions adopted by other regions.

Thus, a strategic development programme is necessary because without such a programme it is impossible to engage financial resources that are so needed to obtain an economic increase. The main objective that it has to be in mind during the elaboration of new development strategy for Jiu Valley is the *reorganization of JV economy, replacing its dependence upon the mining industry, as a result to the new variety of fields, businesses and qualifications that were created.*

The specific proposals for social and economic rehabilitation of JV are considered as being means of achieving the strategic objectives that offers the general background for development strategy of JV. These proposals were presented in this paper.

Short-term measures of the action plan, necessary to achieve the strategic objectives, will consist in finding solutions for urgent social and economic necessities of the people affected by the mining closing, offering short-term jobs, creating new business and opportunities for professional training. These will be connected with the regeneration actions made by the local community.

On longer-term, the results of these actions will be new long-term jobs, a consolidated and growing economy, improving the quality of environment and infrastructures, all these being enjoyed by the local community, business and tourists of the Jiu Valley area.

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MINERAL GENESIS OF THE Mn BELT IN THE BISTRITA MOUNTAINS, EAST CARPATHIANS, ROMANIA

HIRTOPANU Paulina¹ & SCOTT W. Peter²

¹Geological Survey of Romania, 1 Caransebes street, Bucharest, e-mail: Paulina.Hirtopanu@igr.ro

²Exeter University, UK, Cornwall TR11 5RL, UK, email: peter.w.scott@lineone.net

Geologically and structurally the Bistrița Mn metamorphosed belt belongs to a complex area, the so-called the Eastern Central Carpathians Nappes (ECCN), which represent the Eastern segment of Median Dacides. The ECCN are constituted, from top to bottom, by a system of Alpine Nappes, which in their turn consist of several Variscan tectonic units known and pre-Alpine Shearing Nappes. The Mn belt is situated in the Tg2 level of Tulgheș Group (Variscan Putna Nappe). The current tectonic-structural setting of Bistrița Mn belt corresponds to its development and evolution in a subduction zone, as indicated by the Mn ore evolution from a mineralogical, geochemical and metamorphic perspective. The optical study and SEM analyses of Tg2 level of the proximal vicinity of Mn ore, demonstrated that the Tg2 rocks are retromorphic amphibolites. In the Tg2 rocks, relics of higher metamorphic grade were preserved. The carbonation is the first and main retrograde metamorphic process that has influenced the Tg2 rocks. The decarbonation reactions of rhodochrosite in the Mn deposits was the source of large volumes of CO₂ of petrological importance. The existence of many superimposed metamorphic events, associated with the development of Variscan and Alpine overthrusting nappes, influenced and destroyed the original space relations of the Tg2 level, totally changing its mineralogy.

More than 20 Mn deposits have so far been studied. Initially, they were probably a continuous belt, later fragmented by metamorphism and tectonics. The mineralogy of the Mn Bistrița belt comprises 343 mineral species and mineral varieties thus being some of the most complex deposits in the world. The repeated changes of metamorphic facies is the main cause of a great number of minerals. Many of these minerals are rare species, like manganese humites, johannsenite, nambulite, natronambulite, kozulite, winchite, pyrophanite, manganpyrosmalite, friedelite, shallerite, nelenite, etc. The mineralogical richness as well as their complex mineral equilibria made the Mn ore a promising potential for reconstruction of the conditions of P, T, X, f_{CO_2} , f_{O_2} , f_{CH_4} , $f_{\text{H}_2\text{O}}$, etc thus completing the data on the country rock, strongly influenced by retromorphism and thus more difficult to decipher. The Mn olivines of Bistrița Mn deposits are represented by pure tephroite, ferroan tephroite and ferroan rich tephroite (former knebelite). The absence of quartz in the olivines' association rules out the existence of a medium green schists facies of olivines formation. In the Bistrița Mn belt all of the terms of manganese humites, known so far were determined. The mineralogy of Mn-humites is richer than that

of Mg humites because the ribbeite, leucophoenicite, jerrygibbsite terms do not have Mg equivalents. The garnets of Bistrița Mn deposits belong to three major varieties: spessartine, spessartine-calderite (with two generations) and anisotropic spessartine-grossularite. However, there exists a transformation of one variety into another, with a change of P, T, f_{CO_2} , f_{O_2} conditions. The chemical compositions of the two pyroxenoids rhodonite and pyroxmangite are clearly outlined forming different compositional fields, thus showing the existence of a compositional miscibility gap between the two mineral. In Bistrița Mn belt the rhodonite never appears associated with pyroxmangite, each of them forming distinct associations or ore types, having different stability fields, according with their PT conditions; the pyroxmangite proves to be a high P low T polymorph of the rhodonite. The appearance of pyroxmangite-magnetite association in the Bistrița Mn belt is of great petrological importance, this being a less dense alternative parageneses, which probably substituted the calderite. This change was proved by experimental synthesis of calderite (Lattard & Schreyer, 1983). The nambulite (Li>Na) and natronambulite (Na>Li), alkali hydrated pyroxenoids, were discovered recently in Mn Bistrița belt. The first johannsenite occurrence in Bistrița Mn belt is closer to the diopsid-hedenbergite because of its high content in Ca, Fe and Mg. The Na-pyroxenes, important constituents of Mn ore, generally belong to aegirine-augite with very great compositional variations, reflected by the frequent marginal and sectorial zonation. The great variation of chemistry as illustrated by the chemical profiles realised by SEM analyses, the compositional zonation, and the Ti presence, are the specific features of clino pyroxenes in Mn-metamorphosed cherts of the blueschists facies. The namansilite occurrence, the Mn analogue of aegirine, in association with other minerals with Mn^{3+} is specific to subduction zones. The occurrence of Fe-Mn-Mg amphiboles, sodo-calcic, sodic and calcic require an unusual composition of the entire rock and the ore and also a special evolution of P-T conditions. The presence of kozulite, the Mn analogue of arfvedsonite, with a content of ca 0.60pfu Li, shows that Li is a major cation. The compositional zonations of amphiboles, with the core made of mangangrunerite or grunerite and its margin of magnesioriebeckite or crossite show the radical changes in its chemical composition. Apart from the brown biotite, green biotite, muscovite, sericite and phengite, constituents of the Tg2 level rocks, there are also in the Mn ore the following micas: Mn biotite, norrishite, phlogopite with Ni and kinoshitalite as accessory minerals. The absence of micas gives Mn ore a great compactity, totally different from the foliated texture of the country rocks. In all the Mn deposits of Bistrița belt, a rare group of Mn phyllosilicates with Cl and As were determined (manganpyrosmalite, friedelite, megillite, nelenite, etc). The bannisterite, ganophyllite, parsettensite of the stilpnomelane group were determined and described as new minerals for the Bistrița Mn belt. The chlorites are especially represented by the terms of chlinocllore and pennantite series, both having an important Al-Tschermakite molecules. The

first occurrence of minnesotaite, the iron analogue of talc in the ferriferous associations of low metamorphic grade (stilpnomelane, greenalite, magnetite), formed at the expense of grunerite. The bementite with its isotropic variante neotocite, the kellyite (the Mn analogue of amesite), the caryopillite, greenalite and chlinoclore of serpentine type were all described. Both the presence of Ba feldspars and the low frequency of baryte in the Mn ore may indicate a lack of sulphur in the deposition fluids. The Fe-Mn oxides (jacobsonite, iwakiite, hausmannite, braunite, pyrophanite, magnetite, hematite) form interlayers in the two important groups of ore/Mn rocks, i.e., silicate-oxide (gondite) and carbonate-silicate-oxide (queluzite), which although may sometimes be in the same sequence, never occur adjacently, suggesting that they evolved from different precursors. The alabandite occurs in the tephroite-jacobsonite Mn ore and in massive sulphides (Puiu, Broșteni, Holdița). The recent determination of alabandite in the Holdița sulphides-baryte, Broșteni and Puiu sulphide deposits demonstrates the common origin of sulphides, Mn and Ba from a submarine hydrothermalism, associated with a subduction zone. In the oxidised zone 33 minerals were determined. There is here a strong metal concentration, hence the economic importance of these deposits.

The textural, mineralogical (the presence of many end members) and geochemical features (the sharp separation of Mn from Fe, the low content in Co+Ni+Cu, the samples' plotting on to Bonatti's submarine hydrothermal field, etc) are all arguments in favour of a submarine hydrothermal origin of the Bistrița Mn deposits. The first metamorphic event M_1 was probably HP/LT, when we suppose that the calderite were formed under the conditions of a subduction zone. The metamorphites of event M_1 (Caledonian) were transient and underwent destruction, a frequent phenomenon in the younger metamorphites, such as the Alpine ones. The obduction was continued by the M_2 event, the first metamorphic event probably of Variscan orogenesis, when there appeared the alternative parageneses pyroxmangite-magnetite/hematite - a less dense equivalent of the calderite, at lower PT values, but in the same HP/LT domain. The association johannsenite-grossularite-Mn-calcite, metamorphosed under granulite facies conditions and Fe-rich tephroite belong to the same metamorphic event. In the M_3 metamorphic event formed the colorless pyroxenes or green of augite type (augite-hedenbergite, diopsid-augite) or omphacite type etc which constituted the core of zoned pyroxene grains on which grew marginally the pyroxenes of aegirine-acmite-jadeite type of M_4 metamorphic event. The rhodonite, tephroite, old Fe-rhodochrosite from undersaturated associations formed at $t > 581 \pm 10^\circ\text{C}$, X_{CO_2} very high, $X_{\text{H}_2\text{O}}$ null, the environment being completely anhydrous. In the second stage of the M_3 event, which marks the beginning of some retrograde changes, also accompanied by cooling, the Mn humite formed from tephroite, under high $a_{\text{H}_2\text{O}}$. To this metamorphic event belongs the retrograde transformation of johannsenite into rhodonite, the formation of alkali hydropyroxenoids (nambulite and

natronambulite) on rhodonite, through the substitution of Ca by Li, Na respectively, under high X_{H_2O} conditions. The high f_{O_2} necessary for nambulite and natronambulite to occur, may be deduced from their association with braunite and hausmannite (between 10^{-7} and 10^{-3} bar (estimated from the stability field of braunite). In the M_4 event of the late Variscan or may be Alpine orogenesis- a spectacular retrograde mineralogical transformation of Mn ore took place. This was characterized by the occurrence of alkali pyroxenes and amphiboles. The conditions of M_4 event, i.e. $P > 9 \text{ Kb}$ and $T < 450^\circ \text{C}$ have been evaluated from experimental diagram Jadeite (glaucofane)-Aegirine (Magnesioriebeckite). (Wood, 1980) and from diagram Jd-Ae-Q (Brown & Ghent, 1983) based on jadeite component of Na pyroxene of Bistrița Mn ore. The alkali blue amphiboles grew zoned, concentric on nonalkali amphiboles, being associated with pyroxmangite, the high pressure polymorph of MnSiO_3 , composition. The zonation reflects the change of metamorphism conditions, from the amphibolite (core of grain) to blueschists facies (margin of grain). The spessartine-calderite II associated with Na pyroxenes and amphiboles also belongs to this metamorphic event. Its chemical composition totally lacking Mg and Ti, is the feature of garnets grown under the blueschist facies conditions. In the M_5 metamorphic event a mineral neoformation takes place under conditions of the greenschist facies, represented by phyllosilicates of stilpnomelane type, grown on pyroxmangite and of the pyrosmalite type, grown on tephroite and rhodonite. The clockwise evolutive trend of Bistrița Mn metamorphic belt is specific to metamorphic terrains, tectonically thickened by overthrusting, matches the nappe structure of the Bistrița Mountains in which it occurs. The Bistrița Mn belt occurs in the disturbed structural setting, detaching from the initial ophiolites, with which probably evolved for a while and which were not found until now or were totally destroyed by repeated metamorphism, the same way the Tg2 level was totally transformed. The Bistrița Mn chert is not in stratigraphic coherence with the oceanic crust (the ophiolites) as occurs in other Mn deposits (St Marcel-Italy, Haute Maurienne-France, Andros-Greece), but geochemical evidence indicates their evolution from an oceanic crust. The mineralogical and petrographical evidences show the presence of some indicators of HP/LT metamorphism sequences, even of some HP/LT recurrences. During tectonical evolution the manganese ore underwent two subduction processes; the first one during M_1 event, may be Caledonian (a palaeosubduction) and the second one during M_4 event, may be Alpine.

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MINERALOGY OF GALATI BLASTFURNACE SLAGS

HIRTOPANU¹ Paulina, UDUBASA¹ Gheorghe, ¹HARTOPANU Ion

¹Geological Institute of Romania, Caransebes street, Bucharest, Romania

e-mail: Paulina.Hirtopanu@igr.ro

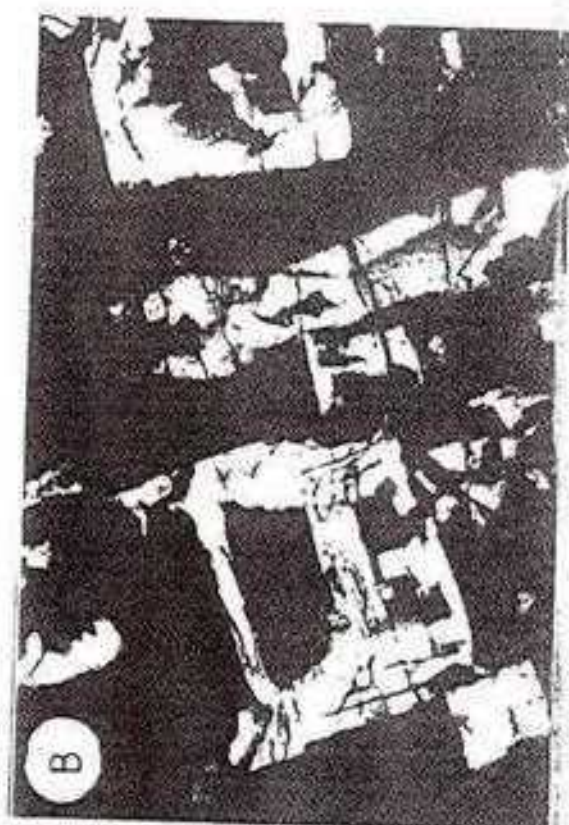
The samples of granulated slags were collected from the blastfurnace dump. The granulated slags are produced by very rapid quenching in a fast moving stream of water, shortly after the molten slags leave the blastfurnace. About 100 slag samples were studied microscopically (appearance, textures, mineralogy) and also some chemical references were made. The described minerals were used to establish the bulk chemical composition of the slags, conditions of formation and some relevant phase equilibria data. The Galati slags are quenched from an initial T of ca 1400-1500-°C, cooled a little since leaving the blastfurnace. Macroscopically, the granulated blastfurnace slags have a vitreous appearance. Their colour is generally black, rarely brown to grey-brown or yellow. Small vesicles (ca 1mm) are common in the larger samples. Occasionally vitreous fabrics occur. In thin sections they present many cracks, some of which are perlitic. There are abundant vesicles which vary in size. The glass dominates overall the grains.

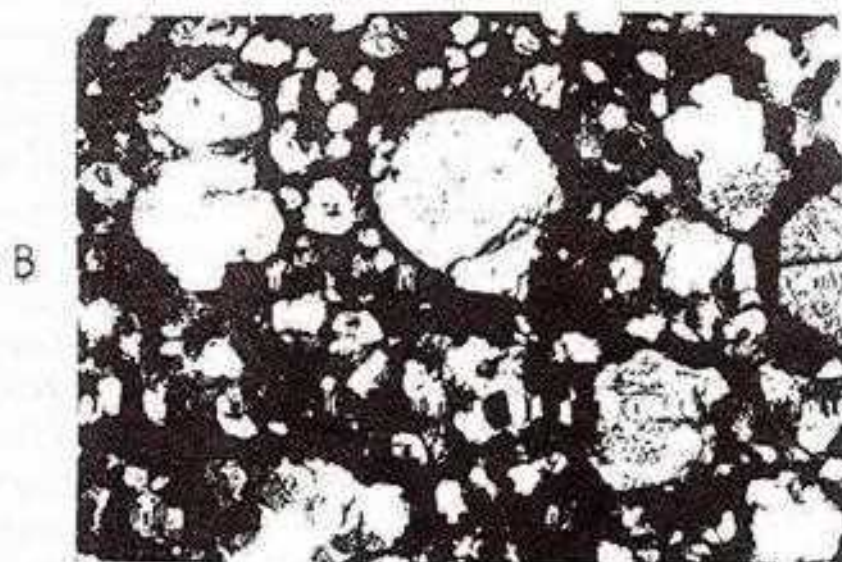
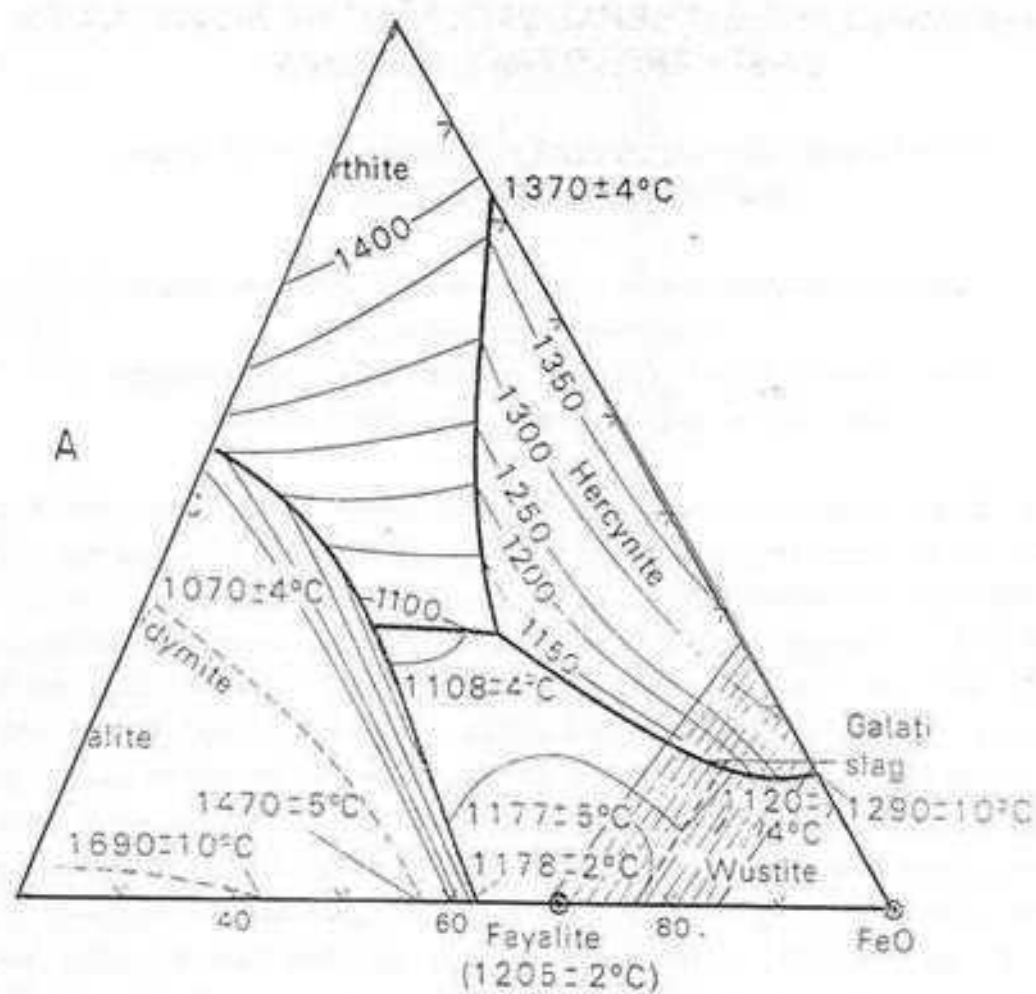
Melilite is the major crystalline phase in all samples and occur as euhedral, prismatic forms (Plate I/A,B), with crystals sometimes twinned. It is a solid solution of akermanite ($2\text{CaO}.\text{MgO}.\text{SiO}_2$) and gehlenite ($2\text{CaO}.\text{Al}_2\text{O}_3.\text{SiO}_2$). The melilite occurring in cluster and as isolated crystals are zoned (Plate I/C,D). Zoning is common with both concentric and sector type. The larger melilite grains formed in the slag slowly cooled prior to quenching. In some samples there appear other small crystallites (cuboid) of melilite with curved faces, formed when the slags quickly cooled prior to quenching. The large melilites contain inclusions of **native Fe** mostly oriented concentrically in the crystal (Plate I/C,D). The inclusions are common as elongate patches situated at right angles to each crystal face. The iron inclusions appear as they are incorporated into the growing crystal. In some melilite crystals there occur dendritic inclusions of **oldhamite** (CaMgS). The crystal growth of oldhamite developed from a nucleus by repetitive branching. Sometimes the oldhamite inclusions are very concentrated almost throughout all the crystal giving it an opaque appearance. In some melilite samples, larger inclusions of oldhamite and stellate cluster (ca 0,4mm) occur. Also, oldhamite appears as euhedral individual crystals. The **fayalite** appears as round and elongate grains with a concentrically zonation (Plate II, B). The **anorthite** is present as **glass**. Because the conditions in the bloomery furnace were reducing it is unlikely that any oxides of Fe higher than **wustite** (FeO) could have existed when the slags were tapped from the furnace. In the fayalite bearing samples there is no silica present, it is all bound up in anorthite and fayalite. The

excess FeO remains as wustite. The wustite forms oriented submillimeter blebs in fayalite and glass. Rarely, striated crystals of **dicalcium silicates** ($2\text{CaO} \cdot \text{SiO}_2$) with a high lime content appear. **Merwinite** ($3\text{CaO} \cdot \text{MgO} \cdot 2\text{SiO}_2$) has a pale brownish or pale greenish colour. It has a subrectangular to rhomboidal shape with ragged edges. Sometimes the merwinite crystals are irregular with a skeletal form due to quench crystallisation. Frequently it forms clusters in the glass. The **perowskite** (CaTiO_3) has high refringence, brownish color and it is isotropic. It occurs in association with big zoned melilite crystals. The hercynite spinel (FeAl_2O_4) as individual red grains occurs associated with fayalite and wustite. Accessory, big grains of anhydrous apatite (**whitlockite** ?) are present. From the mineralogical composition of the Galati slags we appreciated approximately their chemical composition: high in FeO, CaO, MgO and low in Al_2O_3 and P_2O_5 . The melting temperature of the Galati slags can be appreciated from the phase diagram Anorthite- SiO_2 -Fayalite (Plate II, A, hatched area).

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URANIUM-SULPHIDE MINERALISATION IN THE BISTRITA MTS, EAST CARPATHIANS, ROMANIA

HIRTOPANU¹ Paulina, UDUBASA¹ Gheorghe, SCOTT² Peter,
HARTOPANU¹ Ion, BARBIR³ Gabriel

¹Geological Institute of Romania, 1 Caransebes street, Bucharest, Romania,
e-mail: Paulina.Hirtopanu@igr.ro

²Exeter University, Cornwall, TR11 5RL, UK, email: peter.w.scott@lineone.net

³National Company of Uranium, Suceava Branch, Romania

The uranium mineralisations at Crucea are situated in Bretila Group at the proximity contact with the Tg3 level. Geologically and structurally it belongs to a complex area, the so called Eastern Central Carpathians Nappes (ECCN). The ECCN are constituted from top to bottom by a system of Alpine Nappes –which in their turn consist of several Variscan tectonic units named also pre-Alpine Nappes. The Crucea Uranium deposit is situated in the Variscan Rarau Nappe (represented by the oldest Bretila Group) which thrusts over the Putna Nappe (represented by the youngest Tulghes Group). This is the only major thrusting in the area. Because its tectonic setting, the host rocks of uranium minerals are strongly retromorphosed, highly carbonated, forming a tectonic zone, characterised by crushing, cataclasis and microbreccia formation. The samples for analyses were collected from Bretila Group rocks hosting the Crucea uranium mineralisation. The microscopical study and SEM analyses allowed us to determine uranium oxides, uranium silicates, uranyl silicates, uranium (uranyl ?) silicate sulphates, uranyl sulphates, uranyl carbonates and uranyl phosphates. The primary uranium ore from Crucea deposit is mainly constituted by **uraninite** (Plate I, fig A, point A). The uraninite is white and has a irregular shapes, enclosed in black carbonaceous matter (point B on the fig A/plate I). Its chemical composition is shown in the SEM profile A (Plate I). Beside uranium, it contains very little Ca, Al, Si and P. In the SEM profile B of the same plate on can see the chemical composition of the carbonaceous matter, indicating only C with very little S. In polished thin section the carbonaceous matter is intensely anisotropic and has relatively high reflectance, which means a high degree of crystallisation. The **pitchblende** is the metamictic, amorphous substance which results from the transformation of uraninite, containing up to 5wt % water. **Coffinite**, the uranium tetragonal silicate differs from uraninite, being anisotropic. Other uranium silicates determined by SEM analyses in the Crucea deposits are: **ursilite**, **uranophane**, **uranosilite**, **weeksite**, **soddyite** and **clarkeite**. The last one is a result of hydrothermal transformation of the uraninite. The high Ti and Ca content of some U-silicates indicate the probable presence of a mineral from the **sklodowskite** group. The chemical analyses on intensely anisotropic and high reflectance carbonaceous matter, which has a high degree of crystallisation, indicate only C with very little S (SEM analyses)(Plate I, profile B). The amount of S from carbonaceous matter could have been derived from biogenetic material and/or reduction of sulphate. The Ba and Si together with uranium in the chemical profile of some grains are a proof of the **kasolite** presence in this mineralisation. The SEM analyses indicate a U-

sulphate-silicate, which probably is a new mineral (mineral X) (Hirtopanu & Barbir, 2004). Its chemical profile is shown in fig.4. The uranyl-sulphates are: **uranopilite**, **zippeite**. The uranyl-carbonates are: **zellerite**, **uranocalcarite**. The uranyl phosphates contains generally Ca and Mg: **upalite**, **uranospatite**, **autunite**, **mundite**, **saleeite**, **novacekite**. In the Plate II on can see the image of some Uranium silicate and their chemical composition variation (3 chemical profiles from point 1, 2 and 3 on the picture).

The sulphides comprise three mineral associations: (1) dominated by **pyrite**, **pyrrhotite** (2) polymetallic dominated by Pb-Zn-Cu, represented by **chalcopyrite**, **sphalerite**, **galena**, **bornite**, **bournonite**; (3) Ni-Co-As sulphides dominated by **pentlandite**, **polydymite**, **gersdorffite**, **rammelsbergite**, **bravoite**, associated with calcite, hematite, siderite. The U mineralisation is situated between (2) and (3) association, because frequently it substitutes pyrite and pyrrhotite. There are relics of **ursilite** in pyrite (Plate I, fig B). Because its association, the uranium mineralisation seems to be hydrothermal in origin, but it was tectonically strongly transformed and remobilized after leaving the original source. There is some concentric zonations with **gersdorffite** in the centre and with **pentlandite** at the rims of the grains. Also, a very nice zonation is shown in Plate I fig C, with **pentlandite** at the margin (a), Ni-pyrrhotite in the middle (b) and mineral X in centre of the grain (c). The chemical profile of mineral X is shown in the Plate I, profile G1c. In the plate I fig B on can see the relics of pyrite (grey) in uranium silicate, **ursilite** (white), with concentric zonation. In the other grain the zonation shows: As-Ni sulphide (**gersdorffite**) in the margin, **pentlandite** (in the middle) and **ursilite** in the centre of the grain. Other sulphides, like **tetrahedrite**, **tennantite**, **marcasite**, **bravoite**, etc, were also determined.

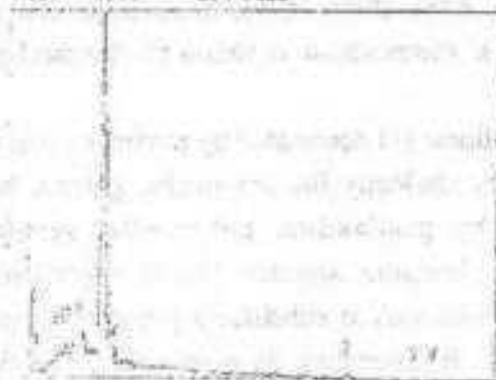
The protore of U mineralisations of Brettila Group rocks was probably a carbonaceous matter with a very high carbon concentration deposited on the Precambrian sea floor. Subsequently the U mineralisations were accumulated by complex metasomatic oxidation-reduction processes, which promoted destruction (degradation) of the organic matter and the repeated precipitation of the ore components, followed/accompanied by a strong remobilization/migration. Recently the uranium mineralisations, through its geologic setting and mineralogical composition looks like a hydrothermal vein one, but it was tectonically strongly transformed and remobilized from the original source. The U mineralisation and the sulphides, especially Ni-Co-As seems to be contemporary. To solve this problem we need some isotopic analyses to establish the nature (organic or mineral) of carbonaceous matter. If the carbonaceous matter will prove to be of mineral origin, then it can be formed by reducing of carbonates. The decarbonation reactions usually produce CO_2 and CO , which decompose into graphite and oxygen, below the graphite buffer curve (at very low oxygen fugacities). The special tectonical conditions to form the carbonaceous matter in this way were available in this area. If the isotopic analyses will give a mineral nature of the carbonaceous matter, its age could be younger, at last contemporaneous with the thrusting of Rebra Group over Tulghes Group.

References

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Plate 1

X-RAY: 0 - 20 keV
Live: 100s Preset: 100s Remaining: 0s
Peak: 1362 25% Dead



PCW: 0L
9.490 keV
CH: 4624
145 cts
RENT: PROFILE A

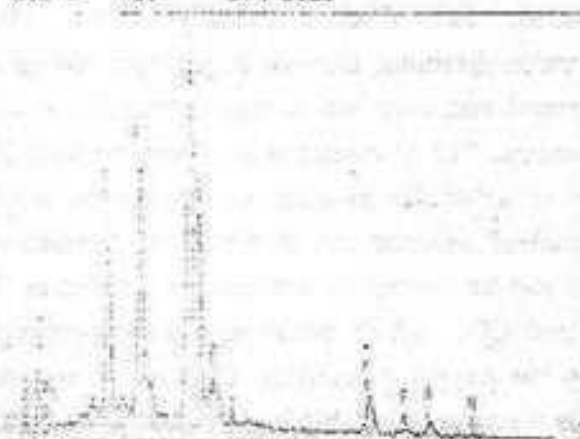
X-RAY: 0 - 20 keV
Live: 100s Preset: 100s Remaining: 0s
Peak: 1112 10% Dead



PCW: 0L
9.200 keV
CH: 2214
140 cts
RENT: PROFILE B

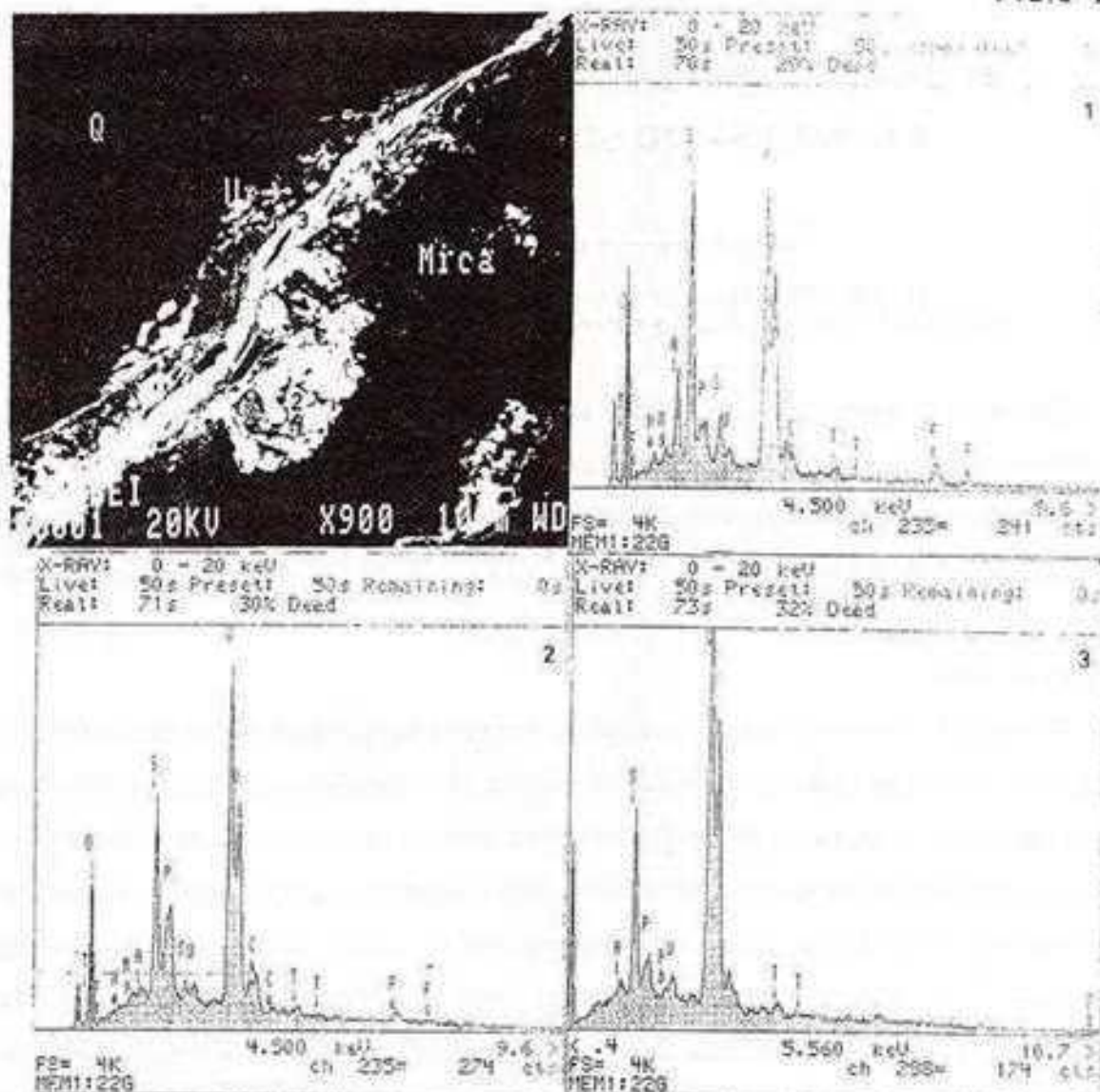


X-RAY: 0 - 20 keV
Live: 50s Preset: 50s Remaining: 0s
Peak: 727 31% Dead



PCW: 4K
5.060 keV
CH: 2134
138 cts
RENT: 01 c





GEOCHEMISTRY AND EVOLUTION OF THE NEOPROTEROZOIC INTRUSIVE COMPLEX OF IBITUBA - ITAPINA, IN THE RIO DOCE REGION IN THE MINAS GERAIS AND ESPÍRITO SANTO STATES, EASTERN BRAZIL

HORN Heinrich Adolf¹, BILAL Essaid²

(1) IGC, UFMG, Belo Horizonte-MG. Av. Antônio Carlos, 6627 - Brazil

(2) CNRS-UMR6425, SPIN-Ecole National Supérieure des Mines, St. Etienne - France.

Geological setting : The Ibituba-Itapina ring like intrusive Complex (537 Ma up to 520 Ma) is localized within the Espírito Santo State, Brazil, at the southern and northern margins of the Rio Doce river between the cities of Baixo Guandu and Aimorés in the west and Colatina in the east. The intrusive bodies emplaced within the Juiz de Fora and Paraíba do Sul Complexes of Archean to Proterozoic age and show six main intrusive bodies and several smaller ones, all of them with a complex structure.

The ring like intrusive Complex consists of three main facies which are, in order of intrusion: fine grained diorite, generally in the center of the ring like intrusive complex, hyperstene-bearing granite ring and/or granodiorite rim ring. The contact between these main facies of the pluton and the surrounding wall-rocks are generally sharp or with a mimetic zone in the host rocks and always nearly vertical. Intra-plutonic contacts are characterized by locally intense mixing and mingling phenomena in the Intrusive Complex along the contacts indicate that synchronous or nearby emplacement of these granitoids and such crystal differentiation in situ had an important role in the genesis of the granitoids suite. These granitoids contain many microgranular enclaves and wall rock xenoliths. The magmatic texture is generally preserved, but locally in the marginal region of complex solid deformation is developed, and may have been related with their emplacement.

The diorite generally has a heterogranular texture. The most frequent mineral association is plagioclase (50%), andesine composition $An_{34,6-40,7}$ in a groundmass and $An_{36,9-43,5}$ in phenocrysts plagioclase, sometimes it exhibit in core labradorite composition, 15% pyroxene (augite and ferrossilite), 15% quartz, 5% amphibole, 5% biotite (annite) and 5% K-feldspar (perthite and mesoperthite). Accessory mineral phases (5%) are zircon, apatite, magnetite, ilmenite and pyrite.

Hyperstene-bearing granite show a porphyritic texture with plagioclase phenocrysts (37%) An_{33} to An_{27} , pyroxene (10%) orthopyroxene and low proportion of clinopyroxene, anhedral k-feldspar (20%), quartz (15%), biotite (10) and amphibole (5%). Zircon, apatite, magnetite and ilmenite are the most conspicuous accessory minerals. The granodiorite show the same texture as

the hyperstene-bearing granite, but with high modal k-feldspar (25-40%), low (20-30%) modal plagioclase ($An_{24,4-30,3}$ in matrix and $An_{22,6-30,6}$ in phenocrysts), quartz (10-25%) and biotite (5-10%). Apatite, zircon and Fe-Ti oxides are accessory minerals (3%).

The biotite from the diorite generally has higher *mg*-number (43-38) comparatively to the biotites from hyperstene bearing granite (30-24) and granodiorite (32-21). Amphibole is predominantly hastingsite-hornblende and edenite-hornblende. Composition variation in the amphibole was controlled by edenitic substitution. Emplacement pressure and temperature were estimated using the Al in hornblende barometers (6 up to 7 kbar) and orthopyroxene and clinopyroxene composition from diorite and hyperstene-bearing granite thermometer (1000°C and 750°C respectively).

The all facies of the ring like intrusive complex are cut and intruded by porphyritic granitoids suite which is constituted essentially by coarse grained granite, granodiorite and fine granite. This suite represents a few volume (10-20%) into the ring like intrusive complex. The porphyritic granitoids suite contains k-feldspar (40%), quartz (20%), plagioclase (20%), biotite (2-10%), muscovite, rare amphibole. Monazite, titanite, apatite, magnetite and ilmenite are common accessory minerals. The biotites from the porphyritic granitoids suite show a *mg*-number from 0.38 to 0.23 and Al rich from 2.82 to 3.31 atoms p.f.u..

Geochemistry: The ring like intrusive complex is characteristic of metaluminous rocks and they have a algaipitic index ((Na+K)/Al) ranging from 0.45 to 0.77. These granitoids show a broad range of SiO₂ content, from 51 to 71 wt %. The total (Na₂O+K₂O) increase from 5 to 10 wt % with SiO₂ and is broad overlap alkaline and sub-alkaline granitoids field. In all facies Al₂O₃, Na₂O and CaO decrease linearly with increase SiO₂, indicating to the plagioclase crystallization from the melt during the magmatic differentiation. In all facies, P₂O₅, TiO₂, MgO, Fe₂O₃, MnO, Zn and Ni decrease also linearly with SiO₂. The MgO/TiO₂ ratio of these rocks is low near to 1, and this is a typical feature of sub alkaline granites (Bilal & Giret, 1997). The Ba/Sr, Sr/Rb, Ba/Rb, Zn/MgO and Sc/MgO ratios of these granitoids pointing to the important role of fractional crystallization of pyroxene and plagioclase in first time and amphibole, biotite and k-feldspar in second time. The total (Zr+Nb+Ce+Y) content is higher from 500 to 1000ppm and compared to post tectonic granitoids. All facies exhibit similar chondrite normalized REE patterns, which are characterized by a greater Σ REE abundances (200 - 800ppm), wide LREE, low HREE ($10 < (La/Yb)_N < 200$).

The porphyritic granitoids suite is characterized by higher ASI range from 0.82 to 1.35, K₂O contents from 2 to 8.4 wt %, the total (Na₂O+K₂O) contents from 5.45 to 10.6 wt % and more feriferous, Fe₂O₃ contents from 0.52 to 6.56 wt %. The porphyritic granitoids suite reach their highest ASI under unusual high MgO values (2.1 wt %) and low SiO₂ (63 wt %), The ASI increase

up to 1.35 under MgO values (0.7 wt %) and SiO₂ values (70 wt %), and decrease after. This behavior may be related to the influence of the two magmatic sources, metasedimentary and (Fe, Mg)-rich mantle (lamprophyres). The Al₂O₃, TiO₂, MnO, MgO, CaO contents decrease linearly with increasing SiO₂. Na₂O show broadly decreasing trends. The K₂O contents increase with SiO₂.

These granitoids are characterized by very low Ni, (1-9ppm), Co (0.8-7ppm), Th (3-22ppm), Sr (56-467ppm) and Rb (61-217ppm) contents and high Ba (464-2940ppm) contents. The REE patterns of the different facies show close similarities. The LREE contents are relatively high ($20 < (La/Yb)_{CN} < 33$) and have a lower or even absent Eu anomalies.

Discussion and conclusion: The Ibituba-Itapina ring like intrusive Complex are characterized very high K₂O contents and the FeO_T/(FeO_T+MgO) ratios. They are may be compared to Fe-K granitoids suite of late Variscan belt in Europe. The Zr-ASI-FMMT diagram discriminate also the different Neoproterozoic granitoid suites of Rio Doce region. The FMMT is the total of FeO_T+MgO+MnO+TiO₂ corresponding to Fe-Mg-minerals in the granitoids suites, essentially Biotite present in all facies of these granitoids suites and which included up to 80% of the zircon. In all granitoids suites, the FMMT decrease from the last to the most differentiated facies. The Fe-Mg minerals (biotite) seem to controls the behavior of Zr during melt segregation. The behavior of Zr seems also to depend to ASI in different granitoids suites. The Zr contents decrease strongly in the sin-tectonic granitoids suite (peraluminous) and moderately in pre-tectonic granitoids suite (metaluminous). The Zr contents increase in late- to post-tectonic granitoids suites up to saturated of Zr in melt and decrease in the most differentiated facies. The zircon solubility is strongly controlled by ASI in melt. The porphyritic granitoids suite show the same trend as the pre-tectonic owing the same ASI evolution. In sin-tectonic suite, the zircon is an early crystallized mineral and is included within biotite, thus producing a strong depleting of Zr contents in residual melt.

Petrological features of the Neoproterozoic granitoid suites of Rio Doce region are known to related to tectonic setting. The plutonism in the Rio Doce region was formed over time span of about 95 Ma (595 Ma up to 500 Ma). Detailed mapping, petrological characterization, geochemistry and geochronology have been necessary to resolve the complex Neoproterozoic granitoid suites of Rio Doce region. So far, no exist the Neoproterozoic oceanic crust in central and south part of Ribeira Belt, the many features indicate the continent-continent collision pattern in the central part of Ribeira Belt. The pre-tectonic granitoids (Galileia Suite) were crystallized (595 Ma.) under high pressure (8-10kbar) and high temperature (750°C - 850 °C). The presence into these granitoids, the labradorite, the grossularite-rich garnets, the two zircon populations, the mafic enclaves, the high ⁸⁷Sr/⁸⁶Sr_(t) ratio (0.712 -0.713) and the negative εNd₍₆₀₀₎ (from -8.9 to 9.3), suggest that a important interaction of upper mantle mafic magmas with continental crustal source.

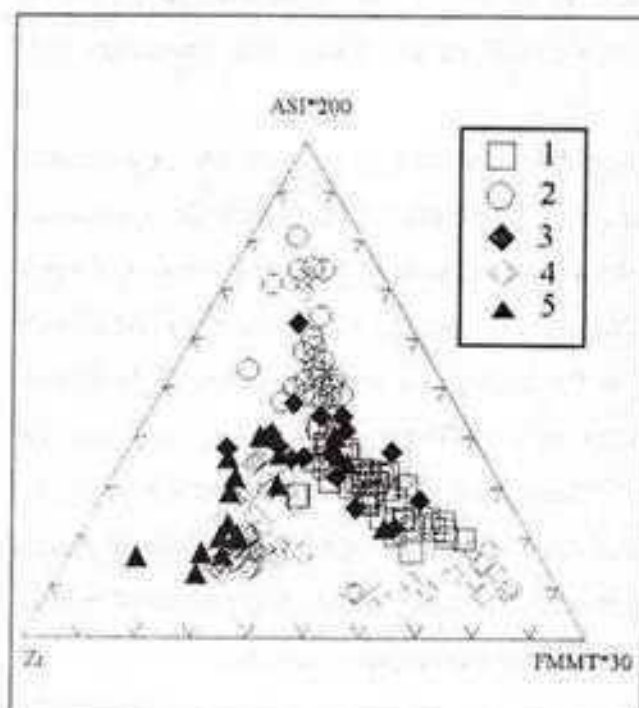


Figure 1: Neoproterozoic granitoids suites of the Baixo Guandu region plotted in Zr-ASI-FMMT diagram. 1: pre-tectonic granitoids, 2: syn-tectonic granitoids, 3: porphyritic granites, 4: hypersthene granite, (3 and 4 belong to the late and post tectonic granitoids), 5: post-tectonic granitoids. The granites 3, 4 and 5 which belong to the Itapina-Ibituba Intrusive Complex.

These granitoids were exhumed at 4kbar and 700°C during a main deformation (D1) corresponding to collision event. The exhumation of the pre-tectonic granitoids is estimated to 2 mm/year. The preserve initial composition of the amphibole, the calcic-rich plagioclase and grossularite-rich garnet corroborates the quick exhumation. In the course of decompression and in reply to thermal relaxation, the Paleoproterozoic metasediments were subjected to a first partial melting giving, the leucogranites (Urucum Suite) and the first pegmatites group, the sin-tectonic granitoids (582 Ma). This main tectono-metamorphic event was dated at 590-565 Ma. The recent study demonstrate a important contribution of Paleoproterozoic crust in genesis of pre- and sin-tectonic granitoids.

The second deformation phase (D2), corresponding of the extension episode, was related to strong tectonics reactivating thrust zones and marked by the exhumation of adjacent high grade gneiss rocks (Juiz de Fora and Paraíba do Sul Complexes). We considerate the extensive tectonic linked up the exhumation of metamorphic zones of orogeny as well as isostatic effect in compression context. The Aimores, Ibituba and Itapina ring like intrusive Complex late tectonic granitoids have taken place during this event. Their intrusion was related to opening linked with thrust and strike-slip tectonic, as shown by Ibituba and Itapina ring like complex and was coeval with the tectonic juxtaposition by strike-slip faulting. The direction of opening linked with the emplacement of the plutons was W-E in Ibituba and Itapina complexes and WSW-ENE in Aimores complex. The second deformation (D2) is accompanied by the slight development of second partial

melting giving porphyritic granitoids suite and second pegmatites group. The geochemical and petrography feature of porphyritic granitoids suite, very different to the sin-tectonic suite typically crustal composition, implies the different source material of the porphyritic granitoids suite probably the high grade orthogneiss rocks.

The end of extension episode is characterized by the emplacement of the post tectonic granitoids Ibituruna massif. The presence of mafic and ultramafic enclaves into the syenite and granite of Ibituruna massif implies a contribution from a mantle source. This indicates that, the post Brasiliano strike-slip faults may have been lithospheric-scale, allowing mantle melts to rise into the upper crust. This tectonic framework is observed in the central and southern sector of the Ribeira Belt. Except in the Araçuaí Belt in the northern part of Minas Gerais state, no exist the Neoproterozoic oceanic lithosphere in other part of Ribeira Belt. The feature magmatic activity, the tectonic framework and the important contribution of Archean and Paleoproterozoic crust of genesis the granitoids suites implies the continent-continent collision pattern in the central part of Ribeira Belt. The many studies on the southern part of Ribeira Belt evoke the same pattern.

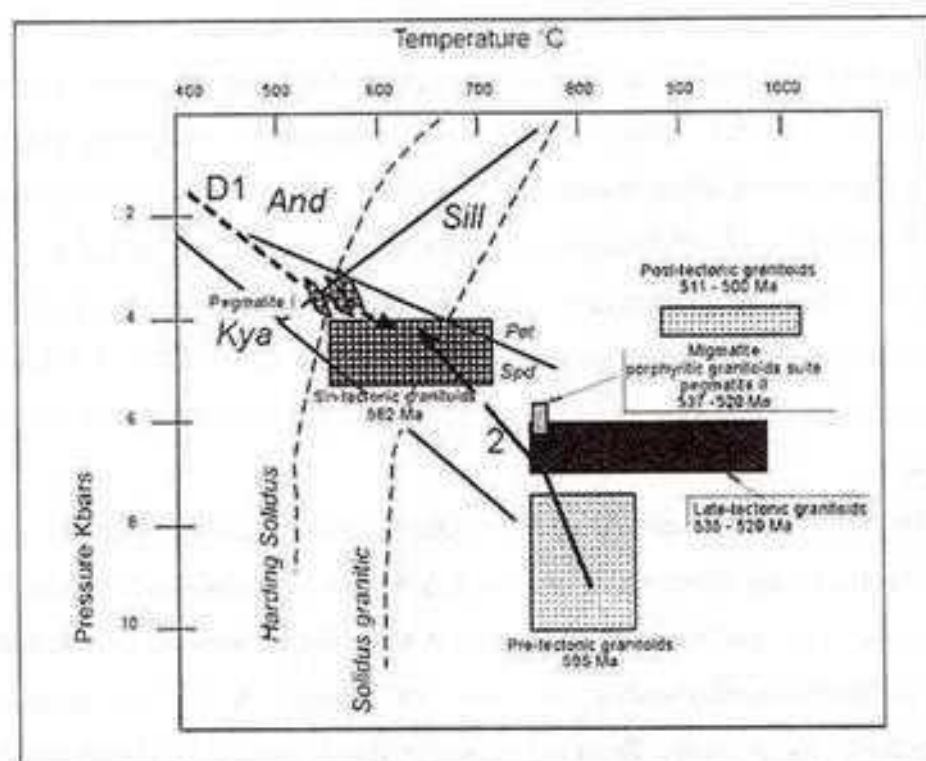


Figure 2 : Pressure-temperature-time path of the Neoproterozoic granitoids suites of Rio Doce Region (Bilal et al. 1999, 2000a ; Horn et al. 1998). The pre-tectonic granitoids (595 Ma) are exhumed (2) during a main deformation D1 (590-565 Ma) corresponding to collision event. The sin-tectonic and rare elements pegmatites I (582). The second phase D2 is characterized by extensional movements (537-520 Ma) and contemporary to late to post granitoids (537-520 Ma) and rare elements pegmatites II. The post-tectonic granitoids were emplacement in crustal depth around 511-500 Ma.

LATE ARCHAEOAN POST-COLLISIONAL GRANITES IN MOEDA COMPLEX (SOUTHERN SÃO FRANCISCO CRATON, MINAS GERAIS, BRAZIL)

M. L. Lacerda¹, E. Bilal², J.M. Correia Neves¹

1- Instituto de Geociências, Universidade Federal de Minas Gerais, E-mail: Romanoaw@ufmg.br

2- CNRS-UMR 6524, Ecole Nationale Supérieure des Mines de Saint-Etienne, Email : bilal@emse.fr

The Moeda complex (figure 1, 2) crops out over about 250 km² and show a very complicated geological framework. The BGG and the SPG (2.72 ± 0.003 Gy) intruded the Belo Vale GGM (2.78 ± 0.003 Gy). These rocks underwent several tectonic events, one of them well characterized by the early Proterozoic shear zones which crop out near the eastern contact with the Minas Supergroup (MS). From the Proterozoic onwards they underwent a greenschist facies metamorphism which modified the composition of the biotites from the magmatic field into the metamorphic.

Barra do Gentio Granites (BGG): Eastwards they contact the basal clastic unity of the Proterozoic Minas Supergroup (MSG). The contact corresponds to one large shear zone of about 1.5 km in width. The BGG are coarse grained, light colored and weakly NNW orientated, the main striking direction of the shearing event. They also show a porphyritic structure and biotite clusters. The main mineral phases consist in (K, Na)- feldspar, plagioclase, quartz, ilmenite and fluorite. The contact between the BGG and the Santana do Paraopeba Granodiorites (SPG) is either sharp or gradual and even irregular. However, the main elongation of the SPG, strikes NW cutting the regional trend of the main striking direction of the shearing event. The elongated SPG bodies may be emplaced within tension gashes parallel to the older Pitangui shearing event about 2.6 Gy.

Santana do Paraopeba Granites (SPG): These granitoids crop out westwards of the BGG, between Moeda and Belo Vale villages. Dikes of the SPG granites cut the BGG ones in the eastern part as described above. Towards the north and south, they are limited by the Belo vale Granite-Gneissic- Migmatitic association (Belo Vale GGM). They show from medium to fine grained isotropic structure, sometimes striking slightly according to NNW, and a scanty porphyritic appearance. Plagioclase, quartz, (K, Na)- feldspar and small biotite represent the main mineralogy.

The Belo Vale granite-gneissic-migmatitic association (Belo Vale GGM) : Within this domain finds gneisses and migmatites. The gneisses are fine up to medium grained rocks with quartz, feldspar and biotite rich milimetric up to centimetric bands. Foliation strike is well developed according to NNW. Within the Belo Vale GGM, trondhjemitic- and granitic facies have been characterized. The leucocratic parts of the migmatites, particularly those showing a well developed nebulitic texture, represent anatexis, which sometimes originate bulky masses of magnetite bearing granitic rocks, denominated as Chacrinha dos Pretos granites. These granites are medium up to coarse grained rocks with quartz, (K, Na)-feldspar, plagioclase, Mg rich biotite, and magnetite.

The Belo Vale GGM are slightly peraluminous ($1.02 < ASI < 1.12$) compared to the BGG and the SPG granites (figure 3) an ASI of about 1 together with MgO contents lower than 0.5%, these granites plot within the anorogenic field as defined by (Bilal and Giret, 1997). The mean total alkali contents ($Na_2O + K_2O$) are higher for the BGG and SPG granitoids (8.35%) when compared to those of the Belo Vale GGM (6.85%). The BGG and SPG granitoids show K_2O contents higher than Na_2O , contrary to what is observed in the Belo Vale GGM. The average CaO content is lower in the BGG (0.97%) and the SPG (1.30%), but the Belo Vale GGM show a much higher CaO content (2.25%). The BGG and SPG show the same Fe/Mg atomic ratio of 3.36, higher than that of the Belo Vale GGM 1.86. The MgO/TiO₂ ratios are low and of about of same value for either BGG and SPG with ratios of 1.35. The Belo Vale GGM granitoids, with MgO/TiO₂ ratios ranging from 2.10 up to 3.77 show a clear affinity to calc-alkalic ($MgO/TiO_2 = 2$) and (K-Mg) granites ($MgO/TiO_2 = 4$). The BGG and SPG granitoids have about the same Nb (16 - 19 ppm), Zr (157 - 243 ppm), Sr (80 - 120 ppm) and Y (58 ppm) contents. The anomalously high Y contents which sometimes is found in these rocks, especially in the SPG ones outcropping as dykes have not been considered. The Belo Vale GGM granitoid show much lower Nb (6 - 9 ppm), Zr (119 - 161 ppm) and Y (10 ppm) mean contents. The Sr contents (195 - 392 ppm) of the Belo Vale GGM rocks are higher than those of the BGG and SPG granites, the last two both show about the same mean value. The Rb average contents of BGG (233 ppm) and SPG (256 ppm) are higher than those of the Belo Vale GGM (132 - 154 ppm). So the Sr/Rb ratio drops from about 3 in the BGG and SPG to 0.63 in the Belo Vale GGM. The Th contents of the BGG (32 ppm) and SPG (27 - 46 ppm) are higher than those of the Belo Vale trondjemite (11 ppm) but similar to Belo Vale K-granite (34 ppm).

The range of chondrite normalized REE (figure 5) average values for the BGG and SPG granitoids are enriched in the HREE when compared to Belo Vale trondjemites and K-granites. The $(La/Yb)_N$ ratio for the BGG and SPG granitoids lies in the range of 8.3 - 12.4 and the value for the same ratio is 18 for the Belo Vale trondjemite and 70 for the Belo Vale K-granite. The last rocks show a very low ΣREE (81 - 193 ppm) content compared to those of the BGG and SPG (about 250 ppm). The negative Eu anomaly is greatly enhanced from a Eu/Eu* ratio ranging from 0.22 up to 0.82 for Belo Vale trondjemites and K-granites and from 0.28 up to 0.97 for the BGG and SPG ones. The REE patterns shown by Belo Vale trondjemites requires the presence of garnet in the source to explain the high concentration of the HREE.

The average spidergrams normalized by the Ocean Ridge Granite (ORG), show similar patterns for the BGG and SPG granitoids (figure 6). Even though these granites are homogeneous regarding their trace elements contents, a few samples are particularly rich in HFS elements and in HREE. The BGG and SPG spidergrams are characterized by an important enrichment in K, Rb, Ba, Th and LREE. Even though they are comparable to the Skaergaard patterns (Pearce *et al.*, 1984) they

show higher Rb, Th and Sm contents when compared to the Skaergaard rocks. The Belo Vale GGM (Trondjemite and K-granite) have lower REE and HFS elements contents. Their patterns are similar to those of Yunnan (China) regarded as sin-collision granites (Pearce *et al.*, 1984) according of the high LILE/HFS ratios and low Nb and Y contents in this granitoids.

The BGG and SPG gather within the A2 sub-type field Eby's (1992). The Y/Nb ratios are characteristic of continental crust and island arc basalt's. The geochemical patterns of the Belo Vale GGM are similar to those of the sin-collisional granites

The Barra do Gentio Granites (BGG) and the Santana do Paraopeba Granites (SPG) show an intrusive relationship to the Belo Vale Granite-Gneiss-Migmatitic association (Belo Vale GGM). Within the latter one, trondjemites and granodiorites (TTG), represent the oldest of the aforementioned granitoid facies. The isotopic (U-Pb) geochronological data of the Belo Vale GGM unity points to 2.78 ± 0.003 Gy, corresponding to an event known in the region as the Rio das Velhas orogeny. However the Belo Vale GGM has been later reworked originating the BGG and SPG granites emplaced in the primitive sialic crust. The petrological interpretation of the available lithogeochemical data allowed us to conclude that both the BGG and SPG are A-type subalkali granites. These last BGG and SPG younger granites have been emplaced during the late Archaean (2.72 ± 0.003 Gy, U-Pb), in post-collisional and anorogenic conditions. The $\epsilon_{Nd} = -3.07$ value, the MgO/TiO₂ and Y/Nb ratios indicate that the genesis of these last granites took place within a thin and primitive continental crust (2.95 ± 0.003 Gy Tmd). These granites may have been generated by the interaction of basaltic magmas from a deep mantle source with an evolved lower crust, under an extensional regime. The high content in volatile components, such as F, and the high temperature (900°C) of the A-type granite liquidus facilitate the melting of the lower crust in contact with mantle-derived melts Clemens *et al.* (1986). This resulted in magmas with A-type geochemical features. They seem to represent a very important event contributing to the accretion of the early continental crust outcropping in the southern part of the São Francisco Craton.

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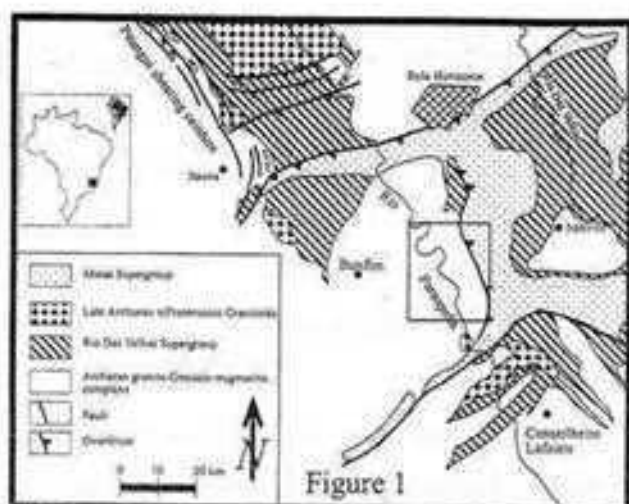


Figure 1

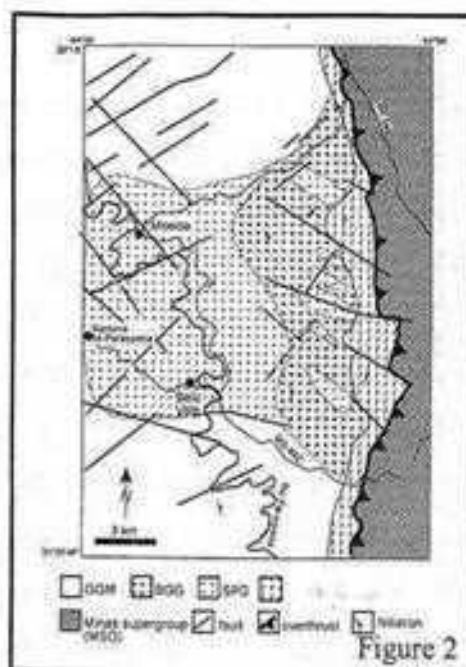


Figure 2

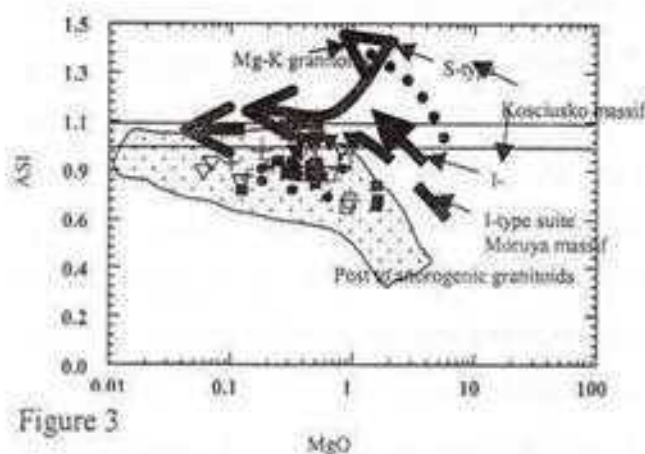


Figure 3

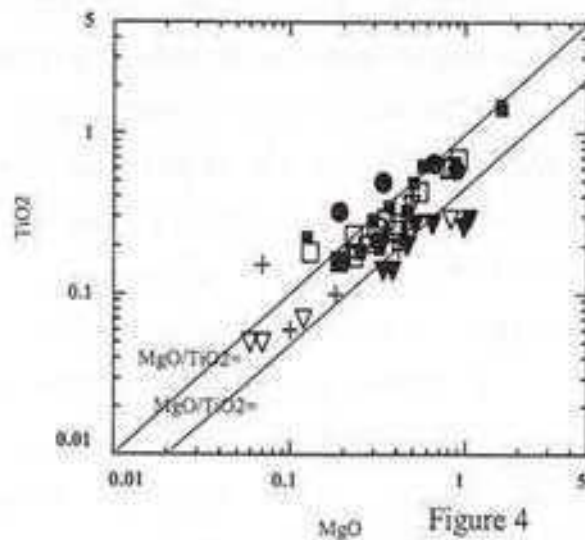


Figure 4

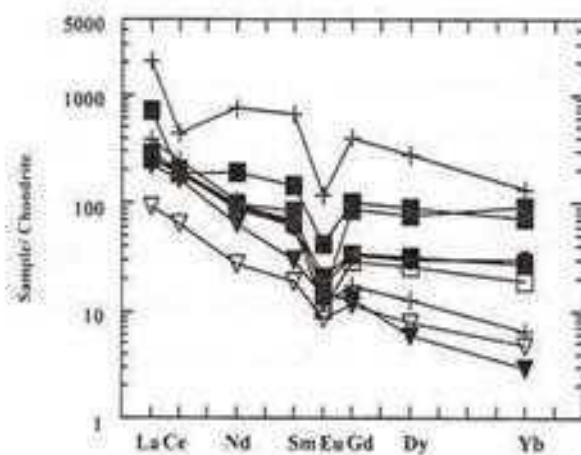


Figure 5

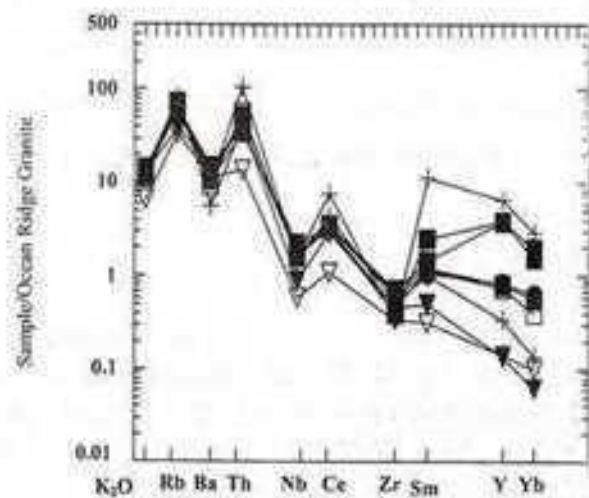


Figure 6

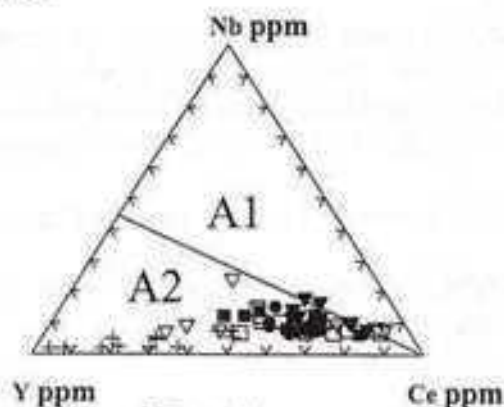
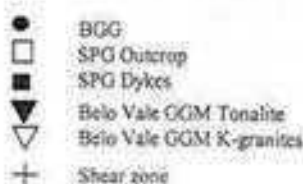


Figure 7



Figures captions:

- Figure 1: Geological sketch of the Archaean and early Proterozoic region in the southern part of the São Francisco Craton (see text for details).
- Figure 2: Geological sketch of the region Moeda-Belo Vale (Minas Gerais, Brazil).
- Figure 3: ASI versus MgO% for the granitoids outcropping near and between the small towns Moeda and Belo Vale (diagram after Bilal and Giret (1997)).
- Figure 4: Plot of the studied granitoids within the diagram $\text{TiO}_2\%$ versus MgO% after Bilal and Giret (1997). Read the text for explanation.
- Figure 5: Rare earth element patterns of the studied granitoids.
- Figure 6: Sample/Ocean Ridge Granite spidergrams for the different types of the studied granitoids
- Figure 7: Nb-Y-Ce plot for the studied granitoids. Fields A₁ and A₂ corresponding to sub-types of A type granites as defined by Eby (1992).

VEIN SETS AND HYDROTHERMAL ALTERATION IN THE CETATE – CÂRNIC AREA, ROȘIA MONTANĂ DISTRICT, ROMANIA

S. MANSKE¹, T. ULLRICH², T. J. REYNOLDS³, G. O'CONNOR⁴

¹Dept. of Geology and Geological Engineering, Colorado School of Mines, Golden, CO, USA, smanske@worldnet.att.net; ²Pacific Centre for Isotopic and Geochemical Research, Univ. of British Columbia, Vancouver, BC, Canada, tullrich@eos.ubc.ca; ³FLUID INC., Denver, CO, USA, fluidinc@comcast.net; ⁴Gabriel Resources Ltd., Toronto, Canada, gary.oconnor@rmgc.ro.

Large-scale (1:250) mapping of mine benches, road cuts, and underground workings in the Cetate and Cârnic dacite bodies in the Roșia Montană area has delineated the paragenesis of vein sets and hydrothermal alteration for the two historically most important Au-Ag-mineralized centers in the district. Data on alteration, vein sets, and mineralized zones in the district were obtained through the "Anaconda" mapping technique (Einaudi, 1997). Bench and drift map data were augmented with reconnaissance survey of exposures outside of the mine workings and review of key drill cores.

As noted by Tămaș (2002), exposures of dacite in the Roșia Montană maar / diatreme complex rarely are unaltered. The freshest dacite rock encountered in this study occurs as clasts in drill core of a phreatomagmatic breccia underlying the Coma valley, south of the Cetate pit. This rock is a quartz-, magnetite, and hornblende-bearing porphyry with mild chlorite-smectite alteration. Surface exposures of dacite are in general much more altered. Distal to mineralized zones on the northeast flank of Cârnic hill, a hornblende- and biotite-bearing dacite displays pervasive alteration of the mafic fraction to chlorite, oxyminerals, and clays, and clay-calcite alteration of most feldspar phenocrysts. The original igneous magnetite persists unaltered. This chlorite-smectite-calcite imprint lends the rock a distinctly green coloration but it is more properly regarded as an "intermediate argillic" alteration rather than propylitization in the strictest sense (e.g., Barton *et al.*, 1991).

Closer to mineralized zones, the chlorite-smectite-calcite alteration is overprinted by sulfidation of the original igneous magnetite and a progressive bleaching as illite replaces chlorite. This phyllic-argillic imprint creates the widespread bleached effect in most outcrops of dacite around the historic workings. Petrographically this alteration style is characterized by the development of fine-grained sericite and turbid brown clays. The argillic fraction generally exhibits moderate to high birefringence under a petrographic microscope, indicative of smectites as opposed to kaolinite group minerals. XRD scans on altered feldspar phenocrysts from a number of samples

in the phyllic-argillic zone indicate that the sericite is an ordered, mixed-layer illite-smectite clay. Although supergene argillization occurs on weathered exposures, the presence of the illite-smectite alteration in the sulfide zone demonstrates that it is hypogene in origin.

In general, the most highly mineralized zones in dacite are characterized by durable forms of rock alteration such as quartz-illite-pyrite, replacement adularia, and silicification. Where intensely developed, these alteration types may destroy most of the primary igneous texture of the dacite. Particularly in the Cetate area, there is a tendency for the pervasive alteration types described above to show a rough zonal pattern away from the dacite / vent breccia contacts, with proximal silicification and adularia flooding giving way to quartz-illite-pyrite and ultimately phyllic-argillic alteration toward the interior of the flow-dome mass. Empirically it has long been noted that higher precious-metals values are spatially congruent with silicified and/or adularia-altered dacite and vent breccia (O'Connor *et al.*, 2002), but it is not conversely true that all silicified zones carry significant gold grades.

Quartz-illite-pyrite (QIP) alteration forms halos on quartz veins and also local zones of more pervasive character. Quartz-illite-pyrite alteration encroaches upon bleached, phyllic-argillically altered rock, and also may form a border on more intensely silicified or adularia-altered zones. In hand specimen or mine bench, the QIP alteration type is distinguished from more extensive silicification by a scratch test - it is easily scored with a knife blade or steel dental pick. In thin section, QIP-altered dacite shows illite developed both in phenocrysts and rock matrix and fine-grained pyrite may locally compose > 5 vol. % of such altered rock.

In the Cetate area, strong silicification is volumetrically minor within unfractured dacite, being more characteristic of breccia matrix on the margins of the flow-dome complex, or within the adjacent diatreme host. On Cărnăc, silicified zones likewise tend to fall near the margins of the dome or along the contact with the medial phreatic breccia column, but strong silicification also is evident along certain structures within the interior of the dacite mass.

Adularia flooding occurs as halos on veins, pervasive alteration in breccia fragments, and as meters-wide zones in mine bench, where very fine-grained adularia replaces rock matrix. Adularia alteration and silicification tend to be commingled in bench face or drift rib, and timing relations may be ambiguous. In part the ambiguity arises because adularia clearly was introduced into the system at more than one stage of alteration or mineralization. Thin section observations indicate that adularia replacement of original plagioclase phenocrysts in dacite was widespread ("adularia I" of Tămaș, 2002), even in those zones where a pervasive phyllic-argillic imprint became the dominant alteration type. Adularia also is an important accessory in many of the sulfide-bearing vein sets ("adularia II" of Tămaș, 2002). Secondary adularia in many cases has been overprinted by phyllic-argillic alteration.

A distinct sequence of hydrothermal veins in the Cetate-Cârnic area was distinguished through crosscutting and overprinting relations; (a) "chinga" veins, (b) pyrite veins, (c) gray quartz veins, and (d) quartz-adularia veins. The chinga veins are irregular, black, strongly silicified fracture fillings ranging from a few millimeters to several centimeters in width. Their dark color is due to extremely finely-divided pyrite and a fine-grained opaque that is thought to be graphite inherited from the sedimentary basement of the maar / diatreme complex.

Within the Cetate dacite, the early set of very fine pyritic stringers average a millimeter or less in thickness. These pyritic veinlets are most characteristic of phyllic-argillically altered dacite.

Gray quartz-pyrite veins in the Cetate pit range from millimeters to centimeters in width and are filled with a porous, felted meshwork of millimeter-scale quartz prisms and interstitial pyrite. The veins are very sulfidic, with quartz and pyrite present in subequal proportions. Wall rock dacite is altered to QIP or silicified, and the vein halos can bulk 3 – 5 vol. % disseminated pyrite. Thicker examples of gray quartz veins commonly exhibit breccia texture.

A similar generation of quartz veins is found in Cârnic, with some textural variations. Some Cârnic quartz veins are banded with an earlier stage of very dark, highly sulfidic fine-grained quartz being reopened and infilled with lighter-gray, less sulfide-rich quartz. These veins are more likely to have a distinct centerline than the Cetate examples, and may also manifest vugs lined with late-stage vitreous, prismatic quartz.

Late quartz-adularia-pyrite veins occur both in the Cetate and the Cârnic dacite bodies and commonly are extremely vuggy. Open crevices contain pockets of centimeters-long quartz prisms and are lined with fine-grained, drusy adularia. The pyrite content of the veins and their wall rocks tends to be distinctly lower than in the case of the gray quartz stringers, with disseminated pyrite present at about 1 vol. % in adularia-altered dacite.

The development of hydrothermal veins in the Cetate-Cârnic area was punctuated by the intrusion of the Glamm breccia column, a phreatomagmatic pipe that lies between the two dacite bodies. The Glamm breccia is cut by two distinct vein types. Early (post-Glamm) coxcomb quartz veins form a set of millimeters-thick stringers with a distinct centerline. The coxcomb quartz stringers are cut or overprinted by a later generation of banded quartz-carbonate-sulfide veins that range up to several centimeters in thickness. Rhodochrosite is the major vein mineral, but the compound quartz-carbonate-sulfide veins also contain fine-grained adularia. Base-metal sulfide bands are composed of sphalerite, chalcopyrite, galena, and minor pyrite, with accessory sulfosalts. The halos of both coxcomb quartz and rhodochrosite-bearing veins in the argillaceous Glamm matrix are indurated with minor amounts of carbonate and disseminated sulfide.

Most quartz-bearing veins in the Cetate-Cârnic area form sheeted sets with strongly preferred orientations, rather than random stockworks. The predominant strike direction for quartz

veins in the Cetate dacite is NE, whereas on Cârnic hill it is NNW, and in the Glamm breccia, due north.

Fluid inclusion data were acquired from a character set of samples comprising (a) prismatic quartz lining a vug from a quartz-adularia-pyrite vein in altered dacite on the west end of Cetate pit, (b) quartz from the coxcomb veins cutting the Glamm breccia, and (c) late-stage vitreous quartz filling the centerline of a banded quartz-carbonate-sulfide vein, also cutting the Glamm breccia. All three samples contain planes of coeval liquid-rich and vapor-rich inclusions with very low salinities. For the quartz-adularia vein sample, the highest homogenization temperatures were in the range 245 ° - 250 ° C. The coxcomb vein quartz contains inclusions that homogenized as high as 230° - 235° C. The quartz from the late-stage rhodochrosite vein showed evidence of boiling at temperatures as high as 280° - 290° C, suggesting a thermal rejuvenation of the system with the formation of the latest carbonate veins.

$^{40}\text{Ar}/^{39}\text{Ar}$ radiometric dates on neoformed, hydrothermal vein adularia from a quartz-adularia-pyrite vein in dacite from the Cetate pit yield ages of $12.78 \pm .09$ and $12.71 \pm .13$ Ma, which we regard as a mineralization age for the system. An $^{40}\text{Ar}/^{39}\text{Ar}$ date on hornblende from juvenile dacite clasts in the phreatomagmatic breccia south of Cetate- Cârnic yields an age of 11.0 ± 0.8 Ma, indicating that eruptive activity continued in the maar / diatreme complex for at least one million years after the bulk of the alteration and Au-Ag mineralization in the dacite flow-domes.

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MINERALOGICAL DATA ON THE BAT GUANO DEPOSIT FROM GURA PONICOVEI CAVE (ALMAJ MOUNTAINS, ROMANIA)

MARINCEA Ștefan¹, DUMITRAȘ Delia Georgeta¹,
DIACONU Gabriel², FRANSOLET, André-Mathieu³

¹ Department RIMTI, Geological Institute of Romania, 1 Caransebeș Str., RO-012271, Bucharest, Romania; ² "Emil Racoviță" Speleological Institute, 11 Frumoasă Str., RO-010985, Bucharest, Romania; ³ Laboratoire de Minéralogie, Université de Liège, Sart-Tilman, Bâtiment B 18, B-4000 Liège, Belgium

The Gura Ponicovei Cave is located in Almaj Mountains, in the lower basin of Ponicova River, at about 1-km upstream from its confluent with the Danube. The cave is also known under two other names, i.e. the Ponicova Cave and the Liliacilor Cave (the Bat Cave) from Dubova.

Developed along a system of minor faults generally trending NW-SE that affects the massive limestones of Jurassic-Aptian age from the Ciucarul Mare Hill, the cave, of 1666-m long, is composed of five main galleries. From these, only one, namely the Bat Gallery, is of interest for the present study. This gallery is dry, has about 300 m in length and is composed of a 200-m long passage continued by a large ellipsoidal room (100 x 60 m in apex, where is over 30-m high). A relatively low humidity (80 - 98 %) and a mean temperature of about 11°C, with small variations over the seasons, favored the presence of an active bat colony.

In this gallery, a deposit of slightly indurate, dry pulverulent guano covers the cave floor, enclosing some boulders and speleothem fragments fallen from the roof and walls. It overcoats a detrital argillaceous sequence of unknown thickness. The phosphate-rich bed, up to 1.5 m thick, includes thick sequences of detrital deposits, generally affected by the solutions derived from the surrounding guano. As a rule, the illite-rich sequences grades laterally into taranakite-rich. Beside taranakite, the guano deposit from Gura Ponicovei comprises francoanellite, hydroxylapatite, brushite, ardealite, monetite, calcite, quartz, illite (the 2M1 polytype), interstratified kaolinite-illite and amorphous iron sesquioxides.

The purpose of the present study was to gain additional data on the mineral species in the deposit. The information obtained was mainly based on scanning electron microscopy coupled with energy-dispersive scans, X-ray powder diffraction (Cu K α , λ = 1.54056 Å) and infrared absorption spectrometry. All the analytical facilities, procedures and experimental details are similar to those already described by Marincea *et al.* (2002) and Dumitraș *et al.* (2004).

Hydroxylapatite generally occurs as ochre to orange crusts whose SEM examination shows that they are composed by thick beds of crystalline aggregates whose morphology varies from randomly disposed laths to post-colloidal, rosette-like, deposits. The individual crystals generally

have hexagonal habit and rarely attain 20 μm across and 1 μm thick. The mineral has a high crystallinity, the crystallinity index of the sample whose unit-cell parameters are given in Table 1 being I.C. = 0,031 (Simpson, 1964).

Table 1. Unit-cell parameters of selected mineral species from the bat guano deposit from Gura Ponicevei, refined from X-ray powder data*

Mineral	System, S.G. ⁽¹⁾	Sample	a (Å)	b (Å)	c (Å)	α (°)	β (°)	γ (°)	n ⁽²⁾	N ⁽³⁾
hydroxylapatite	H, P6 ₃ /m	PGP 4 B	9.418(3)	-	6.870(3)	-	-	-	7	62
brushite	M, Ia	PGP 1 B	5.802(2)	15.162(5)	6.230(2)	-	116.45(2)	-	7	97
ardealite	M, Cc	PGP 3	5.718(2)	30.967(9)	6.254(2)	-	117.11(2)	-	5	138
monetite	A, P1	PGP 1 C	6.874(3)	6.631(3)	7.012(4)	96.35(3)	103.90(3)	88.73(3)	10	78
taranakite	R, R3c	PGP 2 B	8.703(2)	-	95.03(4)	-	-	-	9	104
francoanellite	R, R3c	PGP 2 B	8.681(9)	-	82.14(12)	-	-	-	6	20
quartz	R, P31	PGP 1 A	4.909(2)	-	5.402(3)	-	-	-	2	22
calcite	R, R3c	PGP 1 C	4.980(2)	-	17.006(9)	-	-	-	3	25

(1) space group; (2) number of refining cycles; (3) number of reflections used for refinement. Range of 2 θ angles used for collecting reflections: 16 - 88° for hydroxylapatite, 10 - 90° for brushite and calcite, 10 - 76° for ardealite, 16-70° for monetite, 5-66° for taranakite and francoanellite, 20 - 90° for quartz.

The unit-cell parameters fit with a carbonate-bearing hydroxylapatite, since *c* is slightly smaller than the value given by Elliott (1994) for the stoichiometric hydroxylapatite [*a* = 9.4176(5) Å and *c* = 6.8814(5) Å].

Brushite commonly occurs as very fine-grained snow-white coatings of up to 1 cm thick, deposited on hydroxylapatite. The mineral also occurs as subcentimetric spherules enclosed by the detrital-rich sequences from the guano mass. The SEM study shows that, in both cases, randomly oriented clusters of crystals with individuals reaching up to 15 μm in length compose the brushite aggregates. The typical crystals are up to 10 μm long, 5 μm wide and 1 μm thick.

The unit-cell parameters in Table 1 are slightly smaller than those obtained by Beevers (1958) for the synthetic brushite [*a* = 5.812(2) Å, *b* = 15.180(3) Å, *c* = 6.239(2) Å and β = 116.42(2)°], which is probably due to the smaller degree of hydration of our sample.

The infrared absorption spectrum recorded for a representative sample reflects: (1) the non-equivalent position of the structural water (split stretchings at 3540 and 3459 cm^{-1} and 3278 and 3160 cm^{-1} , respectively, and bendings at 1769 and 1649 cm^{-1}); (2) the presence of a hydrogen bond involving HPO₄ groups (stretching at 2926 cm^{-1}); (3) a band multiplicity fitting with a C₃ punctual symmetry of the phosphate groups (PO₄ and HPO₄ stretchings at 1132, 1067, 1004, 985 and 893 cm^{-1} and bendings at 563, 527 și 405 cm^{-1}).

Ardealite occurs as randomly oriented aggregates lining the fractures of the masses of hydroxylapatite and brushite or as overcoats on hydroxylapatite. SEM study shows that these aggregates are composed of irregular platy grains or laths up to 20 μm in length, 5 μm in width and

1 μm thick. The cell parameters in Table 1, refined in the space group *Cc* (Sakae *et al.*, 1978) matches well with those given by Sakae *et al.* (1978) for the synthetic $\text{Ca}_2(\text{HPO}_4)(\text{SO}_4)\cdot 4\text{H}_2\text{O}$ [$a = 5.721(5)$ Å, $b = 30.992(5)$ Å, $c = 6.250(4)$ Å and $\beta = 117.26(6)^\circ$].

Monetite is invariably associated with brushite, which forms porous coatings of re-hydration on brushite + monetite aggregates. The mineral occurs as lath-shaped to flat acicular crystals, in parallel to subparallel aggregates up to 0.1 mm in size, composed by crystals grown together in random orientation. The crystals are flattened on a plane that apparently corresponds to (010). They are typically 10- μm long and 4- μm wide; exceptional individuals reach 15 μm in length.

The unit-cell parameters in Table 1 are in good agreement with those given for the synthetic monetite by Dickens *et al.* (1971) [$a = 6.910(1)$ Å, $b = 6.627(2)$ Å, $c = 6.998(2)$ Å, $\alpha = 96.34(2)^\circ$, $\beta = 103.82(2)^\circ$, $\gamma = 88.33(2)^\circ$].

Taranakite occurs as thick beds of chalky white material with earthy appearance, interbedded with detrital, illite-bearing material. The thickness of individual taranakite-bearing beds ranges from some millimeters to several centimeters. The lateral continuity of these beds is on the scale of few meters. Individual crystals are very fine-grained; their grain size is quite variable, although generally close to 10 μm across. The crystals are typically hexagonal in habit, often truncated and thick tabular on (0001). The unit-cell parameters calculated for a representative sample of taranakite (Table 1) compare favorably with those given by value reported by Dick *et al.* (1998) for the synthetic $\text{K}_3\text{Al}_5(\text{HPO}_4)_6(\text{PO}_4)_2\cdot 18\text{H}_2\text{O}$ [$a = 8.7025(11)$ Å, $c = 95.05(1)$ Å as refined from X-ray powder data]. The infrared spectrum recorded for the sample whose unit-cell parameters are given in Table 1 agrees with the presence, at Gura Ponicevei, of an ammonium-poor taranakite, since the bands attributable to NH_4 basic vibrations (*i.e.*, the ν_3 stretching at 3230 cm^{-1} and the in-plane bendings ν_4' and ν_4 at 1463 and 1432 cm^{-1} , respectively) are weak. In the O-H stretching region, the infrared absorption spectrum shows three bands, whose frequency and width indicate hydrogen-bonded O-H stretching vibrations. They are centered at 3455 , 3017 and 2426 cm^{-1} , respectively. According to the bond distance - frequency correlation of Libowitzky (1999), these frequencies correspond to O-H...O distances of 2.843 Å, 2.653 Å and 2.560 Å, respectively. The H-O-H "scissors" bending of H_2O occurs at 1658 cm^{-1} .

Francoanellite forms a relatively minor constituent of the bat guano deposit. This mineral occurs as stack-like aggregates composed by minute platelets and is commonly admixed with taranakite. The SEM images show that the mineral occurs as strongly intergrown tabular crystals with hexagonal habit, difficult to discriminate from the admixed taranakite crystals. The discrimination between the two phases has been made, however, on the basis of an X-ray powder diffraction pattern that clearly shows lines for which unambiguous indexing was possible as pertaining to francoanellite. The unit-cell parameters refined from these reflections (Table 1) are

smaller than those refined by Smith and Brown (1959) for the synthetic $\text{H}_6\text{K}_3\text{Al}_5(\text{PO}_4)_8 \cdot 13\text{H}_2\text{O}$ ($a = 8.71 \text{ \AA}$ and $c = 82.50 \text{ \AA}$), which accounts for limited $(\text{NH}_4)^+$ -for- K^+ and Fe^{3+} -for-Al substitutions that probably parallel those in taranakite.

Calcite is quite abundant in the guano mass, where calcareous boulders unaffected by the phosphoric solutions are composed by this mineral. The unit-cell parameters in Table 1 are smaller than those given by Effenberger *et al.* (1981) for the stoichiometric calcite [$a = 4.9896(2) \text{ \AA}$ and $c = 17.0610(11) \text{ \AA}$], which probably accounts for the presence at Gura Ponicevei of a magnesian calcite.

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HOLLOW, NON – FIXED HYDROTHERMAL CONCRETIONS – A MINERALOGICAL CURIOSITY FROM THE HERJA – (BAIA MARE) ORE DEPOSIT

MÂRZA I.¹, HALLBAUER D.K.², FORRAY F.¹

¹ Babeş - Bolyai Univ., Fac. of Biology & Geology, Dept. of Mineralogy, M. Kogălniceanu nr. 1,
3400 Cluj-Napoca.

² Faculty of Sciences, Dept. of Geology, Stellenbosch 7600, South Africa.

Abstract: *The present paper describes a new type of concretions for Romania: loose (non-fixed) hydrothermal concretions with a central void, a mineralogenetic curiosity from the Herja (Baia Mare) ore deposit. The wall of the concretions is made up of siderite and includes jamesonite microcrystals. The concretions are 20 - 30 mm in diameter, the sideritic wall is 3 - 5 mm thick and the central void (rich in loose siderite microcrystals) has 15 - 21 mm in diameter. The concretioning was produced in a hydrothermal environment, probably by bubbling in geodes filled with high-density hydrothermal solutions.*

Key words: hollow, non-fixed hydrothermal concretions, Herja (Baia Mare).

General considerations. Numerous recent and older studies exist on the petrography, mineralogy and metallogeny of the Herja ore deposit, of which we mention the investigations of Borcoş et al. (1973), Ghiurcă (1985), Cook & Damian (1997). There is no report of the concretions studied by us in any published source concerning the Herja ore deposit.

The Herja ore deposit presents many mineralogenetic curiosities. Of these we cite some that may be related to our subject. As mineralogical – structural rarities, we mention free calcite spherules, 3 - 5 cm in diameter (without a central void), formed in geodes (not fixed on a mineral support); some are white, some black, and some are curiously half black and half white; the black color is due to jamesonite microinclusions incorporated from the hydrothermal environment where they formed. We also mention jamesonite ring crystals (Ghiurcă, 1985) found in cavities (geodes).

The concretions described in the present paper had been exhibited as ordinary specimens at the Mineral Exhibitions organized by the A.M.P.G.A.R. (Association of Amateur Mineralogists, Paleontologists and Gemmologists of Romania) in 1998 (one collector owned 6-8 specimens); they were named *balls* owing to their spherical shape. Their hydrothermal origin and consequently their scientific importance were noticed by one of the authors (Mârza). At a sudden shaking, one could perceive a noise provoked by some material within the *balls* and so we initially assumed they contained captive hydrothermal original fluids, which would have proven novel and of great

scientific interest¹; however, after cutting them, the material within consisted only of loose or weakly cemented microminerals.

Occurrence. The hydrothermal concretions presented, a great mineralogenetic curiosity, probably were provided by miners working at the Herja ore deposit (Baia Mare) during the 60's - 70's. The association (sulfides-sulfosalts, carbonates, with jamesonite etc) is typical for the vein system from the **Herja Southern Group (Șălan - Clementina)**. The following observation sustains the above facts: the mineral associations from the geodes with carbonates (and not quartz) and jamesonite rings from Herja - examined in specimens from prof. Ghiurcă's personal collection² are similar to the ones described in the present note, including the mineralogenetic conditions; the difference is obviously in the more numerous mineral species from the geodes with jamesonite. We do not possess more precise data on the location of the concretions in the Herja ore deposit.

Morphology. The concretions discussed are spheroidal (Fig. 1, 2); the biggest one measures 31 mm in diameter, and has 3 - 5 mm thickness of the mineral wall and 21 mm diameter of the void. The outer surface is rugged - microcrystalline, marked by microcavities disposed between the microcrystalline aggregates; larger crystals (2 - 3 mm) with rhombohedral shape are evidenced in certain places. Jamesonite microcrystals are observed on the rugged surface, especially in microcavities.

The mineral walls of the concretions have a slightly inconstant thickness (3 - 5 mm; Fig. 1, 2), which implies different feeding periods during their formation. Macroscopically, the wall has a microgranular structure, containing larger isolated rhombohedral crystals with the same mineral composition as the concretion wall. The color of the concretions is light gray with local ferruginous stains resulted from supergene alteration.

The inner part (Fig. 2) is coated by microgranular siderite aggregates, with some larger rhombohedral crystals (1 - 3 mm). Thousands of such translucent rhombohedral microcrystals (0.05 - 0.10 mm), partially showing crystallographic faces, and rare, larger rhombohedrons (up to 2 mm) are loose in the central void (Fig. 1, 3, 4); the noise produced at a sudden shaking, noticed when taking them close to the ear, is provoked by the movement of the loose microcrystals. In some concretions, a part of the microcrystals from the hollow are weakly cemented, resulting spheroidal concretions (Fig. 1, 3).

Numerous fine acicular jamesonite crystals (0.5 - 1 mm length) are caught at the surface of the loose siderite crystals, or are partially englobed inside them. Jamesonite micro-needles were also found in the inner walls, sometimes forming local concentrations clearly seen under the

¹ The price of the balls was initially insignificant. I imprudently shook them close to the ear when the seller was watching; he imitated my gesture; hearing the sound and observing my interest for them, he raised the price tenfold. We thank Dr. Gy. Jakab, who provided two specimens obtained through a sample exchange.

² We also thank Prof. dr. V. Ghiurcă who kindly provided the jamesonite specimens from his personal collection for examination.

binocular. It therefore results that jamesonite deposition and crystallization has integrally joined the siderite concretioning. Accidental gypsum crystals were observed in thin sections, while some sphalerite and marcasite microcrystals (0.5 - 1 mm) associated to the loose microcrystals from the inner void were observed at the binocular microscope.

Mineralogical composition. The carbonate building the concretion wall is slightly effervescent by HCl treatment - observable at the binocular magnifier - resulting a ferruginous precipitate. The microscopic analysis of this resulting part shows: granular aggregates of sideritic composition (cca 95%) and microlamellar gypsum (cca 5%); one can accidentally notice jamesonite fiber-like inclusions (0.0075 – 0.15 mm length) inside the carbonate grains. The X-ray analyzes¹ point to a sideritic composition of both wall and loose carbonate microcrystals (siderite rhombohedrons, Fig. 4) within the central void (table 1).

Table 1. The main XRD values resulted from the analysis of a concretion

Concretion wall		Microcrystals from the internal void	
d (Å)	Intensity	d (Å)	Intensity
2.811	100	2.791	100
2.300	20	2.124	20
1.967	20	1.951	20
1.873	12	1.788	12
1.726	35	1.726	35
1.424	11	1.425	11
1.350	11	1.432	11

The crystallization succession of the loose microcrystals within the concretion is siderite, jamesonite, sfalerite, marcasite and gypsum.

Discussion. We name *free (non-fixed) hydrothermal concretions*, the balls analysed - coming from the Herja, Baia Mare hydrothermal ore deposit (with LS - type mineralizations). The genesis of these concretions is interesting, and a possible explanation could be the following: they could form in a small basin filled with hydrothermal solutions, probably in a larger geode. The concretioning started and probably continued by means of a bubbling process under the effect of high-density hydrothermal solutions rich in gaseous phase, circulating on fissures, feeding the geode and simultaneously producing the gas bubbles assuring the flotability of the concretions. In such conditions, the concretions could individually develop through continuous - discontinuous movements in a hydrothermal environment. Once they reached a weight that no longer allowed flotability (the examined weight varies between 23 and 25 g), they deposited at the bottom of the geode pool. The process could possibly begin around large gas bubbles formed during the bubbling

¹ We express our gratitude to Dr. Toth Aniko and Prof. Dr. Lucretia Ghergari, who kindly performed the roentgen analysis of the samples.

process. The hydrothermal solutions consisted of an aqueous component rich in disperse (mineral) phase of a sludge type (muddy, turbid); its composition was mainly carbonatic (CO_3^{2-} , Fe), and subordinately sulfidic (S^{2-} , Fe, Sb, Pb, Zn) and sulphatic (SO_4^{2-} , Ca). The chemistry of the hydrothermal solutions determined the formation of the mineral association of the wall (siderite, gypsum, jamesonite) and of the microcrystals from the inner void (siderite, jamesonite, sphalerite, marcasite, gypsum); the mentioned order also indicates the crystallization order of both associations.

The loose microcrystals within the hydrothermal concretions (siderite, jamesonite, sphalerite, marcasite, gypsum) had crystallized from the original hydrothermal solution confined within the concretion, after the formation of the outside wall. At least two distinct paragenetic types developed in the geodes within the jamesonitic ores from Herja: one rich in quartz microcrystals (loose, sub-millimetric crystals with both terminations visible), common sulphides and jamesonite (including jamesonite rings, first described by Ghiurcă, 1985), and another formed in a carbonatic environment (without quartz), poor in sulphides, including jamesonite (lacking jamesonite rings); the hydrothermal concretions described by us belong to this second type.

Spherules somewhat comparable as genesis mechanism with the ones described are also mentioned from the speleal environment: calcite or aragonite *cave bubbles*, respectively hollow spheres (1 – 5 mm in diameter), with a smooth or rugged surface, generated in karstic conditions, in small water pools, covering air bubbles formed in the pool (Hill & Forti, 1997).

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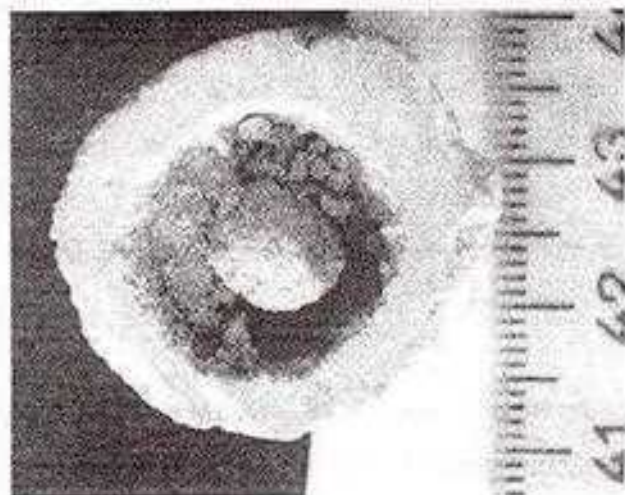


Fig. 1 - Hydrothermal concretion (cross-section). The zoned structure of the concretion wall and the mineral content of the central void are slightly visible.

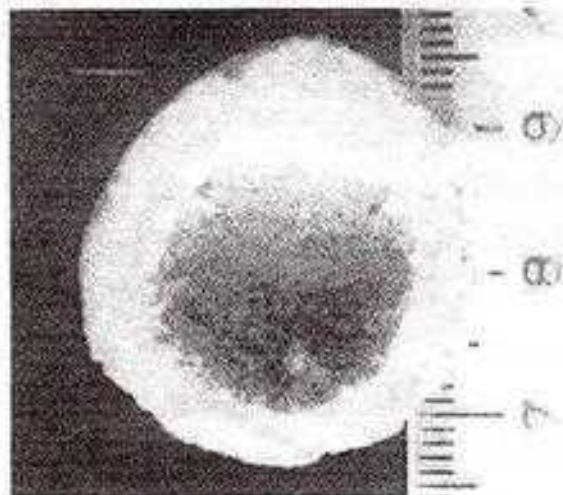


Fig. 2 - A hemisphere of a hydrothermal concretion with the internal microcrystals removed (by the author). Relatively large siderite crystals (about 2 mm) develop locally on the internal wall

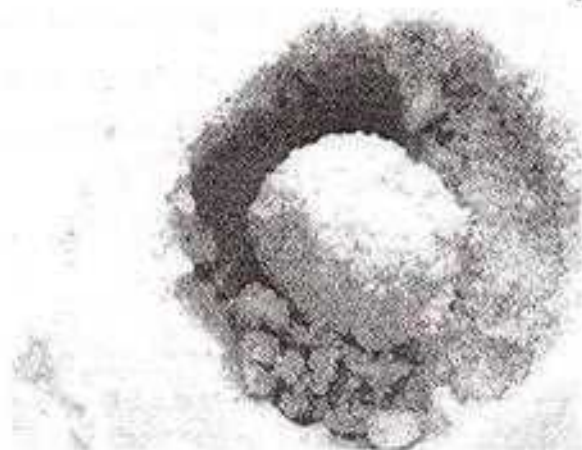


Fig. 3 - General view of the mineral content within the internal void of a concretion. In the center, among loose microcrystals, a sphere (about 8 mm diameter) resulted by cementation ("agglutination") is visible.



Fig. 4 - Rhombohedral siderite microcrystals from the internal void of the concretion (ranging between 0.1 - 2 mm)

PETROMETALLOGENIC UNITS RELATED TO MAGMATIC DOMAIN-DISTINGUISHING CRITERIA

MARZA¹ Ioan, KOVACS² Marinel

¹ Babes Bolyai University, 3400 Cluj Napoca, 11, Avram Iancu str., e-mail: ioanmarza@personal.ro

² North University Baia Mare, 4800 Baia Mare, 62/A, Victor Babes str., e-mail: marinelkovacs@yahoo.com

1. Introduction. The lack of a single and unanimously accepted opinion regarding the systematics of metallogenic-petrometallogenic units and their identification led in time to regrettable inconsistencies. Initially, the metallogenic units and subunits based on economic criteria and on the spatial (geographical) distribution of ores have been taken into account. Later on, new criteria based on geological elements have been involved (according to Launay, de L., 1913; Emmons, 1913; Lindgren, 1933; Bateman, 1956; Petraschek, 1965 and many others).

The introduction of the petrometallogenic concept in the study of ore deposits (Abdullaev, 1954; Mărza, 1990, 1995, 1999) has represented an important moment in understanding the genesis of the ores, specially based on global tectonics. In his papers, Mărza promotes a new view on the petrogen-metallogen concepts, based on an inseparable process developed in all the geological environments (magmatic, metamorphic, exogeneous). Considering the magmatic metallogenesis as inseparable from petrogenesis, it is rather more correct to take into account the petrometallogenic units and subunits than the metallogenic ones.

The paper approaches the criteria necessary in distinguishing the petrometallogenic units and subunits from the magmatic field, specially those from the mobile areas (rift and subduction). These units and subunits are briefly characterized as well, with examples from Romania.

2. Distinguishing criteria of the petrometallogenic units. In order to define criteria to distinguish the petrometallogenic units it is difficult to identify the stages of the evolution of the spatial units (provinces) and their correlation with petrometallogenic epochs (as geochronologic, temporal sequences). The specificity of the time and space evolution of magmatogenic geostructures (mobile and anorogene), expressed by its products-rocks and mineralizations-different as amount and quality, determines the split of units into metallogenic-petrometallogenic subunits. Some of the resulted criteria are as follows in the systematics of petrometallogenic units.

- a. **The geostructure (type of geostructure)** represents the tectostructural element, the basic criterium in petrometallogenic systematics. Based on this criterium, the major petrometallogenic units, the petrometallogenic belts and provinces respectively, may be defined.

- b. **The stages/substages of the temporal and spatial evolution of the geostructures** form another criterium in order to identifying petrometallogenic subunits.
- c. **The homogeneous petrogene-metallogene character** of the geostructural units and subunits in a certain stage of temporal and spatial evolution. Based on this criterium, magmatic petrotypes, metallogenic phases, types of mineralizations (veins, metasomatic bodies, endogeneous breccias, etc), geochemical systems (LS and HS), geochemical associations (major and minor elements), mineral paragenesis, ore structures and textures, metal sources and thermobaric regime have been defined. The petrogene and metallogene indices of a specific area facilitate the assesement and the identification of the petrometallogene units. Multiphase products from a structural unit/subunit disturb this process of understanding but identifying the magmatic evolution and the cogenetic metallogenesis is the best way leading to a correct interpretation.
- d. **Comparative criterium** (resulted from the above mentioned) consists of a permanent comparative analysis of petrogene-metallogene parameters of the investigated structures, outlining isopetrometallogene surfaces with different positions within the geostructures.
- e. **The spatial criterium** (area of development) is an undeterminant factor which sometimes needs to be taken into account.

3. Petrometallogenic units related to the magmatic domain from mobile zones. The magmatic field from mobile areas consists of a typical gradational succession of petrometallogene units: belts, provinces, subprovinces, districts, fields, ore deposits and ore bodies as follows.

The petrometallogenic belts correspond to the largest structural-petrometallogenic (magmatogenic) units, superimposed over the limits of the plates in different stages of evolution. They are liniar structures with compressive character (subduction zones, eg. the Alpine-Carpathian structure) or expansive character (rifts, eg. East-African Rift). Petrometallogenesis is correlated with the type of geostructure, generating predominantly intermediary magmatites in subduction areas (with complex and gold-silver mineralizations) and basic magmatites in rift areas (with Cr, Fe, Ti, etc. orthomagmatic mineralizations and volcanogenic-sedimentary ones).

The petrometallogenic provinces are units subordinated to belts, more or less incorporated into belts. They correspond to continental and subcontinental megastructures (frequently up to 1000 km size) and consist of a relative homogeneous (monocyclic, rarely expressed) and heterogeneous (polycyclic, frequently expressed) petrometallogenesis. The mobile megastructures (subductive, riftogene) corresponding to provinces may develop into a relative short period of geological time, having a less differentiated petrometallogenesis or may develop in a succession of

stages covering a longer time interval and leading to segments of different petrometallogenesis, outlining subprovinces, districts, etc.

The province represents the basic unit in petrometallogene systematics, independent of the endogeneous or exogeneous field; the magmatogene provinces or the tectostrutural frame is tightly correlated with the petrogenic-metallogenic epochs. The petrometallogene provinces are spatial geostructural units with a structogene evolution, specific magmatism and metallogeny. The petrometallogene epochs are geochronologic sequences of petrometallogene evolution.

The petrometallogenetic subprovinces are subordinate units, counterparts of provinces with specific features not necessarily outlined as separated in the systematics.

The petrometallogenic districts correspond to mezostructures (regional structures) which are subordinated to provinces/subprovinces or may form independent structures developed on areas not more than 100 km. Districts have homogeneous characters in most of the cases (eg. Brad-Sacaramb, Stanija-Zlatna, etc., Au-Ag +/- Te, veins and breccia pipe structures), with differences own to polycyclicality or stage evolution (eg. Oas, Baia Mare districts with complex-Pb, Zn, Cu and Au-Ag).

The petrometallogenic fields are districtual subunits (not more than tens of kilometers size, around 30 km the most well developed ones); they may be identified within some of the districts, based on specific characters or may be isolated, without any connections with the districts, with a monocyclic petrometallogeny (eg. Rodna petrometallogenic field with base metal mineralizations associated to Neogene magmatic rocks).

The ore deposits, composed of several or a single ore body (eg. porphyry copper structures, Fe, Cr, Ti orthomagmatic stratabound bodies), are locally developed, reflecting the general features of a major geostructure they belong to. Their sizes differ very much, from very large to very small ore deposits (Laznicka, 1999; Marza, 1999).

The hydrothermal ore deposits associated to the Neogene magmatism from Baia Mare region may be considered as belonging to well outlined petrometallogenic units and subunits in accordance with the above mentioned criteria. These units may be defined as follows:

The Tertiary petrometallogenic province of the Carpathians, as a major unit corresponding to the geostructures represented by the subduction area from the European Plate margin. Calc-alkaline magmatic rocks related to the Miocene subduction are associated with typical Au-Ag and base metal epithermal and subordinate porphyry copper mineralizations.

The petrometallogenic subunit including Baia Mare ore deposits may be defined as the **Eastern Carpathians Neogene petrometallogenic subprovince** corresponding to the Neogene volcanic chain and associated mineralizations represented by Slansky-Vihorlat-Gutai-Beregovo-Oas-Gutai-Calimani-Gurghiu-Harghita Mts. Magmatic rocks are predominant andesites belonging to

the intermediate arc-type volcanism with typical epithermal mineralizations (less in Calimani-Gurghiu-Harghita Mts.).

The Neogene petrometallogenic subprovince of the Eastern Carpathians consists of several **districts** among which Beregovo-Oas (Turt) and Baia Mare are including the epithermal ore deposits from Oas Mts. and Gutai Mts., respectively. **Beregovo-Oas petrometallogenic district** includes the Neogene magmatic rocks from Transcarpatia (Gutin Range and Beregovo) and Oas Mts. with similar volcanological and petrological features. Most of the volcanic structures are represented by extrusive domes of acide and intermediate composition (Kovacs, Fulop, 2002). Mineralizations are epithermal base metal + Au-Ag and some of them Hg as well.

Baia Mare petrometallogenic district includes the Neogene magmatites and associated epithermal mineralizations from Gutai Mts. The mineralizations consist of typical low-sulfidation, related intrusions, predominant vein-hosted polymetallic and gold-rich epithermal deposits (Kovacs, 2001). The hydrothermal alterations are predominant adularia-sericite type.

The spatial distribution of the ore deposits within Baia Mare district is determined by the structural/tectonic control of the Carlibaba-Carei (Dragos Voda/Bogdan Voda) transcrustal fault from the southern part of Gutai Mts.

Three **petrometallogenic fields** may be outlined as subunits of the Baia Mare district, with spatial distribution and distinctive features: Ilba-Nistru, Sasar-Dealul Crucii, Herja-Baiut. Sasar-Dealul Crucii petrometallogenic field represents a typical low-sulfidation gold epithermal system and Ilba-Nistru and Herja-Baiut fields include low-sulfidation base metal+/- gold, copper epithermal deposits.

The ore deposits, as subunits of the petrometallogenic fields, have generally been identified based on their distinctive peculiarities. Each one of them may be more or less consistent with the types of epithermal ore deposits defined by Leach and Corbett (1996). Sasar ore deposit is therefore a typical quartz, gold-silver low-sulfidation epithermal deposit and Cavnice ore deposit represents a typical carbonate base-metal gold related intrusions epithermal deposit.

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THE PERPHOSPHOROUS LEUCOGRANITES OF THE MINAS GERAIS STATE, BRAZIL

Fernando Machado MELLO¹, Essaid BILAL²

1- Departamento de Geociências - IA - Universidade Federal Rural do Rio de Janeiro, BR 465, Km 7-
Seropédica-RJ, CEP 23851-970 – Brésil, fermam11@ufrrj.br.

2- CNRS-UMR6425, Département GÉNERIC, Ecole Nationale Supérieure des Mines de Saint-Etienne, 158,
Cours Fauriel, 42023 Cedex 2, Saint-Etienne, France. bilal@emse.fr.

Geological setting :

The Rio Doce region is located in the central northern part of the Mantiqueira Structural Province, east of São Francisco Craton in the eastern Minas Gerais and north-western Espírito Santo states. This province is represented by Neoproterozoic mobile belts that surrounded the São Francisco cratonic block and is associated to the Brazilian orogeny (600 - 450 Ma). These mobile belts reworked the early-Proterozoic basement (high and low-grade metamorphic rocks of Piedade, Paraíba do Sul and Pocrane Complexes; Juiz de Fora, late-Proterozoic supracrustal sequences (Rio Doce group) and enabled the intrusion of granitoid plutons and pegmatite's. Several rare metals and gem mineral rich pegmatite's are positioned at the São Tomé foliation plane.

The regional evolution was linked to the Governador-North Guaçu- and Vitoria shear zones. Two main deformation phases (D1 and D2) pre-and post-dating the pluton emplacement and were developed under amphibolite facies conditions. The first deformation (D1) was responsible for penetrative foliation (solid state) N10°-30°W/middle to high angle and mineral lineation of the host rocks and the granitoids. It affected pre-tectonic granites and controlled magmatic foliation the syn-tectonic granitoids. This foliation, the associated oblique lineations and kinematics studies suggest that subvertical shear zones were important during the emplacement of these granitoids. The second one was characterized by the cleavage crenulation, boudinage and normal faults and it was associated to extensive phase late- and post-tectonic granitoids. The recent geochronology study demonstrate existence of two tectono-metamorphic events in this region dated at 590-565 Ma and 535-520 Ma.

Perphosphorous leucogranites:

We study many little leucogranites body linked to the pegmatites localised in south of Teófilo Otoni city. They are controlled by a previous main compressive deformation phase D1. The ten individual zircon crystals within leucogranites are dating 579 ± 5 Ma. The very Sr-enriched and Nd-depleted initial ratios ($0.782 \leq \text{Sr}^{87}/\text{Sr}^{86}_{(i)} \leq 0.823$ and $-8.2 \leq \text{Nd}_{(600)} \leq 7.4$) must be related to an

important role of a crustal source. They are linked with Urucum granite suite in Governador Gallilea region.

The syn-tectonic magmatic series are related to crustal melting produced by decompression and thermal relaxation (550-700°C and 4-5 kbar).

These perphosphorous leucogranites display porphyritic textures and are characterized by the presence of apatite phenocrystal (2cm) and P-rich feldspars. The Plagioclase feldspar in leucogranites varies from An₅₀ to An₂₅ composition and found phosphorus values between 1.0 and 2.5 wt % P₂O₅. Apatite in the leucogranites show two groups based on chemistry and occurrence: the phenocrystal apatite enriched in Mn disseminated within the leucogranites and the small apatite disseminated within plagioclase feldspar where Mn-depleted.

They are highly peraluminous (1.07<ASI<1.38) and, from the porphyritic granites to the aplopegmatitic facies. Their P₂O₅ (0.28 to 1.06 wt%) decrease with SiO₂ increase 72 up to 75wt%. Very high concentrations of P₂O₅ in silicic per-aluminous granites are symptomatic of strong differentiation. In a same way, a decrease of major elements (CaO, Fe₂O₃, MgO, TiO₂) and of trace elements (Zn, V, Sc, Co, Cr, Ni, REE) is observed from the Medena Megmatites, Urucum granites suite to the aplopegmatites. The MgO/TiO₂ ratio nears 3, which may be compared to the typical granites of crustal origin.

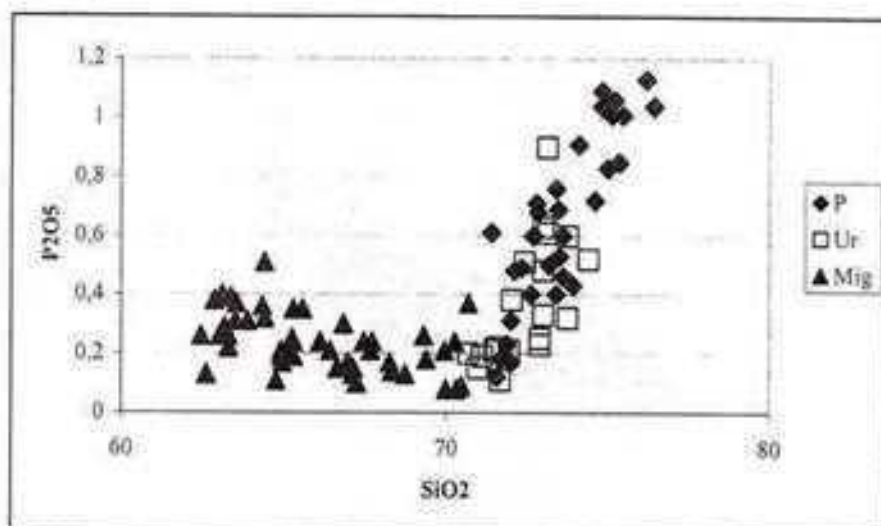


Figure 1: P₂O₅ versus SiO₂ diagram of perphosphorous leucogranites (P), Urucum suite (Ur) and Medena migmatites (Mig) from Minas Gerais state (Brazil).

The perphosphorous leucogranites are linked with Urucum granite suite and migmatites suites in eastern of Minas Gerais state. The plots of P₂O₅ versus SiO₂ show a regular variation the P₂O₅ in the granite decreases at SiO₂ (72%) from this point onwards P₂O₅ increases.

Mineralogically these perphosphorous leucogranites and pegmatites are characterized by the presence of rare phosphates (amblygonite, triphyllite, triplite, brazilianite). The trend is related to

the later stages of magmatic differentiation. The P_2O_5 is concentrated in the late magmatic stage with Rb, Li and shows a negative correlation with CaO. The Ca activity may be influenced the apatite solubility.

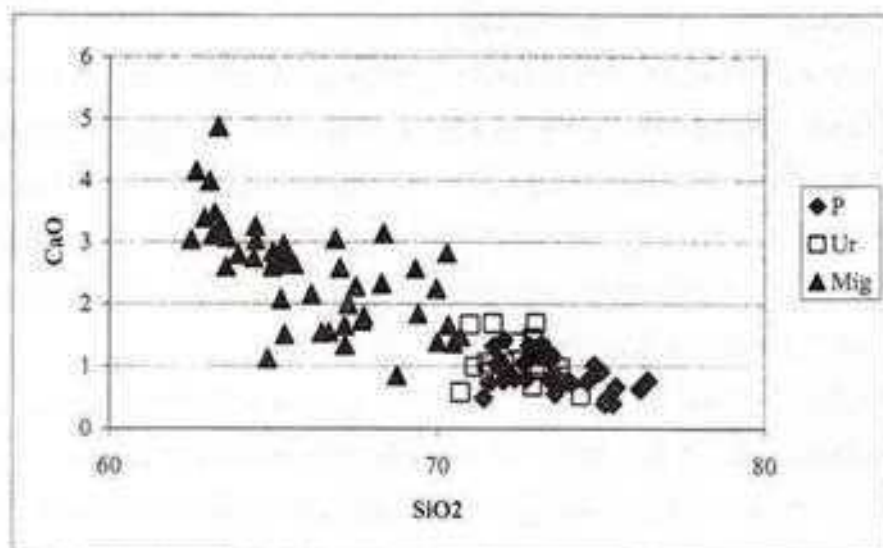


Figure 2: CaO versus SiO_2 diagram of perphosphorous leucogranites (P), Urucum suite (Ur) and Medena migmatites (Mig) from Minas Gerais state (Brazil).

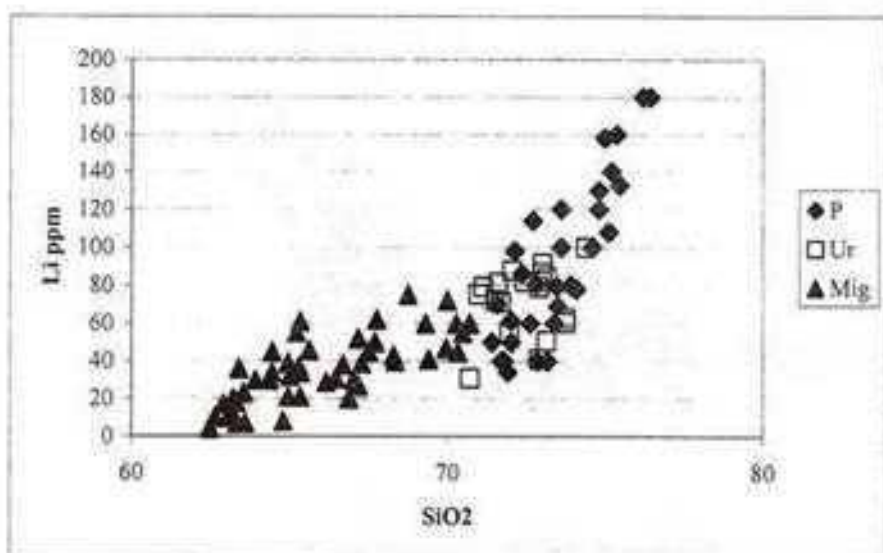


Figure 3: Li versus SiO_2 diagram of perphosphorous leucogranites (P), Urucum suite (Ur) and Medena migmatites (Mig) from Minas Gerais state (Brazil).

However, the Medena migmatites trend seems to be compatible with the presence of restitic apatite. We observed in biotite restitic the small apatite and zircon inclusions. The phosphorus enrichment would be associated to restite unmixing during the segregation of anatectic melt. The P_2O_5 behaviour in the granitoids suites from Minas Gerais state must be related to two important factors : the inheritance of apatite in crustal melt and the later stages of magmatic differentiation.

SUBALKALINE AIMORÉS MASSIF, MINAS GERAIS - BRAZIL

Fernando Machado MELLO¹, Essaïd BILAL², Romulo MACHADO³, Jacques MOUTTE²

1- Departamento de Geociências - IA - Universidade Federal Rural do Rio de Janeiro, BR 465, Km 7 - Seropédica-RJ, CEP 23851-970 - Brésil, fermamilo@ufrrj.br.

2- CNRS-UMR6425, Département GÉNERIC, Ecole Nationale Supérieure des Mines de Saint-Etienne, 158, Cours Fauriel, 42023 Cedex 2, Saint-Etienne, France, bilal@emse.fr and moutte@emse.fr.

3- Instituto de Geociências - Universidade de São Paulo, Rua do Lago, 52-Cidade Universitária - São Paulo-SP - CEP 05508-900 - Brésil

Geological Setting: The Aimorés massif occurs at Aimorés city, 570 km northeast of Belo Horizonte, capital of the Minas Gerais State (Brazil). It is located in the northern region of the Paraíba do Sul Belt. It is intrusif in the Paleoproterozoic granulite Juiz de Fora and Pocrane Complexes and also in ortho- and paragneisses of the Paraíba do Sul Complex. This last unit had an important isotopic remobilisation during the Brasiliano Orogeny. The large Aimorés body has an almost perfect circular geometry of 12 km de diameter resembling a perfect impact crater. The high angle contacts with the country rocks are tectonics, diffuse and dips to inner parts of the intrusion. From the center to the borders we discriminate: one pyroxene monzodiorite; one porphyritic charnockite that forms a discontinuous ring and a porphyritic granite which forms the borders of the massif. There is outcrops of titanite monzodiorite southeast of the massif. Mecanic mixture of the charnockite and monzodiorite or charnockite with porphyritic granite are observed. The facies shows interpenetrating contacts that suggests contemporaneity emplacement. All this facies have enclaves of variable composition (tonalitic, granodioritic or granitic), sometimes with dozen meters mega enclaves in Hy-monzodiorite). One garnet granite, the latter pulse intrusion, with little volume, is intrusif in the monzodiorite and in the porphyritic granite. In general, the magmatic texture of all rocks are preserved from the weathering and shows some solid state deformations features.

Petrography: *The Hypersthene-Monzodiorite (HMD)* has an inequigranular porphyritic texture (locally feldspar megacrysts 4cm long). Main mineral phases are 50% plagioclase andesine (An_{35-41}) in matrix and An_{37-41} for the megacrysts, rarely labradorite), 15% de pyroxene (essentially ferrosilites and little augite), 8% of quartz, 5% of amphibole (ferro-pargasite), 5% of biotite (annite) and 12% of K-feldspar (perthite and mesoperthite). The accessory minerals (5% of total volume) are zircon, apatite, magnetite and ilmenite. Plagioclases are variable in size (0.25mm to 1cm in matrix and 4cm maximum for megacrysts) and have pyroxene, apatite, zircon and oxydes inclusions. The ferrosilites are sometimes replaced by amphibole and/or biotite. *The titanite quartz-monzodiorite (TQM)* is an

essentially medium to fine grained unit. Its distinguished from the monzodiorite by the missing pyroxene and has 15% of K-feldspath and titanite (5% of total rock volume), by the increasing proportions of 10% amphibole (ferro-pargasite) and 10% biotite (annite), and decreasing proportions of plagioclase (45%). The accessory minerals are zircon, apatite, magnetite and ilmenite. *The charnockite (HG)* (hypersthene-granite) shows a porphyritic texture and coarse crystals. Main phases are 10% of pyroxenes (orthopyroxene and minor clinopyroxene), 32% of plagioclase (An_{27-33}), 23% of K-feldspar, 20% of quartz, 7% of biotite (annite), 5% of amphibole (ferro-pargasite) and 3% of accessory minerals (zircon, apatite, magnetite and ilmenite). *The porphyritic granite (PG)* has a similar textures to those of charnockite but it is distinguished by the of main mineral phases: 35% of K-feldspar, 25% of plagioclase (An_{24-30} in matrix and An_{23-31} for megacrysts), 25% of quartz, 5% of amphibole, 7% of biotite and has 3% accessory minerals. *The garnet-granite (GG)* is coarse grained leucogranite locally a medium- to fine grained rock. It has an garnet of almandin composition (3%), 23% of plagioclase (An_{22-24}), 45% of perthitic microcline (in the matrix as little crystals or megacrysts), 27% of quartz and 2% of biotite. The accessory minerals are apatite, zircon, monazite, ilmenite and magnetite.

The biotites of different facies are true biotites ($X_{Fe} > 1/3$) and have annite composition. The X_{Fe} ratio ($100 \times Fe/(Fe+Mg)$) of this biotites changes from one facies to another, from 59 to 62 in monzodiorites and mega enclaves, from 75 to 76 in charnockite, from 75 to 79 in granite porphyritic. This X_{Fe} ratio exceed 40 to 70 in biotites from garnet granite. The Al_2O_3 , FeO and MgO contents of biotites from monzodiorites, charnockite and granites are comparables with those from biotites of ferro-potassics subalkalines granitoids. In the other hand, biotites from GG are aluminous and their compositions are close to the biotites of aluminous-potassic granites of the Guéret Massif (Massif Central, France). The pyroxenes (augite and ferrosilite) shows a positive correlation between the Al_2O_3 and MgO contents, from monzodiorites to charnockites. The pyroxenes from monzodiorite are richer in Al_2O_3 : 0.95% to 0.5% in orthopyroxenes, and 1.35% to 1% in clinopyroxenes. The geothermometer cpx-opx, furnishes 876°C for pyroxenes cristallisation temperatures (monzodiorites) and 860°C for charnockites. The amphiboles of the differents facies are calcics and have ferro-pargasite composition. The X_{Fe} ratio and the alkalines (Na_2O and K_2O) contents of the amphiboles increases from HMG to PG and shows a continuous evolution between that facies. This amphiboles were, according to the geobarometer method of Schmidt (1992), crystallized under pressions of 6 ± 0.4 Kbar. The zircons are characterized by high HfO_2 contents, from 0.71% to 1.65%, the majority of this contents higher than 1.3% of HfO_2 . This values are signs of strong crustal contribution.

Geochemistry: The different facies of the Aimorés pluton are metaluminous, except for the large enclaves LE embedded in the HMD and GG, that have peraluminous character. The aluminium saturation index ($ASI = \text{molar } Al_2O_3 / (CaO + Na_2O + K_2O)$) is about 1 and algaicity index $((Na+K)/Al)$ is ranging from 0.45 to 0.77. They arrive at alumine saturation ($ACNK=1$) for MgO contents of 0.8%. This evolution is comparable to that observed in sub-alkaline stanniferous granitoids from Goiás State, Brazil, to the anorogenic granitoids from the southwest United States, to the Várzea Alegre Massif, Brazil in the south of the studied massif, and also from the alkaline massif of Air in Nigeria. The sum of the alkalis ($Na_2O + K_2O$) increase from 5% to 10% with increasing contents of silica. The negative correlation of Al_2O_3 , Na_2O and CaO in relation to silica can explain plagioclase fractioning. The MgO/TiO_2 ratio nearby 1 is common in post-collisional granitoids.

The Ba/Sr and Zn/MgO ratios and also Sr/Rb , Ba/Rb , and Sc/MgO indicate an important role in the mineral phases differentiation history of this granitoids, from the pyroxene and plagioclase first and amphibole, biotite and K-feldspar on final phases. The sum ($Zr+Nb+Ce+Y$) of this granitoids, ranging from 500 ppm to 1000 ppm, is comparable to post-collisional granitoids. The LE, country rocks and also the GG have a composition close to those from orogenic granites.

Discussion and conclusion: The geometry of the Aimorés Massif units include high dipping magmatic foliations to the inner parts of the massif. The entire body represents a root level of a K-rich hy-granitoid pluton. The emplacement was at 6 ± 0.4 kbars under temperatures higher than $870^\circ C$. Petrographycs and geochemical data shows sub-alkaline character of the different facies. This Hy-granitoids are metaluminous to weakly peraluminous. They show high K_2O , Rb and Ba contents and low Th in relation with comparable ferro-potassic late to post-collisional granites of the Hercynic Ridge in Europe, but similars with charnockites from the border of the Várzea Alegre Massif, in the Espírito Santo State (Brazil). The large enclaves inside the Hy-monzodiorite unit have an tonalitic-granodioritic composition that are similar to those from the pre-collisional granitoids (suite Galiléia) in the region. These granitoids are believed to involve mantle and crust-derived components and they are indubtelly of mixed origin. The Aimorés Massif a part of a group that build the later portions of the Brasileiro mountain chain in its late- to post-orogenic stage, beggining its firsts emplacement injections in the transition from the compressive to extensive orogenic phase. This was marked by the exhumation of the nearby high grade country rocks of the Juiz de Fora and Paraíba do Sul Complexes.

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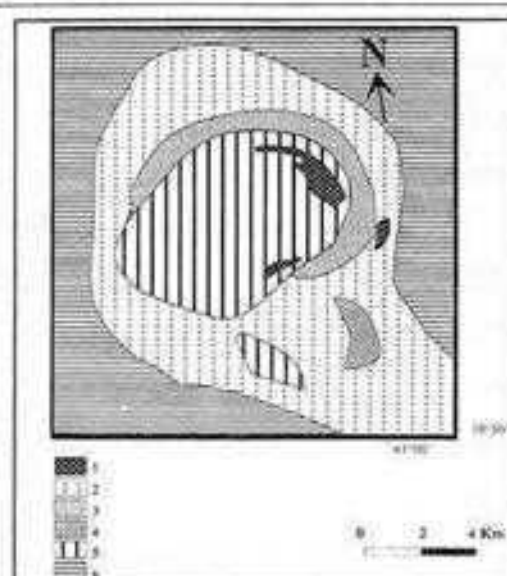


Figure 1 – Geological sketch map of the Aimorés Massif. 1- Garnet-Granite (GG); 2- Porphyritic-Granite (PG); 3- Charnockite (HG); 4- Titanite-quartz-monzodiorite (TQM); 5- Hypersthene-Monzodiorite (HM); 6- Gnaissic-granitic-granulitic basement.

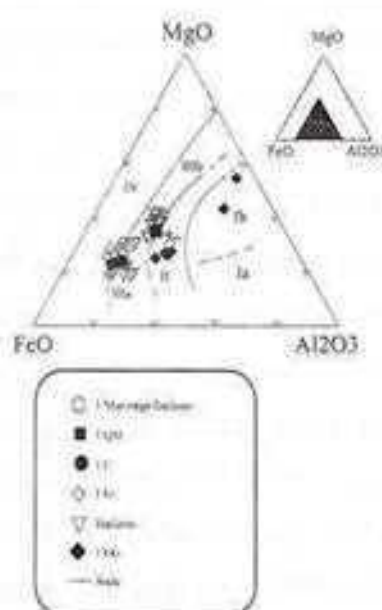


Figure 2 – Plots of biotites compositions from the different facies of the Aimorés Massif in FeO, MgO, Al₂O₃ diagram. Ia : Aluminium-Potassium Serie from Limousin; Ib : Aluminium-Potassium Guéret type; II : Calc-alkaline Serie Corse; III : Série Subalkaline Serie with: ferro-potassic and b: magnesium-potassium; IV : Alkaline Serie.

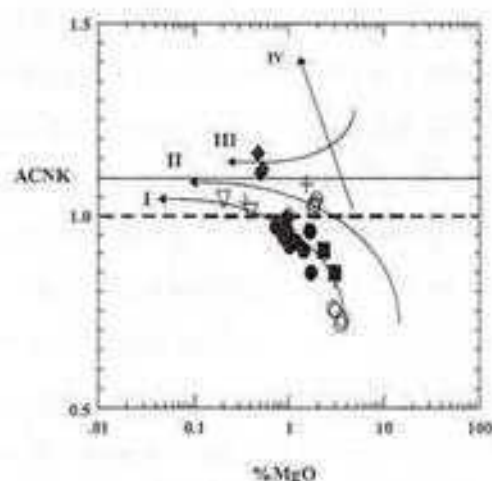


Figure 3- Plots of the different facies of the massif de Aimorés in the diagram MgO versus ACNK ($ACNK = Al_2O_3 / (CaO + Na_2O + K_2O)$ in moles). I : subalkalines to alkalines suites; II : calc-alkaline suite from Meruya batholite of Lachlan Fold Belt, Australia; III : S type suite of de Kosciusko massif, Lachlan Fold Belt, Australia and IV : Magnesium-potassic suite

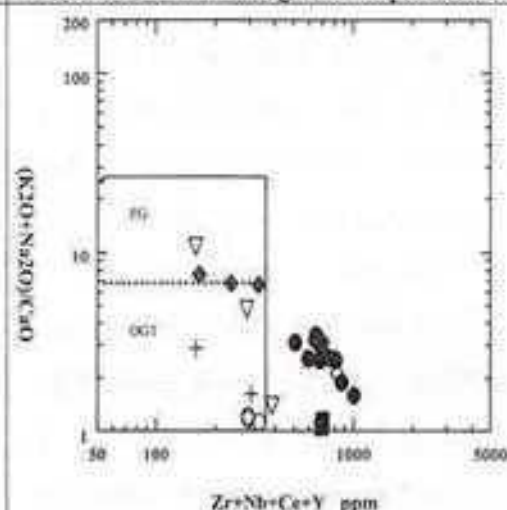


Figure 4 – Plot of trace elements in the diagram Zr+Nb+Ce+Y versus (K₂O+Na₂O)/CaO : orogenic granites and FG : fractionated granite.

A NEW STYLE OF MINERALISATION IDENTIFIED AT ROSIA MONTANA

A. MINUT¹, S. LEARY², C. SZENTESY¹, G. O'CONNOR¹

¹S.C. Rosia Montana Gold Corporation S.A., 321, Piata Str., Rosia Montana, Alba County, Romania,

adrian.minut@rmgc.ro, cecilia.szentesy@rmgc.ro, gary.oconnor@rmgc.ro,

²Resource Service Group-Global, Perth, Australia, steve.leary@rsgglobal.com.

The Rosia Montana gold-silver deposit is considered to be a maar-diatreme complex of Neogene age characterized by a wide variety of breccias which include phreatomagmatic, hydrothermal, tectonic and sub-aqueous reworked varieties. This complex have been intruded by two dacite porphyry sub-volcanic intrusives. Adjacent to and beneath the dacite dome and associated phreato-magmatic breccia complexes occur Cretaceous sediments, which are dominantly comprised of shales with subordinate sandstones and conglomerates.

The mineralisation at Rosia Montana is dominantly disseminated, with associated stockwork, mineralised breccias and veins and is interpreted to represent a low sulphidation epithermal sistem. The hosts lithologies for gold-silver mineralisation are represented by dacite and dacite breccia, phreatomagmatic breccia, reworked "vent" breccia, polymictic breccia pipes and cretaceous sediments. Gold has been identified mainly as electrum and occurs as free gold and as inclusions in pyrite, intergrown with, and overgrown Ag-sulphosalts, base metals, tellurides or carbonate and barite.

Recent structural and geological re-interpretation of the geology at Rosia Montana through the re-logging of drill core and detailed geological and structural field mapping has confirmed the existence of significant zones of gold and silver mineralization within the host sediments. This mineralisation has been identified at Igre, Gauri, Cos and East Carnic.

The mineralisation is characterized by the presence of a number of quartz-carbonate veins and hydrothermal crackle breccias with zones of more intense mosaic (jigsaw) brecciation within the sediments beneath and adjacent to the vent breccia-sediments contact. Clasts are always very angular and are made up of locally derived sediments. Veins and breccia matrix are usually vuggy, sometimes with a colloform banded texture. Mineralization is dominated by carbonate (calcite and secondary rhodocrosite), quartz and pyrite subordinate galena and sphalerite and rare chalcopyrite. Importantly, mineralization is interpreted to have occurred due to the boiling of hydrothermal fluids, along

structures cutting through the sediments and not via the diatreme complex as previously interpreted. As the importance of these zones was previously not recognized, a number of drill holes were stopped within zones of higher grade mineralization. The sediment hosted zones of mineralization have been located within the Tarina-Igre area as well as the Cetate-Gauri area of Rosia Montana and have excellent exploration potential.

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BORON OF QUARTZ AS GENETIC AND METALLOGENETIC INDICATOR

MURARIU Titus

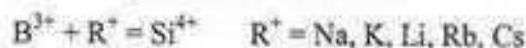
"Al. I. Cuza" University of Iași, Blvd. Carol I 20A, e-mail: murariu@uaic.ro

Boron is a widespread constituent of crustal rocks, being found in sedimentary, volcanic, plutonic and metamorphic environments. The Earth's upper continental crust (average of 15 ppm B) is highly enriched in boron relative to the primitive mantle, which is inferred to have had 0,6 ppm B.

Boron (atomic number 5) is the only non-metal in Group III of the periodic table and has many similarities to silicon and carbon.

The boron content of most minerals varies over a wide range. If the amount of boron available during the crystallization of major minerals is too low to allow the formation of independent boron minerals such as tourmaline, boron will replace major and minor elements in their minerals. The most important rock-forming minerals containing trace amounts of boron are micas.

The boron content of quartz range from 0,0 to 25 ppm (Stavrov and Khitrov, 1960). The presence of B in the crystal structure of quartz is the result of the following isomorphous substitution:



In the structure of quartz, boron forms $[BO_4]^{4-}$ tetraedra and $[BO_3]^{3-}$ groups or boron replaces silica in the $[SiO_4]^{4-}$ tetraedra. The boron occurs and in the gas-liquid inclusions in quartz.

The present geochemical data from the literature and those obtained by us reveal the possibility of using the boron of quartz as genetic and metallogenetic indicator (Table 1).

Boron is an element accumulated in the late stages of magmatic crystallization.

The boron of quartz from different types granitoids (Lyakhovich, 1973) is higher for quartz of leucogranites and alaskites ($x = 11,5$ ppm) and lower for quartz from granodiorites ($x = 4,0$ ppm). In the quartz of mineralised granitoids (Sn, W, Mo, Li etc), the content of boron is high compared with low values of quartz of barren granitoids (Table 1).

Table 1. Boron in the quartz*

Location	Rock type	B (ppm)
Average	Granitoids	6,3
	Granodiorites	4,0
	Biotite granites	6,3
	Leucogranites and alaskites	11,5
Saian	Fertile granites	16,0
Siberia		30,0
Bavaria	Granitoids	1,9
Transbaikalia		8,0
Saian		6,0
Altai		5,3
Ural		7,8
Caucas		7,4
Kazakhstan		4,5
Average		10,0
Răzoare (PPS)	Granite pegmatites	17,5
Rebra Valley (RPS)		20,0
Iara Valley (GPS)		13,7
Saian		1,0-4,0
Average		100
Average	Greisens	100
Average	Quartz with tourmaline veins	20

* Harder (1965); Lyakhovic (1972); Stavrov and Khitrov (1960); Wedepohl (1974)

Boron has been strongly enriched in quartz from granite pegmatites and greisens (Malikov and Komov, 1970). The geochemical distribution of boron in the quartz of the Carpathian Province Pegmatite revealed high content in the quartz which are associated with tourmaline (shörl).

Quartz from greisens contain up to 100 ppm B.

Boron is an important component of high temperature hydrothermal phases. The boron content in the quartz of the hydrothermal ore deposits from Romania shown following values: 2,5 ppm (Băiut), 3,1 ppm (Cavnic).

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LE CHARRIAGE DES MESOMETAMORPHITES PROTEROZOIQUES SUR LES EPIMETAMORPHITES PALEOZOIQUES DE L'UNITE EPIMETAMORPHIQUE DE POIANA RUSCĂ (CARPATES MERIDIONALES)

MUREȘAN Mircea

Institutul Geologic al României – Str. Caransebeș 1, Sector 1, 78304 București 32; e-mail:
muresanca@xnet.ro

Le **Masif Poiana Ruscă** renferme, dans sa partie septentrionale, l'**Unité épimétamorphiques de Poiana Ruscă (UEPR)**, séparé de les **mésométamorphites** du sud par un plan tectonique qui a un pendage (70-80°) vers le sud – **Ligne directionelle Cinciș-Vadu Dobrii – LCV** (Fig. 1). Kräutner (dans Kräutner et al., 1981, 1990; Kräutner, 1993, 1996) a englobé dans les **Unités Supragétiques** tant l'UEPR que les **mésométamorphites** protérozoïques avoisinantes; les derniers nous les groupons dans l'**Unité Mésométamorphique Supragétique (UMSG)**, dans laquelle sont incluses aussi les roches plus faiblement métamorphisées du Groupe Cîbin. .

Pendant les derniers années, nous avons démontré (Mureșan, 2000, 2003) que l'UEPR renferme deux entités paléozoïques: le **Cristallin de Bătrâna – CBt** (Ordovicien inférieur; épimétamorphisé à la fin de celui-ci), représentant le socle métamorphique calédonien, sur qui repose transgressivement la deuxième pile épimétamorphique, représentée par le **"Cristallin de Poiana Ruscă s. s. – CPR s. s.** (Dévonien-Carbonifère inférieur; épimétamorphisé pendant la Phase Sudète – Kräutner et al., 1973). Puisque, nous avons argumenté récemment (Mureșan, 2003) que le **Cristallin de Nădrag s. l.** revient en réalité à l'UMSG, il en résulte que l'UEPR renferme seulement le CBt et le CPR s. s. L'UEPR est affectée par des importantes lignes (planes) tectoniques directionelles E-O (situées surtout dans la partie méridionale de l'UEPR – Fig. 1) et par des nombreuses fractures hétérocrones (Kräutner et al., 1965, 1968, 1969, 1973; Maier et al., 1969; Mureșan, 1964; 1973), parmi lesquelles, celles obliques (NE-SO) sont, fréquemment, très importantes (Fig. 1): **Faïlle Runc-Cutin (FRC)**, **Faïlle Chergheș-Ruschița (FCR)**, **Faïlle Ferigi-Aredei (FFA)**, **Faïlle Bătrâna (FB)**, **Faïlle Drinova-Curtea (FDC)**.

ARGUMENTS POUR LE CARACTÈRE DE CHARRIAGE DE LA LIGNE CINCIȘ-VADU DOBRII (LCV)

Auparavant, la LCV a été connue comme une faille directionelle (E-O) seulement à l'est de FCR (Maier et al., 1969; Kräutner et al., 1965, 1968, 1969). Ultérieurement, nous avons identifié la LCV aussi à l'O de FCR, jusqu'à la **Faïlle Drinova-Curtea** (Fig. 1); d'ici, la LCV est fortement décrochée jusqu'au nord de l'**Ile Cristalline Buziaș**.

(1) Dans notre opinion, la LCV réunit les caractéristiques principales des planes de charriages de cisaillement, rencontrés à la base des nappes à mésométamorphites charriées sur les épimétamorphites (par exemple, la Nappe alpine de Rarău, dans les Carpates Orientales – Mureșan, 1967, 2002). (a) Ainsi, la LCV est accompagnée par une zone épaisse (100-300 m) de milonites, blastomilonites et de roches rétro-morphes (initialement décrites entre Cinciș et Vadu Dobrii – Maier et al., 1969), formées, pendant le charriage, qui a affecté principalement le mésométamorphites de l'UMSG (les épimétamorphites du CPR s. s. sont seulement laminées et/ou brechifiées). (b) La LCV représente l'élément ruptuel majeur du Massif. Poiana Ruscă, au long de qui prennent contact l'UEPR et l'UMSG, deux entités totalement différentes du point de vue stratigraphiques et métamorphiques. (c) Un argument majeur dans la faveur du caractère de charriage de la LCV, est la présence des quelques schistes muscoviteux à biotite, staurotide et chlorite, dans le sommet du Dealul Româneasca (dans le versant méridional de la Vallée Runcu, c'est-à-dire à 4 km vers NNE de village Sohodol – Fig). Ces roches ont été mises en évidence par Berghes (1975). Selon nous, ces roches représentent, sans doute, des mésométamorphites, faiblement rétro-morphisées (le biotite est partiellement chloritisé); elles sont situées dans le milieu de la surface occupée par le Massif des Dolomites de Hunedoara – MDH (vers la partie supérieure du CPR s. s.). Dans notre opinion, les schistes à staurotide d'ici constituent un petit lambeau de charriage (limité au sud d'une faille directionnelle), qui, dans cette région, représente l'UMSG. Nous considérons que le rétro-morphisme des ces roches s-a produit pendant le charriage de l'UMSG sur l'UEPR.

(2) LCV étant déplacée par la FCR, qui est formée avant du Cretacée supérieur (Kräutner et al., 1969), il en résulte que la LCV est antélaramienne (varisque – cf. Kräutner et al., 1969). (a) Si la LCV est anté-mésozoïque, l'UEPR et l'UMSG constituent une seule entité varisque post-sudète, qui revient aux Unités Supragétiques (cf. Kräutner et al., 1981, 1990; Kräutner, 1993, 1996), mais jamais inconnue dans les Nappes Supragétiques de Banat. (b) Si la LCV est tardive-autrichienne (notre opinion), peut être exister deux solutions principales: (b1) La LCV limite au nord les Unités Supragétiques vis-à-vis d'UEPR, cisailant, en profondeur, toute la Nappe Gétique (qui est, aussi, mésocrétacée, au moins dans sa partie septentrionale, ou le contact de celles-ci avec le Danubien est couvert par le Cénomanién); dans ce cas, l'UEPR peut-être une unité danubienne; (b2) L'UEPR représente une unité supragétique, inférieure vis-à-vis de les Unités Supragétiques de l'UMSG du soubassement du Bassin Rusca Montană.

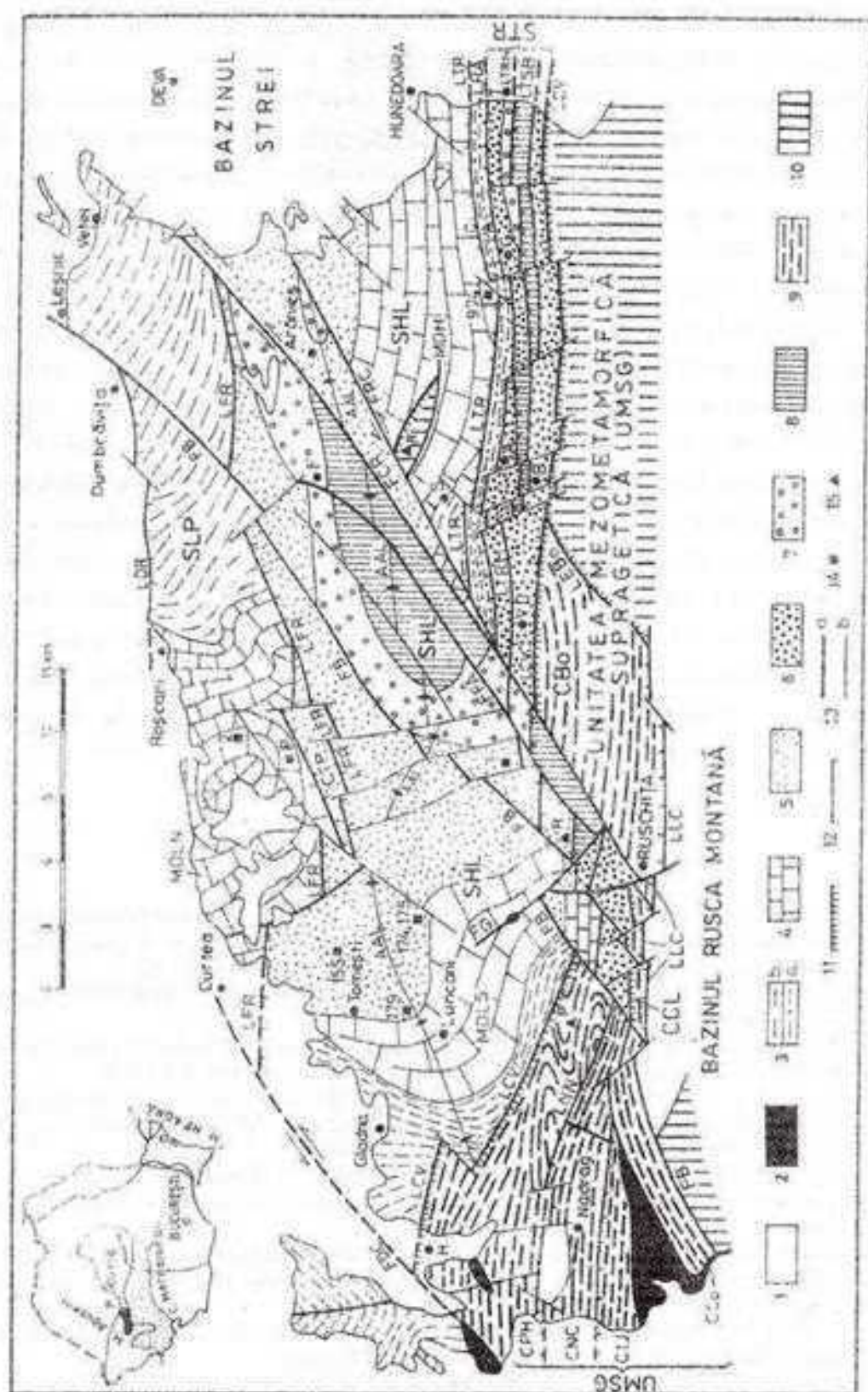


Fig. 1 – ESQUISSE TECTONIQUE ET LITOSTRATIGRAPHIQUE DE L'UNITE EPIMETAMORPHIQUE DE POIANA RUSCĂ (partiellement selon: Kräutner et al., 1965, 1969, 1973, 1990; Maier et al., 1969; Mureșan, 1965, 1968, 1973, 2000, 2003).

Fig. 1: 1, Dépôts mésozoïques et tertiaires; 2, Corps intrusifs banatitiques; **UNITÉ ÉPIMÉTAMORPHIQUE DE POIANA RUSCĂ – UEPR** (3 + 4 + 4 + 5 + 6 + 7 + 8): **Cristallin de Poiana Ruscă – CPR s. s.** – Dévonien-Carbonifère inférieur; métamorphisme sudet (3 + 4 + 5 + 6 + 7); 3 + 4, **Groupe Roșcani – Ro** (3a, Formations Ro1 et Ro2; 3b, Formations Ro2 et Ro3; 4, Formation Ro1; 5 + 6, **Groupe Ghelar – Gh** (5, Faciès septentrional; 6, Faciès méridional); 7, **Groupe Govăjdia – Gv**; 8, **Cristallin de Bătrâna – CBt** (Ordovicien inférieur; métamorphisme calédonien). **UNITÉ MÉSOMÉTAMORPHIQUE SUPRAGÉTIQUE – UMSG** (9 + 10): 9, **Cristallin de Nădrag s. l. – Cnd s. l.** (Protérozoïque moyen); 10, **Mésométamorphites nondivisées** (Protérozoïque moyen); 11, **Charriage** (Ligne Cinciș-Vadu Dobrii – LCV; Ligne Est Bordu – LEB – selon Balintoni & Iancu, 1986); 12, **Lignes tectoniques directionnelles** (LTSB, Teliucul Superior-Bunila; LTRM, Teliuc-Ruda-Muncel; LRA, Retișoara-Alun; LTR, Nord Teliuc-Valea Runcului; LFR, Fața Roșie; LDR, Dumbrăvița-Roșcani; LLC, Lunca Cernei); 13, **Faîles** (13a, faîles importantes: FCR, Chergheș-Ruschiza; FRC, Runc-Cutin; FFA, Ferigi-Aredei; FB, Bătrâna; FDC, Drinova-Curtea; FG, Gropi; 13b, faîles secondaires); 14, **Asociații de palynomorfe**: Dévonien moyen (1); Dévonien supérieur (155, 174, 175, 179, 974); Carbonifère inférieur (2); 15, **Sommets montagneux** (P, Vârful Padeș, 1377 m; R, Vârful Rusca, 1356 m; C, Dealul Cârnu, 757; R, Dealul Româneasca, 890 m); **AUTRES ABRÉVIATIONS**: MDH, Masif des Dolomites de Hunedoara (Ro1); MDLS, Masif des Dolomites de Luncani (Ro1) – zone meridionale; MDLN, Masif des Dolomites de Luncani (Ro1) – zone septentrionale; AAL, Anticlinorium Arăneș-Luncani; **Compartiments tectoniques du Cnd s. l.**: CPH, Padeș-Hăușești; CNC, Nădrag-Crivina; CLJ, Izvodia-Jdioara; CCo, Cornet; CCL, Cracul Lung; CBo, Bordu; STR, Subunité Teliuc-Ruschiza; HLS, Subunité Hunedoara-Luncani; SLP, Subunité Leșnic-Poieni (CTP, Compartiment tectonique Poieni); T, Teliuc; G, Ghelar; A, Alun; B, Bunila; VD, Vadu Dobrii; S, Sobodol; F, Ferigi; P, Poieni; H, Hăușești. N.B. Les dimensions du petit lambeau de charriage du Dealul Româneasca (R) ont été exagérées.

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EXTRACTION OF LANTHANIDES OF APATITES OF THE BRAZILIAN PHOSPHATIC ORES

F. PEREIRA¹, E. BILAL¹

¹ CNRS - UMR 6524 (Ecole Nationale Supérieure des Mines de Saint-Etienne, France)

e-mail : bilal@emse.fr, fernando.pereira8@wanadoo.fr, pereira@emse.fr

The deposit of Angico dos Dias (Brazil), property of the Galvani company, is located at North East of Brazil near (10 kilometers) the town of Caracol (coordinates : 09°18' of Southern latitude and 43°22' of Western longitude) in the division of Bahia and Piauí's states. The Angico dos Dias Complex is a magmatic unit (2011 ± 6 My), where syenites and carbonatites alternate. The syenites unit essentially consists of alkaline feldspaths. Carbonatites are grained and make up 80% of large crystalline carbonate crystals. They also contain in negligibles quantities pyroxenites. Lamprophyres were also detected in veins with a micrograined texture. They are characterized by the abundance of biotites and/or amphiboles in small crystals accompanied according to cases by olivine or feldspaths. Alkaline pyroxenites and diorites appear sporadically. The deposit comes forward a vein of 25m thickness, of an average P_2O_5 content of 16.3% and a measured reserve of 16.4 million of tons. The characteristics of the Angico dos Dias complex are that : the carbonatite contains a high percentage of apatite (superior to 14% on average) and the Nb, Th and U contents of the various lithologies are abnormally low.

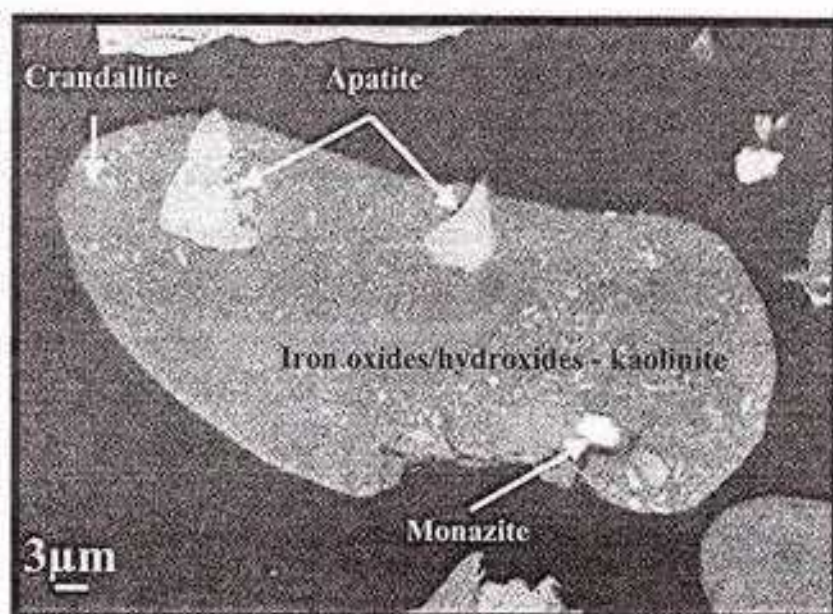


Figure 1 - Mixed aggregates (matrix of kaolinite, crandallite and iron oxides/hydroxides) ; monazite and apatite inclusions.

The phosphatic ore of Angico dos Dias is composed of quartz, fluorapatite and mixed aggregates which are essentially formed by kaolinite, aluminium phosphates of the crandallite's

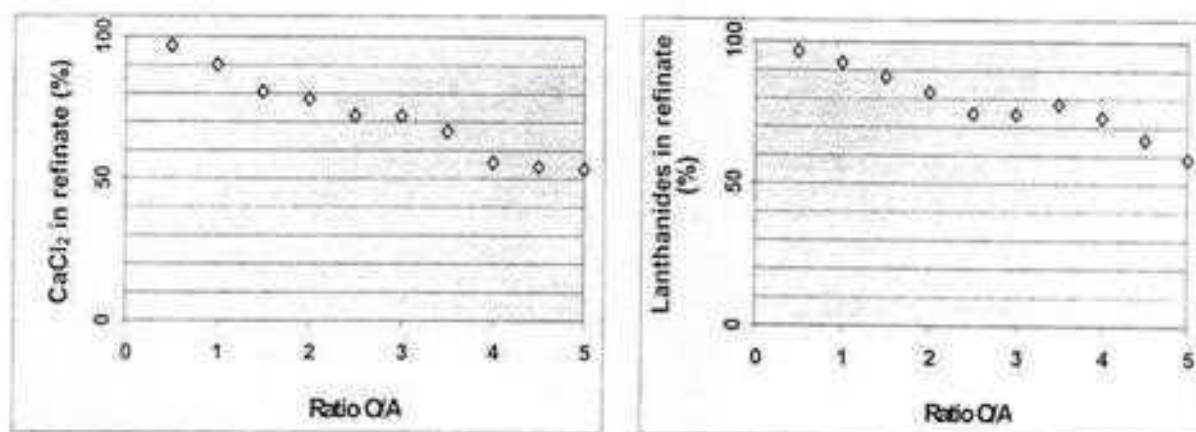
family (contained Ba, Sr and Ca), iron oxides/hydroxides, potassic feldspaths, titanite and magnetite with or without associated ilmenite. The principal rare earth source of the ore is monazite (64%) and to a lesser extent apatite (up to 1%). The monazite is characterized by its fine granulometry and is found as an inclusion either in the apatite grains or in the mixed aggregates. Monazite is always white and the Fe or Fe/Ti minerals are in very clear gray. Agglomerates of several minerals are presents in great quantities. These lasts contain apatite, crandallite, monazite and a formed mixed plasma of kaolinite and iron oxides/hydroxides.

The chemical composition and the granulometric distribution of a sample of the phosphatic ore of Angico dos Dias show a $\text{CaO}/\text{P}_2\text{O}_5$ ratio of 1.17. It is interesting to note the high SiO_2 (25.06%) and Al_2O_3 (9.06%) contents and the low radioactive elements Th and U (<15ppm) contents. The Nb_2O_5 (0.03%) and rare earth elements (0.44%) contents are not very common comparatively to other phosphatic ores of igneous origin. The chemical composition of the phosphatic concentrate of Angico dos Dias/Caracol (Brazil) has a $\text{CaO}/\text{P}_2\text{O}_5$ ratio very close to that of theoretical apatite (1.3), high SiO_2 contents (21.06%) and low Fe_2O_3 , Al_2O_3 and radioactive elements contents (ΣTh , U, Cs = 72ppm) compared to phosphatic concentrates of igneous origin.

Rare earth elements recovery

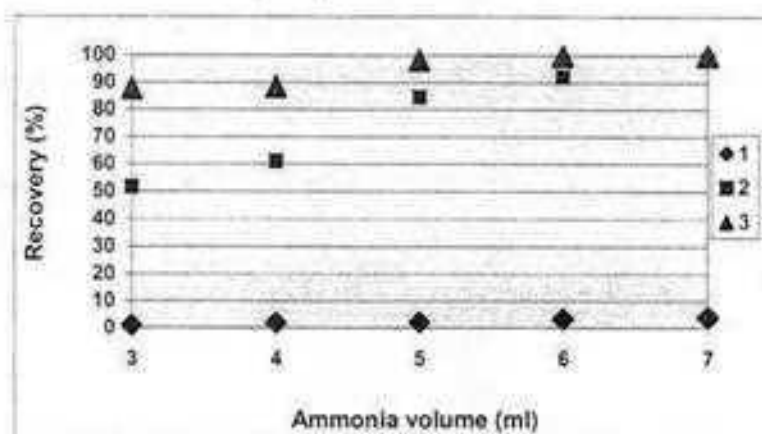
The extraction experiments were undertaken by agitation of the feed aqueous solutions (hydrochloric leachates) and organics (solvent TBP) in beakers, the selected residence time being of 15mn. The reactional mixture was then transferred into a separating funnel so as to make the separation of the phases. The extraction was carried out on three stages while varying the time of contact of 1 to 15mn by steps of 1mn. The collected aqueous phases were analyzed in ionic chromatography for elements Ca, P and REE (Rare Earth Elements) in priority. After liquid-liquid extraction by the tributylphosphate led on three stages, more than 95% of the phosphates contents find themselves in the organic extract while more than 90% of calcium chloride and rare earths remain in the raffinate (figures 2 and 3). In accordance with the work undertaken by Habashi and Awadalla [1986], we opt for a lanthanides precipitation. After extraction by the tributylphosphate led on three stages, 20ml of raffinate thus were added to various quantities of ammonia and oxalic acid under various conditions the whole under agitation and this during 30mn. The collected precipitates were dried, crushed and calcined (at 1000°C) before be analyzed by ICP/AES (Inductively Coupled Plasma). With this intention, we proceeded to their redissolution in an excess hydrochloric acid HCl.

Results



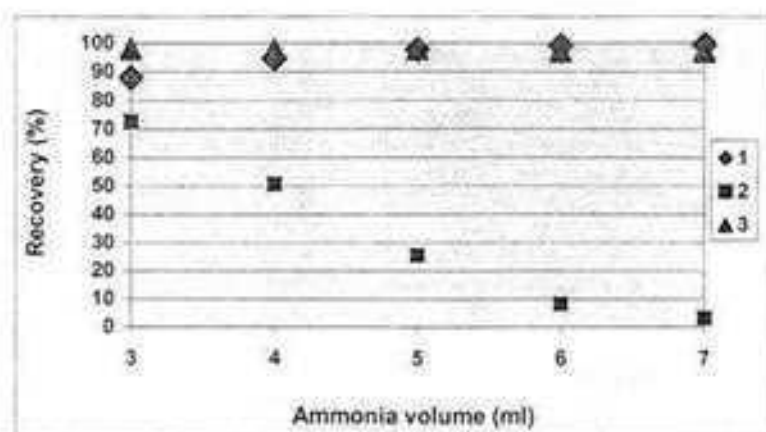
Figures 2 & 3 - CaCl_2 and lanthanides recovery in refineate.

Rare earth elements recovery is excellent whatever the treatment undergone by the aqueous refineate. After treatment by the ammonia one only, the lanthanides recovery proves to be optimal (near the 100%). In parallel, the lanthanides concentrate obtained presents some phosphates impurities. A little less than 90% of the phosphates contents of the aqueous refineate (of low content phosphates, the immense majority of these last being in organic phase after extraction by the tributylphosphate) is found in the residue obtained. The CaO content of this residue remains very low. After treatment by the ammonia and the oxalic acid one only, rare earth elements recovery is total whatever the ammonia volume added. The major disadvantage related to this treatment of aqueous refineate is the presence in the residue of great quantities of CaO (more than 90% of the CaO contents presents in the aqueous refineate, already very rich in this oxide). Moreover, for an obvious reason of cost (suppression of one stage), it remains preferable to treat the aqueous refineate so as to recover the rare earth elements by the ammonia one only. By the means of this method, we managed to recover, in the shape of a rare earth phosphatic concentrate, nearly 80% of the lanthanides, initially presents inside the phosphatic rock.



1 - CaO , 2 - P_2O_5 , 3 - $(\text{REE})_2\text{O}_3$

Figure 4 - CaO , P_2O_5 and $(\text{REE})_2\text{O}_3$ recovery in solid phase (calcined residue) according to the ammonia volume added – aqueous refineate treated by ammonia (ICP/AES analyses).



1 - CaO, 2 - P₂O₅, 3 - (REE)₂O₃

Figure 5 - CaO, P₂O₅ and (REE)₂O₃ recovery in solid phase (calcined residue) according to the ammonia volume added – aqueous refinate treated by ammonia and oxalic acid (ICP/AES analyses).

Conclusion

The characterization of the phosphatic Angico dos Dias/Caracol ore has brought to the fore a simple mineralogical constitution and favourable to treatment. Near monomineralics apatite and quartz grains, mixed

1 - CaO, 2 - P₂O₅, 3 - (REE)₂O₃

e's type and iron

oxides/hydroxides with apatite and quartz inclusions predominate. Fe mineral grains (magnetite/hematite with or without associated ilmenite), feldspaths, titanite and goethite were also detected. The phosphoric acid can be extracted from the hydrochloric leachate by the tributylphosphate. Three stages are theoretically necessary to recover all the phosphoric acid in the organic extract. The extraction experiments, undertaken as well in continuous as discontinuous mode, have appreciably led to the same results, the lanthanides and the calcium chloride being mainly distributed in the aqueous refinate.

The aqueous phase can, as for it, being treated by ammonia in order to recover the lanthanides, initially presents inside the phosphatic rock, in the form of a phosphatic concentrate.

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HYDROTHERMAL ALTERATIONS AND THEIR GEOCHEMICAL IMPLICATIONS REVEALED BY MULTIVARIATE TECHNIQUES (FACTOR ANALYSIS) IN ALMAS-STANIJA ORE FIELD (SOUTHERN APUSENI MOUNTAINS, ROMANIA)

Tiberius POPA, Silvia POPA

S.C. Prospectiuni SA, str. Caransabes 1, Sector 1, 012271-Bucuresti-32 Romania

E-mail: tibipopa@k.ro

The Almas-Stanija ore field is located in the Southern Apuseni Mountains of western Romania. The goal of this paper is to express the hydrothermal alteration zones and factorial

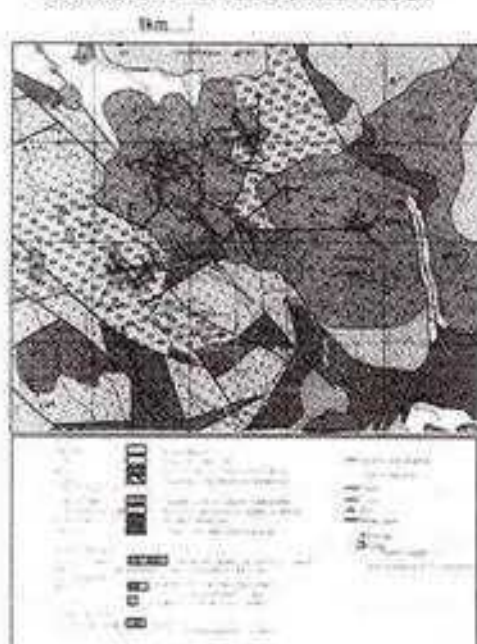


analysis (FA) of geochemical data for Almas-Stanija ore field. A mathematical model is constructed to related geochemical association of wall rock and broadly altered rock zones in Almas-Stanija field.

The Almas-Stanija ore field locates the next exploited and explore ore deposits: Almas-Muncacesca Est, Muncacesca West, Stanija. This is one of the numerous epithermal systems from Romania, where the veins are encased in sericitization with silicification associated with potassium silicate assemblage.

GEOLOGY AND MINERALISATION OF THE DEPOSITS

GEOLOGICAL MAP OF ALMAS-STANIJA REGION



Geological sketch map of Southern Apuseni Mountains (after Alderton, 1999)

The Neogene igneous rocks are the main host of the mineralised veins and are represented by andesites. These andesites contain abundant hornblende and feldspar, together with varying amounts of biotite, quartz and resorbed pyroxene. The andesites occur as intrusive stocks, lava flows and hydrothermal breccias associated. The igneous rocks were intruded through and in to Mesozoic sedimentary (conglomerate, sandstone, siltstone) and basic volcanic ophiolites (basalts and pyroclastics). All these three types of rock have been mineralised, bearing gold-base metals mineralisation.

The Almas-Stanija structure is a low sulphidation polymetallic gold silver + copper deposit, a transitional type of hydrothermal system, from deeper crustal levels.

The hydrothermal fluids become progressively more diluted by the incorporation of increased quantities of ground waters, during migration further from the intrusion heat source, entraining of magmatic volatile in circulating waters to higher crustal levels.

Telescoped system generally display later formed mineralisation typical of higher crustal levels overprinting deeper earlier formed mineralisation. Veins generally comprise dominantly quartz, pyrite, galena, sphalerite, chalcopyrite, calcite, silver, sulphosalts. Some polymetallic veins may evolve to high gold grade epithermal quartz gold silver ores.

WALL ROCK ALTERATION ZONES

After a carefully field mapping and microscopic analysis, it was identified a zoning of alteration selvages. The host rocks have undergone propylitic- potassic -intermediar argillitic -sericitic -silification alteration, increasing in intensity to mineralise veins.

Propylitic alteration is a diffuse and widespread fringe around the margins of the deposits. Ferro-magnesian minerals in the andesites are most affected and they have been variably altered to chlorite, calcite, epidote, magnetite, iron hydroxides. The feldspar has been replaced on fissures with alkali feldspar. The glassy-microcrystalline groundmass presents nests of chlorite and is impregnated with pyrite. The propylitic alteration has an intramagmatic source.

The circulation of the reduced near neutral fluids generates the **potassic** alteration. In the low sulphidation veins system environment, the K-feldspar is produced mainly by loss of pressure and carbon dioxide. Potassic alteration of andesitic rocks consists of varying proportion of quartz,



Thin section photograph of potassic altered breccia (transmitted light, crossed polars)

adularia, chlorite, biotite of neoformed, tourmaline, rutile, iron hydroxides. The ground mass and the fenocrysts are transformed and replaced by neominerals association. In addition, the potassic alteration influence could be observed in the sedimentary rocks and ophiolites, through quartz-adularia fissures and pyrite impregnation.

The sedimentary rocks are host of the veins and undergo a process of potassic alteration, by substitution of cement and compound elements with quartz and adularia /illite.

The intermediate **argillic** alteration is represented considerably, it's like an envelope overlays between potassic and sericitic alteration. It conserves the porphyric texture of the andesite,

the fenocrysts of the plagioclase and the mafics have a uniform aspect and are substituted by neominerals association: illite -montmorillonite -chlorite -calcite -pyrite -iron hydroxides.



Thin section photograph of sericitized andesite (transmitted light, crossed polars). Sericitized tourmaline (tu). Uniform aspect of sericitized fenocrysts. Montmorillonite (mu) formed by hornblende.

Sericitic alteration is the most abundant, widespread and significantly, because it's in the vicinity of the veins. The sericitic alteration is observed in andesites, conglomerates, sandstones and breccia bodies and it is characterized by the neomineral association: sericite- illite- quartz- calcite $\pm$ tourmaline- muscovite- pyrite. The sericitized rocks have a uniformed aspect. The sericite is fine-grained white mica.

GEOCHEMISTRY AND FACTOR ANALYSIS (FA)

The main aim of this study is to define the geochemical associations in the haloes of hydrothermal alteration. A mathematical model is constructed to relate the geochemical composition of the hydrothermal altered rocks and alteration types.

The exploratory FA is a powerful mathematical and statistical tool in handling a great number of numerical data. As a multivariate method, it facilitates the reduction, transformation and organisation of the original data by the use of intricate mathematical techniques, which eventually results in a simple form of factor model. Thus, a factor model represents, in a sense, a minimum of reduction model which explain correlation among observed data, in a few terms, ignoring minimum influences and non-linear effects that may be present (Miesch et al., 1966).

In this study, the chip samples were collected from the outcrops and adits. For each sample 17 descriptors consisting of five alteration types and 11 geochemical variables (minor and trace elements), were observed and includes in the FA.

The alteration type variables were defined as a percent of whole rock studied. It is a system based factor model, which synthesises the variables reducing their relationships to three or four geological significant factors. All variables for whole alter rocks were used in a first hand and subsequent we have used FA in divers combinations for analysing the geochemical association for each type of hydrothermal alteration, for a group of samples with $Au > 0.01$ g/t, a group of samples with K, Ba, Sb analysed resulting the follows factors. The extractions of four or six factors axes, which were chosen as most representative, are presented below. The model is presented in the form of varimax rotated factor matrix.

FA of propylitic alteration shows an arrangement of chemical elements related with the rocks petrogenesis.

FA of potassic rocks samples unit indicates in the main factor the association Pb-Au-Cu, it is characteristic for a telescoped mineralization.

FA of an intermediate argillic rocks unit shows the association Zn-Pb-Au-Ag which is characteristic for epithermal mineralization.

FA of sericitic alteration unit shows in the second factor Pb-Zn-Ag, feature for epithermal mineralisation.

FA of silicic rocks shows association Pb-Au-Cu-Ag which is typical feature for Almas-Stanija epithermal system.

The factors from FA for 10 elements (As, At, Cu, Pb, Zn, Ag, Co, Ni, Cr, Mo) were labelled as follows:

- Factor 1, of mineralization (Pb-As-Zn-Ag)
- Factor 2, of lithogenetic (Cr-Ni-Cu)
- Factor 3, of lithogenetic (Co-Mo)
- Factor 4, of Au-Ag mineralisation.

We used those factors for creating factor maps.

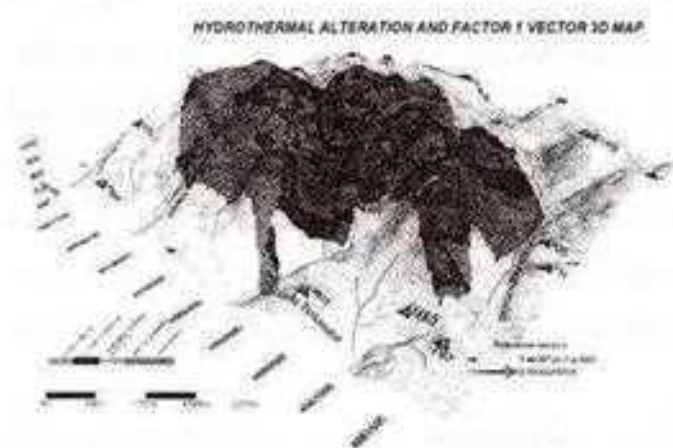
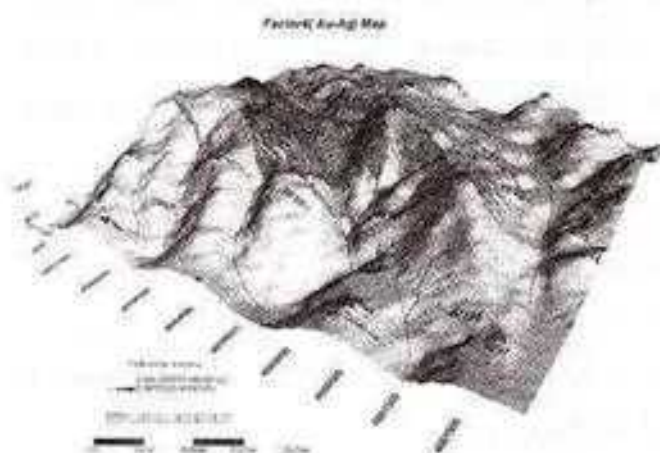
Factor Maps

The possibility for calculating factor scores of each sample is a big advantage, which allows drawing of maps for the spatial distribution of each factor. Factor scores can be particularly useful in creating the **factor maps** which display the areal distribution or influence of a particular factor.

Finally, for each sample, the factor scores can be estimated which replace the value of original variables. These characterise each sample and this may be used in any subsequent classification or correlation analysis.

After determining the geological meaning underlying the relationship among original variables, it was of interest to observe the areal distribution of variances and possible trends hidden behind the respective factor.

In the Factor 1 map, the significant anomalies with geochemical



associations Pb-As-Zn-Ag are spread around the source areas of the intense alteration, near the mineralised bodies. These areas are mostly composed of overlaying alterations: potassic, intermediate argillic and sericitic alteration.

FA for this alteration shows, in general, in the main factor typical association for epithermal style and displays a connection between this overlaying alteration, and epithermal mineralization.

The anomalies of the factor 2 (Cr-Cu-Ni) and 3 (Co-Mo) are scattered in a very irregular pattern over the sedimentary rocks and ophiolitic rocks.

The map of Factor 4 display association Au-Ag which is spread around the mineralised bodies (veins and hydrothermal breccias).

CONCLUSIONS

Many regional and local studies based on extensive use of chip samples as the most convenient sample medium have been orientated to mineral exploration. More rarely, they were focused on some particular topic of more local significance, such as the relationship between the litogeochemistry and hydrothermal alterations.

We constructed a tentative model which related the hydrothermal alterations and geochemical composition of alter rocks. The model is a system based, factor model which synthesized 5 alteration types and 11 geochemical variables (minor and trace elements) and reduced their relationships into a few geologically meaningful factors.

Generally, the elements demonstrate a typical for unequilibrium systems asymmetrical distributions, due to hydrothermal and ore forming processes superimposed on the host rocks. In general, in the main factor the geochemical associations, for samples derived from FA are as follows: Pb-As-Au-Sb-Zn, typical for epithermal system. In the last map it is represented the correlation between hydrothermal alterations and factor 1, represented as vector map. Thus, the extracted groups reflect the existing zonality in the Almas-Stanija ore field. The new correlated data obtains are a good tool for the future explorationists in this region.

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THE ROLE OF THE FLUID INCLUSIONS IN THE GENESIS OF THE GOLD ORE IN NORTHERN LEAOTA MTS

Denisa PREDEȚEANU, Gheorghe C. POPESCU

University of Bucharest, N. Balcescu, no.1, e-mail: denisa@geo.edu.ro; ghpop@geo.edu.ro

Gold mineralization of Leaota Mts. occur along a shear zone in Northern Leaota Mts. The fluid inclusion study has been conducted in order to modeling fluid evolution along the shear zone.

The samples come from gold ore-bearing quartz (Alb R.), quartz from NE-SW veins, similar to the veins that host the gold ore, or from NW-SE oriented veins.

The selected samples are processed in the laboratory, where it was realize thin sections, polished sections and two-side polished sections, with a thickness varying between 100 and 150 microns. The fluid inclusions are analyzed first using non-damaging analytical methods, like microscopy studies and/or analysis at the heating/cooling fluid inclusion stage and then using damaging analytical methods (SEM/EDA).

The microthermometric measurements was perform using a Linkam TMSG600 stage in the Geology Dept. of the Catholic University of Louvain (Louvain-la-Neuve, Belgium) and a Fluid-Inc USGR stage in the Geology Dept. of the University of Torino (Turin, Italy). It was analyze mainly those fluid inclusions that correspond to primary or pseudo-secondary according to Roedder (1984) criteria.

The major element chemical composition is determined with SEM/EDA analysis on the residual salts obtained from decrepitation. The decrepitation was performed after analysis on the microthermometric stage.

The fluid inclusions have irregular usually rounded shapes. Their dimensions range between 2 and 10 microns. The smallest fluid inclusions come from the quartz in the surrounding gneiss, where not all the phase transitions are observed. Their inclusion in a statistical study is not reliable, and they have been excluded from our further analysis.

The microscopy study reveals four types of fluid inclusions (Fig.1):

- fluid inclusions containing a CO₂-bearing liquid
- fluid inclusions containing an aqueous unmixing liquid
- fluid inclusions containing a high-density aqueous solution
- fluid inclusions containing a low-density aqueous solution

From the 15 analyzed samples, only two reach the saturation, where daughter minerals (halite) crystallized at concentrations above 25 %wt.

The detailed petrographic mapping, based on the textural relations obtained from the microscopic study, reveal that the aqueous fluid inclusions and the CO_2 -bearing FI are co-genetic, formed by decomposition of the fluid inclusions containing an unmixing liquid.

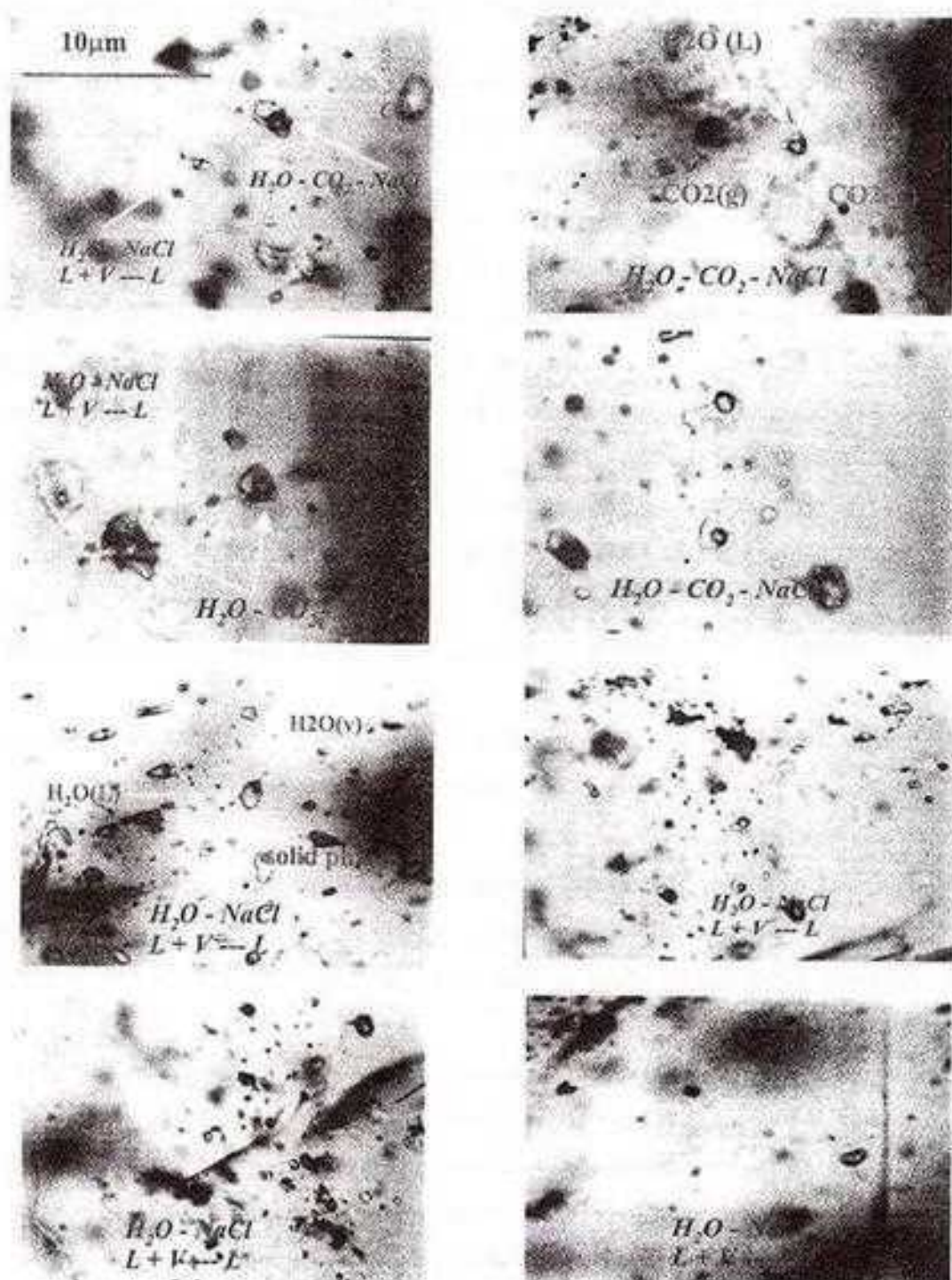


Fig. 1. Types of fluid inclusions in Northern Leaota Mts.

The presence of the three fluid inclusions types along the same rock fractures suggests the phase separation took place with cooling and depressurizing. Based on this assumption, the intersection between the isocores of the CO₂ fluid inclusions and of the aqueous fluid inclusions, show entrapment temperatures of 420 to 120 degrees and pressures of 1.8 to 9.8 kbar (Fig.2).

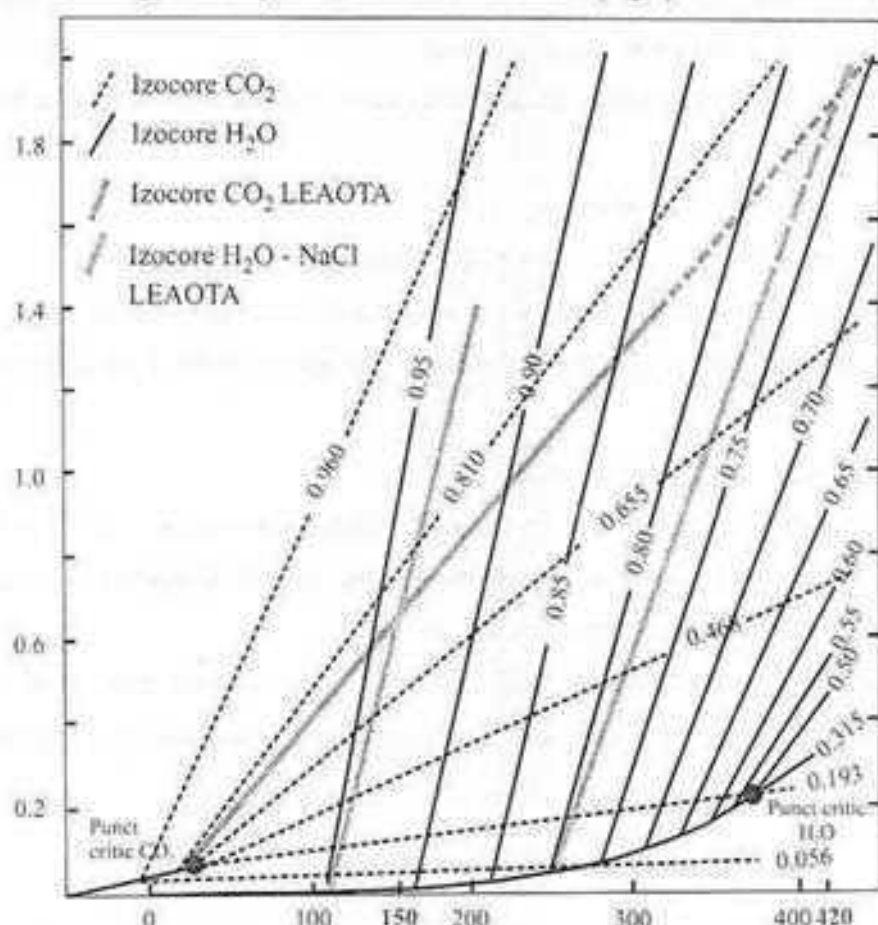


Fig.2. Pressure-temperature diagram showing isochors of H₂O and CO₂. Because of the different slopes of the isochors for these fluids, it is possible to obtain unique P-T points for fluid inclusions that have trapped unmixed fluids (Hollister, 1981).

The petrography and the microthermometry show that the quartz that hosts the gold ore precipitated from a homogeneous fluid, containing H₂O, CO₂ and salts. The dominant salts are NaCl and KCl in the fluid inclusions from Alb V. and Caselor V. and CaCl₂ in the fluid inclusions from the Iuda V. Similar chemical compositions for the residual salts are shown by the SEM/EDA analysis.

As the ligand availability is an essential factor for the gold migration, we also monitor the Cl/S ratio in the fluid inclusions using SEM/EDA. For the samples come from gold ore-bearing quartz (Alb R.), the Cl is a dominant ligand in analyzed fluids.

These suggest that the gold was transported in chlorine complexes, by fluids rich in NaCl and KCl.

Our conclusion also was based on following observations:

- the veins are rich in quartz and poor in sulphides, suggesting a low-pH (the same hypothesis comes from the presence of clay alterations)
- the rock-fluid reaction (hydroxides on pyrite) shows that the fluid had a high Eh
- availability of Cl ligand
- for the chlorine-based complexes:
 - decreasing pH and increasing Eh of the fluid mobilizes the gold
 - increasing pH and decreasing Eh of the fluid concentrates the gold
- separating the CO₂-rich fluid from the aqueous fluid raises the fluid pH according to (Reed in Spencer, 1985):
$$\text{HCO}_3^-(\text{aq}) + \text{H}^+(\text{aq}) \rightarrow \text{H}_2\text{O}(\text{aq}) + \text{CO}_2(\text{g})$$
- the interaction between the fluid and an oxidizing environment (e.g. pyrite to Fe-hydroxides transformation) reduces the solutions (the oxygen activity decreases), accompanied by the gold precipitation from chlorine complexes.

Thermodynamic calculations and fluid inclusion data indicate that gold mineralization precipitated in response to fluid-wallrock reactions and to P-T decreases along the shear zone.

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DEFINING ENVIRONMENTAL CONDITIONS IN MINING AREAS BY MEANS OF GEOCHEMICAL METHODS

I.N.ROBU, L. ROBU

¹Geological Institute of Romania, Caransebes str. 1, 78 344 Bucuresti, Romania, e-mail: inrobu@lgr.ro,
lrobu@lgr.ro

It is very well known that a good function of each natural ecosystem at the macro and/or microstructural level is determined by the interconnections between different parts of it, a high influence being exercised by anthropogenic factors, induced in it by the human activities.

Generally, the anthropogenic factors are represented by industrial activities, consisting of mining and metallurgical works, which in time can become the main pollution factors, especially if the control of state authorities is missing.

Sometimes, the geological natural context is favorable for heavy metal accumulation, when regional clarks are exceeded, determining the appearance of some anomalous zones, but which can or cannot have a pollution effects.

The risk of pollution becomes obviously when the natural and antropic factors are superposed.

A good relevance for establishing of environmental conditions and a connection between potential pollution factors and the state of environment is emphasized by the geochemical investigations. Both, natural and anthropic factors, can be very well emphasized by using of the geochemical methods. Through their specificity, sampling, analyzing and evaluation of the results, the geochemical methods can provide information regarding the state of environment.

The chemical investigations, undertaken for elaboration of the Geochemical Atlas of Romania (1:3 000 000 scale) (Andar et al, 1996), have included sampling and chemical investigations of stream water and sediments, having as result the outlining of the anomalous chemical areas on the Romanian territory.

These anomalous areas included those ones belonging to heavy metals, which emphasized affinities for some kind of rocks or have specific regional distribution (tab.1 and 2).

Table 1 Heavy metals variation in stream sediments on the Romanian territory

1	Zones	Heavy metals
2	Neogen Volcanism Metallogenetic Province (specially Maramures Region)	Pb, Zn, Cu, As
3	East and North-eastern parts of the Moldavian Plateau	Pb, As
4	South and East Carpathians, the maximum Ni value being registered in the Pannonian Basin.	Co, Ni
5	Higher concentrations in the metamorphic rocks then the magmatic and sedimentary rocks	Cr, V, Sr

Table 2 Heavy metals variations in stream sediments on the Romanian territory

1	Zones	Heavy metals
2	Curvature zone of the East Carpathians	As
3	Baia Mare Zone, South-West Pitesti and Central and North Dobrogea	Cd
4	Pitesti - South-West Pitesti and Central Dobrogea	Co, Cr
5	Pitesti-South-eastern Pitesti	Cu
	South-eastern Pitesti South Eastern to Suceava and North and Central Dobrogea	Fe
	North -western to Bucuresti Curvature Zone and East Moldovian Platform	Mo
	South-West Pitesti and Central Dobrogea	Ni
	South-West Pitesti	Pb
	East and South Moldovian Platform and South Dobrogea	Se
	South-eastern Pitesti	V
	South-eastern Pitesti, Baia Mare Zone	Zn

Two important parameters, pH and conductivity, have been considered too. Lower pH values are found in the South and East Carpathians and northern part of the Apuseni Mountains, whereas the highest (8-8.5) are recorded in the southern part of Romanian territory, in the Moldavian Plateau and the Romanian Plain.

The conductivity is variable; frequently it has the similar variations as pH. Lower values ($<100 \mu\text{S}/\text{cm}$) belong to waters collected from mountains areas, whereas high values ($>1000 \mu\text{S}/\text{cm}$) correspond to stream waters from the southern and eastern parts of Romania, as well as those sampled in the central part of the Transylvanian Basin.

It is obviously that the majority of anomalous heavy metals areas are registered in the industrial and mining zones.

The low sampling distribution (0.5 degree longitude and latitude network cell size, and a sample density about one sample per 2000 km^2) and working scale (1:3 000 000) give a general view of the

environmental state, but not a detailed one, so that these kinds of studies have to complete and continue with detailed ones.

Taken into account those above mentioned, detailed geochemical investigations in a mining zone of the Apuseni Mountains (Caraci-Tebea-Mesteacan-Brad-Luncoiu de Jos) area have been effected.

For environmental characterization, some physical and chemical parameters, respectively (pH, conductivity, temperature, dissolved oxygen) have been considered.

The pH variations are considerable, extended between 6.22 (left affluent of Crisul Alb valley) and 8.63 (Lunga valley)

The pH areal distribution (fig.1) emphasized high values in the South and Southwestern part of the investigated zone (Mare Valley, Mica Valley, Satului valley and Tebea valley) and low ones in the eastern part of perimeter, in the Crisul Alb Basin.

Temperature variations, registered between 14-27 September 2003 ($10^{30} - 19^{00}$) are variable between 10.0 – 26.2 °C; maximum values, high for this annual period, have been induced by (i) the high temperature during summer-autumn periods, (ii) lack of rain falling and (iii) the reduced volumes of the water flows. The lowest values belong to the left affluent of the Tebea valley, and highest ones are specifically for water samples collected from Luncii valley, in the crossing sector of Brad town.

The temperature areal distribution (fig.2) emphasized an uniform disposal, but the high level, in the central zone of the perimeter, but the highest values have been registered in the East and Northeastern part of it.

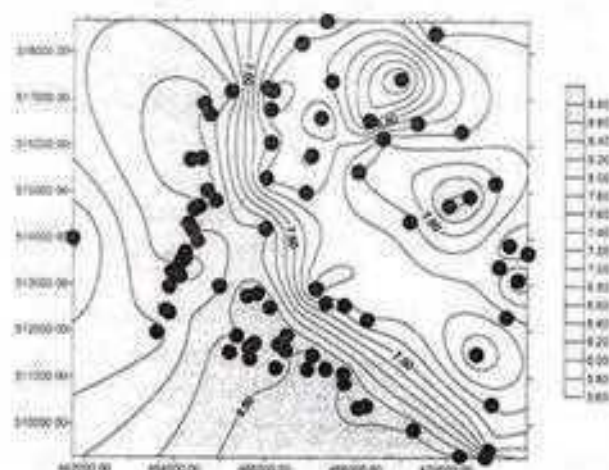


Fig. 1 pH areal distribution in the Caraci-Tebea-Mesteacan-Brad-Luncoiu de Jos Zone

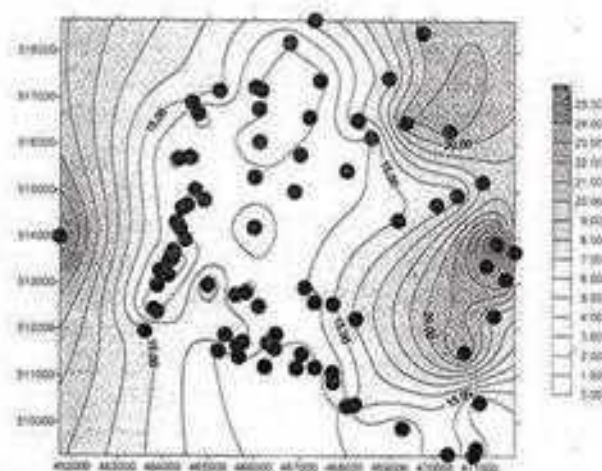


Fig.2 Temperature areal distribution in the Caraci-Tebea-Mesteacan-Brad-Luncoiu de Jos Zone

The conductivity presents high variation, distributed between 98.6 $\mu\text{S}/\text{cm}$ (Mare Valley) and 476 $\mu\text{S}/\text{cm}$ (Satului valley), pointing out the quantity of dissolved salt in the stream water, due to solubility of some salts existed in the solid support of their flowing.

Conductivity areal distribution (fig.3) emphasized the similar distribution in the neogene and ophiolitic magmatic rocks; the values are increasing in the outcropping zones of the sedimentary formations.

Oxygen dissolved in stream water varies between 7.99 (Luncii valley) and 11.27 (Mare Valley), but the majority of samples have values up to 9.

Dissolved oxygen in stream water (fig. 4) emphasizes the maximum values in the central and southern parts of the perimeter in the Tebea, Lunga, Mare and Mica valleys and it is decreasing along the Crisul Alb valley.

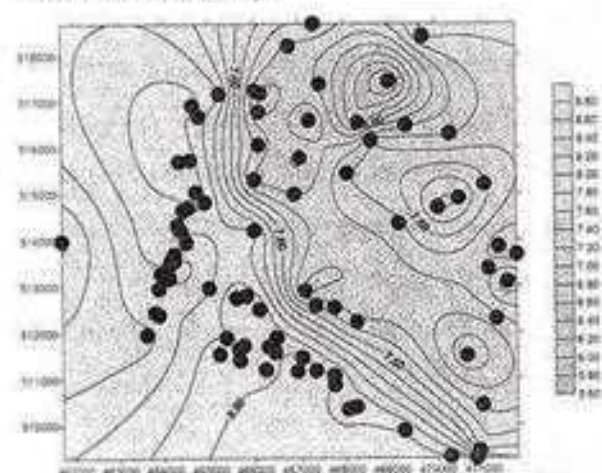


Fig.3 Conductivity areal distribution in the Caraci-Tebea-Mesteacan-Brad-Luncoiu de Jos Zone

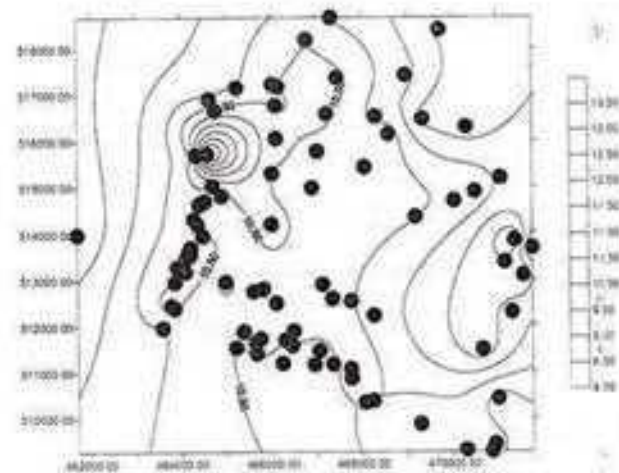


Fig.4 Dissolved oxygen areal distribution in the Caraci-Tebea-Mesteacan-Brad-Luncoiu de Jos Zone

Chemically, the stream water of Tebea and Crisul Alb Basins have been investigated, for As, Pb, Al, Cd, Co, Zn, Fe, Mn, Cu and Ni, their concentrations varying from element to element, having highest values nearby the abandoned mines.

So, the investigated waters did not contain As, Pb, Al, Cd, but Zn, Fe, Mn, Cu, Co and Ni are present in different concentrations. They have large variation intervals, specific for each element, as follows: 0.017-0.099mg/l (Cu), 0.006-0.025 mg/l (Ni), 0.00-0.0.364 mg/l (Zn), 0.00-0.307 mg/l (Fe), 0.00-0.002 mg/l (Co) and 0.00-4.044 mg/ (Mn).

The highest Ni, Zn concentration are registered on Stocului valley, but Cu, Fe, and Mn are present with high contents in steam water of Tebea valley Basin.

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LATE ARCHEAN TO EARLY PROTEROZOIC FLORESTAL GRANITE MASSIF (M.G. BRAZIL)

W.A. ROMANO¹, E. BILAL², J.M. CORREIA-NEVES¹

1- Instituto de Geociências, Universidade Federal de Minas Gerais, E-mail: Romanoaw@oraculo.loc.ufmg.br

2- CNRS-UMR 6524 Ecole Nationale Supérieure des Mines de Saint-Etienne. Email: bilal@emse.fr

The late Archean to early proterozoic Florestal Granitic Massif (FGM) is located in the South zone of the São Francisco Craton, Minas Gerais State in Southeastern Brazil. It has been emplaced (fig. 1) within granites, orthogneiss and migmatites, aged of about 2.8Gy, and volcanic and metasedimentary rocks of the Rio das Velhas Greenstone Belt aged 2.77Gy (U-Pb on zircons, Noce 1995). At its southwestern border the FGM is limited by a NW-SE shear zone, named Pitangui Lineament (Romano and Noce, 1995), which is related to a collisional event between two continental blocks, a southern one (Itaúna) and a northern one (Maravilhas). The vertical to subvertical mylonitic foliation is orientated N140°. The other structural features are lineations, crenulations and folds represented by their axis, they have a same origin and they are related to a monogenic regional deformation.

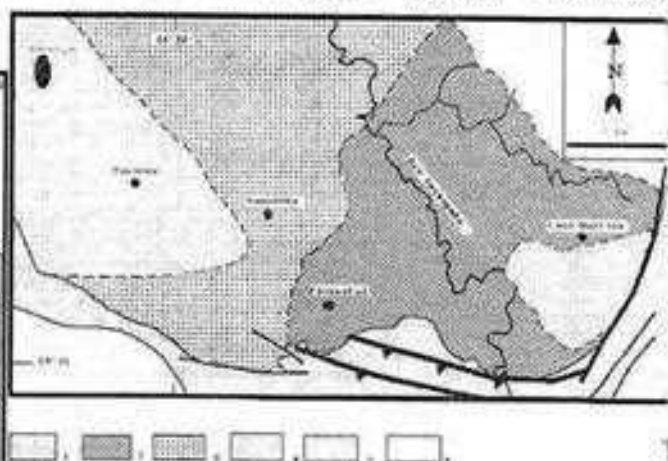
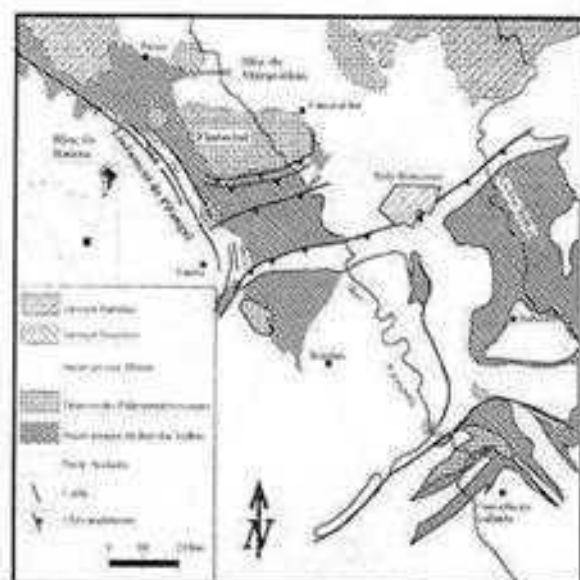


Figure 1.

Figure 2.

Figure 1: Geological sketch map of the western part of Belo Horizonte, after Romano (1989).

Figure 2: Sketch map of the granitic facies in the Florestal massif. 1: Caio Martins. 2: Padre João.

3: Lagoinha. 4: Serra do Tavares. 5: The Supergroup Rio das Velhas Greenstones Belt. 6: Archean basement.

The FGM has an oval shape extending over more than 40 km in the N140 regional trend. Relationships between FMG and the surrounding geological formations evidence the role of crustal megafaults related to a dextral transcurrent shearing fault along the N140 direction in the emplacement of the granitic rocks.

The FGM has a radiometric age of 2.59 ± 0.018 Gy (U-Pb on zircon) and the Sm-Nd method provides a Tdm model age of 2.77 Gy (Romano *et al.* 1991), similar to the age of the surroundings tholeiites and komatiites belonging to the lower volcanic sequence of the Rio das Velhas Greenstone Belt. The low initial isotopic ratio ($I_{SR}=0.704$) of the granitic rocks leads to propose either an isotopic disturbance related to the tectonic event which affected the FMG or a major role of mantle melts in the FMG magmatism. All along the shear zone, both the rocks of the Rio das Velhas Greenstone Belt and of the FGM are affected by a strong hydrothermal alteration which is expressed as well by high Al-contents as by largely developed chloritization and saussuritization.

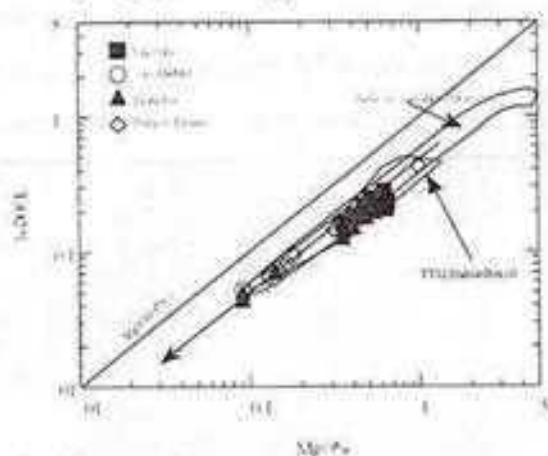


Figure 2

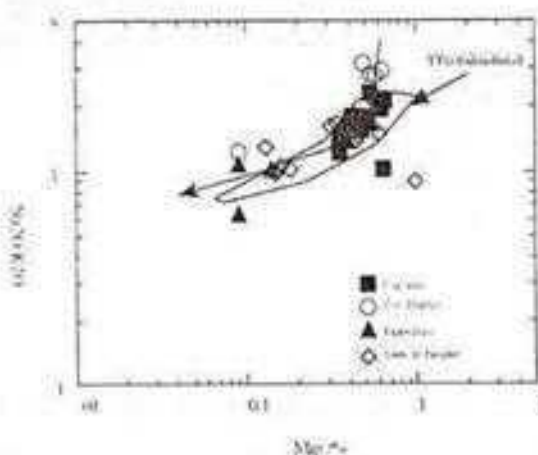


Figure 3

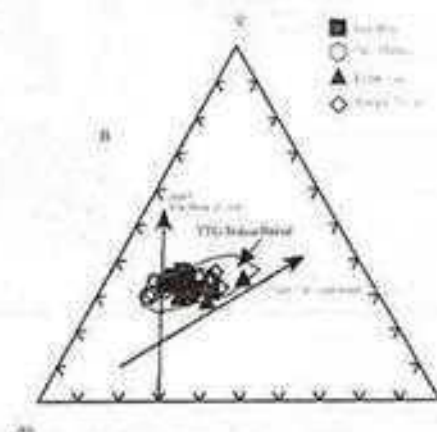
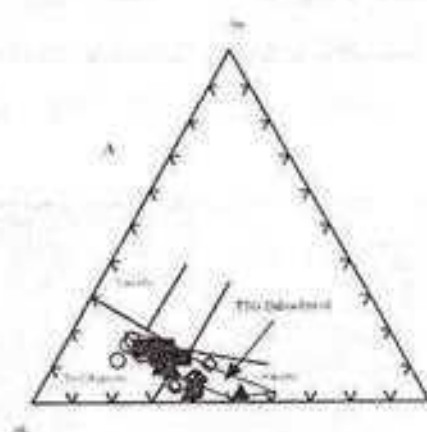


Figure 5A et 5B

Figure 3: Variations of TiO_2 vs MgO for granitoids of Florestal massif compared with the composition fields of calco-alkaline suite of Corsica (Orsini, 1980) and of TTG of Gavião block of Bahia state, Brazil (Santos Pinto, 1996).

Figure 4: Variations of $(\text{Na}_2\text{O}/\text{K}_2\text{O})$ vs MgO for granitoids of the Florestal massif.

Figure 5: Normative composition of granitoids of the Florestal massif in the diagrams: A: Anorthite-Albite-Orthose (after O'Connor, 1965, modified by Barker, 1979) et B: Quartz-Albite-Orthose (Barker and Arth, 1976).

The FGM presents four granitic facies (fig. 2) which may be recognized following their textural grain size (from fine to coarse), their structure (from isotropic to orientated in the regional trend), and their mineralogical content which presents weak variations. However those distinctive facies define an homogeneous group of rocks. The granitic rocks of the FGM are metaluminous to weakly peraluminous with an alumina saturation index (ASI) of ± 1.1 and an alpaite index $(\text{Na}+\text{K})/\text{Al}$ ranging between 0.69 and 0.88. The total alkali ($\text{Na}_2\text{O}+\text{K}_2\text{O}$) content increases from 7% up to 9% positively with the SiO_2 increase, whereas the Al_2O_3 and CaO contents decrease as a consequence of the plagioclase fractionation. Major and minor elements geochemistry (fig. 3, 4, 5a, 5b, 6a & 6b) of the granitic rocks of the FGM evidences a calc-alkaline series of trondhjemitic affinity.

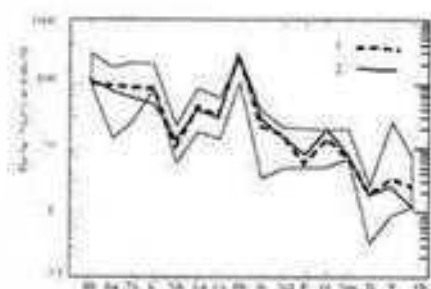
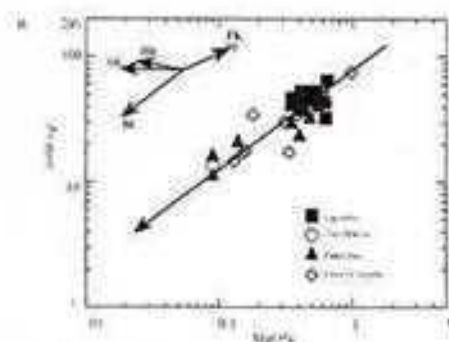


Figure 6: A : Primitive mantle-normalized trace element patterns of granitoids of the Florestal massif; normalizing values after McDonough *et al.*, (1991) compared with 1 : archaean TTG after Condie (1993) et 2 : mean TTG of Gavião block of Bahia state, Brazil (Santos Pinto, 1996).



B : Qualitative evaluation of the mineral association fractionated, Zn vs MgO . Bulk distribution coefficients are after Arth (1976) and Matsui *et al.* (1977). Ol: olivine, cpx: clinopyroxene, Hb: hornblende, Bi: biotite, Pl: plagioclase and FK: K feldspar.

Taking into account their low I_{sr} ratio as well as their model TDM age of 2,77 Gy, an origin involving the partial melting of an early basic to ultrabasic crust mantel-accreted, as evidenced by the 2,77 Ga tholeiites and komatiites of the neighbouring Rio das Velhas Greenstone Belt, may be proposed. Then, the FMG would have been generated following a scenario very close to that of the western Finland TTG (Martin, 1987).

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FROM FLUID INCLUSION STUDY TO GENESIS OF THE ANGURAN ZN-PB DEPOSIT, NW IRAN

Mahmood SADEGHI BOJD,

Birjand University, Birjand, Iran and postdoctoral student in Sweden, Mardtorps gatan3, 584 32,
Linköping, Sweden. E-mail: Sadeghi_bojd@yahoo.com and sadeghi_bojd@comhem.se

Abstract: *The Anguran Zn-Pb deposit is located within the Urumiah-Dokhtar zone, 120 Km west of Zanjan City (47° 20' E, 36° 40' N). It is one of the largest and highest-grade non-sulfide zinc deposits in the world. The data obtained from geothermometric studies of Sphalerite and fluorite associated with Zinc-Lead mineralisation at the Anguran mine are compatible with a structurally controlled, Sedimentary-hydrothermal origin. Homogenization and last ice melting temperature of primary fluid inclusion indicate that mineralization taken place over a temperature range 155-165°C and salinities of inclusion fluids range 18.63 to 22.38 wt.% TDS. Finally According to field geology, mineralogy, Geochemistry and fluid inclusion study Anguran deposit is related to the subsurface activity and the same of Irish – Type Zn-Pb deposits.*

Geology

The Angouran Zn-Pb deposit is situated in the Zanjan Province, NW Iran, approximately 450 km from Tehran. It is one of the largest and highest-grade non-sulfide zinc deposits in the world, and additionally hosts a very high grade sulfide ore body. The resources in 1999 were estimated at 13.5 Mt of non-sulfide ore with 26.4% Zn and 4.5% Pb, and 3.2 Mt of sulfide ore at 37.0% Zn and 2.32% Pb, plus 2.0 Mt of mixed sulfide-carbonate ore at 31.2% Zn and 4.1% Pb. The carbonate ores are currently exploited in an open pit around 2700 m above sea level.

Angouran is located within a metamorphic complex in the central Sanandaj-Sirjan Zone of the Zagros collisional belt close to the Urumieh-Dokhtar magmatic arc. The metamorphic rocks comprise a series of amphibolites, micaschists, and marbles of supposed Precambrian (to Cambrian) age and greenschist to amphibolite facies conditions. The crystalline complex shows internal thrusting and is thrust onto Tertiary sediments at its western margin. The basement rocks are unconformably overlain by Miocene intermediate to acidic pyroclastic and

intrusive igneous rocks, and by a succession of sedimentary deposits. The latter consist mainly of shallow marine limestones of the Aquitanian Qom Formation and evaporite-bearing, red marls and sandstones of the Upper Red Formation. Quaternary travertine terraces complete the stratigraphic section. (Glig et al,2003)

Fluid inclusion study

Considering the fact that fluorite is one of transparent ore minerals in the Anguran deposit, all fluid inclusion microthermometric measurements were carried out on this mineral and Sphalerite. It is also assumed that deposition of the coexisting (cogenetic?) galena and sphalerite has taken place within the temperature range of fluorite deposition. Doubly polished wafers were prepared from the collected samples using mount resin and thin-section methods (craige,1981 ; Roedder,1984).

Using the classifications of Nash and Theodor (1971) and Roedder (1984), Anguran fluid inclusions can morphologically divided into three distinct types:

- 1) Monophase liquid inclusions
- 2) Two phase liquid-vapour inclusions
- 3) Three phase liquid-vapour-daughter mineral inclusions

The second and Third type represents the most and least abundant types, respectively. The degree of filling of inclusions also varies from 100 % for the first type to 70% for the second and Third types. However, the degree of filling of the majority of inclusions ranges between 85-90%. The inclusions appear in various sizes and shapes including lath-shape, bar shape, negative crystal-shape and irregular. The largest observed fluid inclusion measures 150

microns in size and the smallest one just over 5 microns. Some inclusions display evidence of necking down. Figure 1 represents some of the inclusions encountered in crystals at Anguran deposit.

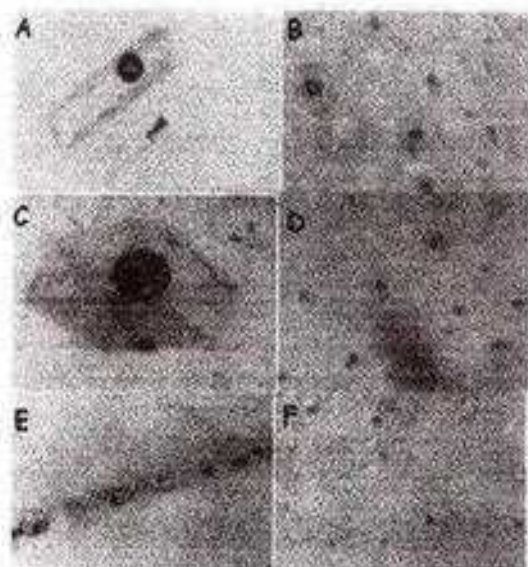
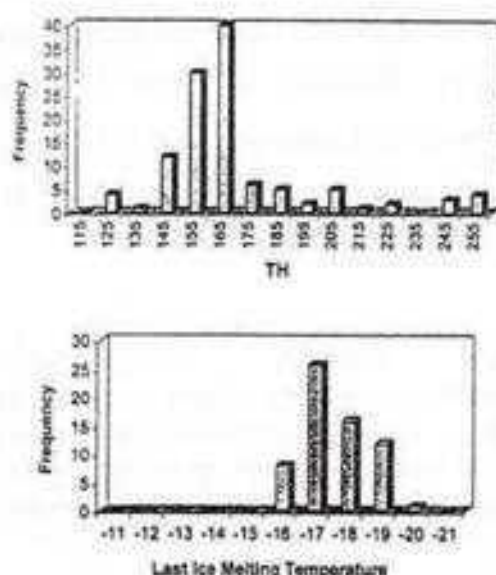


Fig 1: Different type of the Anguran fluid inclusion: A, B, and C are lath-shape, rounded and inclusion with negative crystal shapes respectively, D and E is a trail of pseudo secondary and secondary inclusions and F is a necked -down inclusion(magnification for all inclusion is 500)

Frequency histograms for homogenization and last ice melting temperatures of about 300 primary and pseudo secondary inclusions from Anguran deposit are depicted in figure 2. Homogenization was mostly to a liquid phase. The reported homogenization temperatures are uncorrected for pressure, as the morphology of the inclusions and the open space nature of mineralization indicate that mineralization took place at rather shallow depths where pressure correction can not change the measured homogenization temperatures significantly and hence was considered negligible.

Figure 2 show that mineralization has taken place in a temperature range of 125 to 255°C with a conspicuous peak at 165°C. The last ice melting temperatures of the liquid phase range from between -16 to -20°C with -17°C being the most frequent. This melting range corresponds to a salinity of 18.63 to 22.38 equivalent weight percent NaCl. Eutectic point temperature for $\text{CaCl}_2\text{-H}_2\text{O-NaCl}$ aqueous system is -52°C (Crawford, 1981). The colour of

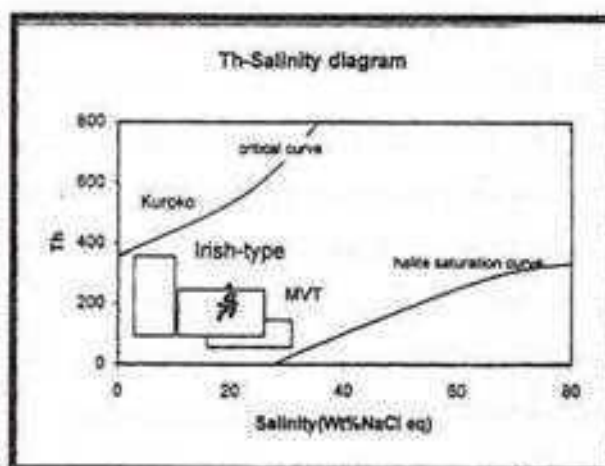


ice during the freezing in Samples of fluorite in Anguran deposit was Brown, indicate that composition of fluid is $\text{CaCl}_2\text{-H}_2\text{O-NaCl}$. Low first (-45°C), hydrohalite (-35°C) and ice melting (-24 to -26°C) temperatures indicate Ca-Na-Cl brines with high salinity (18-23 wt.% TDS) and Ca dominance. Preliminary crush-leach analyses show very high and variable Br/Cl ratios suggesting fluid mixing and probably the participation of highly evaporated sea water.

Fig2: Homogenization and last ice melting temperature of fluid inclusions in Anguran ore deposit.

Although it is difficult to generalise about the properties of fluid inclusions that occur in different type of ore deposit, a number of parameters are consistent enough to be worth summarising. The most obvious and simplest way of characterising the fluid inclusions present in mineralized system is in terms of homogenization temperature and NaCl equivalent salinity. Whilst these properties are not direct functions of fluid temperature and fluid salinity. The general relationship which exist and the natural variability of these two parameters in hydrothermal system make them useful for comparative purposes.

Fig 3 represents a compilation of Th and salinity information from different zinc deposit types, drawing significantly on the summaries of Roedder (1984) together with a wide range of published data (Willkinson, 2001). The main classes of ore deposits occupy broad fields in Th-Salinity space which reflect the basic properties of the fluid involved in their formation and are broadly constrained between the halite saturation curve and the critical curve for pure NaCl solutions. For instance, epithermal deposits are primarily formed from modified, surface-derived fluids that have circulated to a range of depths within the brittle regime of the crust, often in areas of elevated crustal permeability and heat flow. They are therefore typified by low salinity fluids and a range of homogenization temperature that, because of the generally low trapping pressure involved, serve as an approximation of trapping temperature, spanning the typical epithermal range of < 100°C to 300°C. It should be emphasized that such fields are not sharply determined and that examples exist which do not fall in to the defined ranges; such information should solely be used as a guide and provides for the inexperienced worker a feel for the type of data characteristic of different mineralizing systems.



However, the data of fluid inclusions in Anuran deposit shows that the deposit is the same of Irish type Zn deposit.

Fig3: Summary homogenization temperature- salinity diagram illustrating typical ranges for inclusions from different Zn-Pb deposit type. Data of inclusion in the Anguran deposited plotted in this diagram

Fluid density

Homogenization temperature information when coupled with fluid salinity data defines the density of the fluid, irrespective of fluid trapping conditions. Variation in fluid density is particularly important with respect to mechanisms of fluid flow process. A particularly useful diagram in this respect is a conventional Th-Salinity plot but contoured with lines of constant fluid density (Fig 4, Bodnar, 1983). Fluid inclusion data can be plotted on such a diagram and density variations considered. Fluid inclusion data at Anguran deposits plotted in Fig 4.

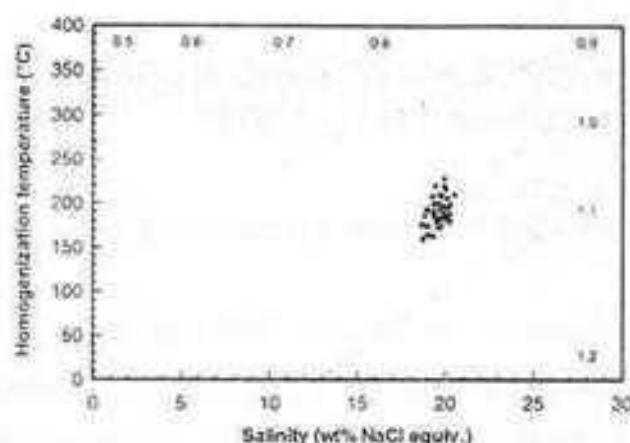


Fig 4- *Th-Salinity plot showing densities gcm^{-3} of vapour-saturated NaCl - H₂O solutions. Data of fluid inclusions of the Anguran deposit plotted in the diagram*

Conclusion

Homogenization and last ice melting temperature of primary fluid inclusion indicate that mineralization taken place over a temperature range 155-165°C and salinities of inclusion fluids range 18.63 to 22.38. Although it is difficult to generalise about the properties of fluid inclusions that occur in different type of ore deposit, a number of parameters are consistent enough to be worth summarising. The most obvious and simplest way of characterising the fluid inclusions present in mineralized system is in terms of homogenization temperature and NaCl equivalent salinity. Whilst these properties are not direct functions of fluid temperature and fluid salinity. The general relationship which exist and the natural variability of these two parameters in hydrothermal system make them useful for comparative purposes. Finally According to field geology ,mineralogy, and fluid inclusion study Anguran deposit is related to the subsurface activity and the same of Irish -Type Zn-Pb deposits.

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DETECTION OF BURIED OLD TOMBS USING GROUND MAGNETIC METHOD IN AN ARCHEOLOGICAL SITE, EGYPT

Mahmoud M. SENOSY

Geology Department, Assiut University, Assiut 71516 Egypt, Email: senosy@aun.edu.eg

Abstract: *The studied archeological site is located in the Western Desert of Egypt. It is characterized by occurrence of large number of buried old cemeteries. Some of these cemeteries that constitute a compound tombs discovered by manual digging, however most of them are still hidden. The ground magnetic survey was conducted to detect the buried tombs. The measurements were taken along eight profiles extending E-W and N-S. The distance between profiles was 60m and between stations along the profile was 3m. The Euler de-convolution and analytic signal were the techniques that gave the most realistic and accurate results. At the middle, northern and eastern parts of the study area, there are a series of high and low magnetic anomalies of circular and semi-circular shape pointing to presence of connected cemeteries. These cemeteries are mainly empty and some of them are include metallic relics or stones of high magnetic minerals (e.g. granite, basalt, diabase,etc). The cemeteries are found at different depth levels beginning from the surface to depth 12m below ground level. Step cemeteries were also recorded in the area especially at depth interval 8 – 12m. Such style of cemeteries was observed by manual excavation in the site. No cemeteries can be expected after depth 12m and any anomalies after this depth may be related to local geologic structures. All cemeteries were constructed away of the major N-S Tarief-Ter fault and its related minor faults. This releasing the fact that, Pharaonien men were aware very well by the geologic features.*

Field work, data processing and interpretation

The total magnetic field intensity survey for the study area was carried out using Geometrics G-850 Proton Precession Magnetometer. The resolution of the magnetometer is about 0.1 nanotesla (nT). The magnetic survey in the area was completed along eight lines extending W-E and N-S. Lengths of these lines ranged from 150 to 370m, while the observations were taken at 3 m interval along the lines. The separation between the survey lines was around 60m. The lines were nominated profile 1, 2, 3,, and 8 (Fig. 1B). Since the magnetic data become available from the field surveys, the data were corrected from the magnetic field diurnal variations using the base station measurements. The total magnetic field intensity and RTP maps of the area were prepared (Fig. 1C & 2A). The residual magnetic anomaly map was also obtained (Fig. 2B).

In any geophysical work, the common parameter sought for by all methods, is undoubtedly, the location of the magnetic source bodies and their depths. To verify and improve the feasibility of the magnetic method in detecting near surface archaeological targets, results of different advanced techniques (e.g. band pass filter, derivative calculations, continuation, spectral analysis, analytic signal and Euler de-convolution) were integrated. The analytic signal and Euler de-convolution were the techniques that gave the most realistic and accurate results.

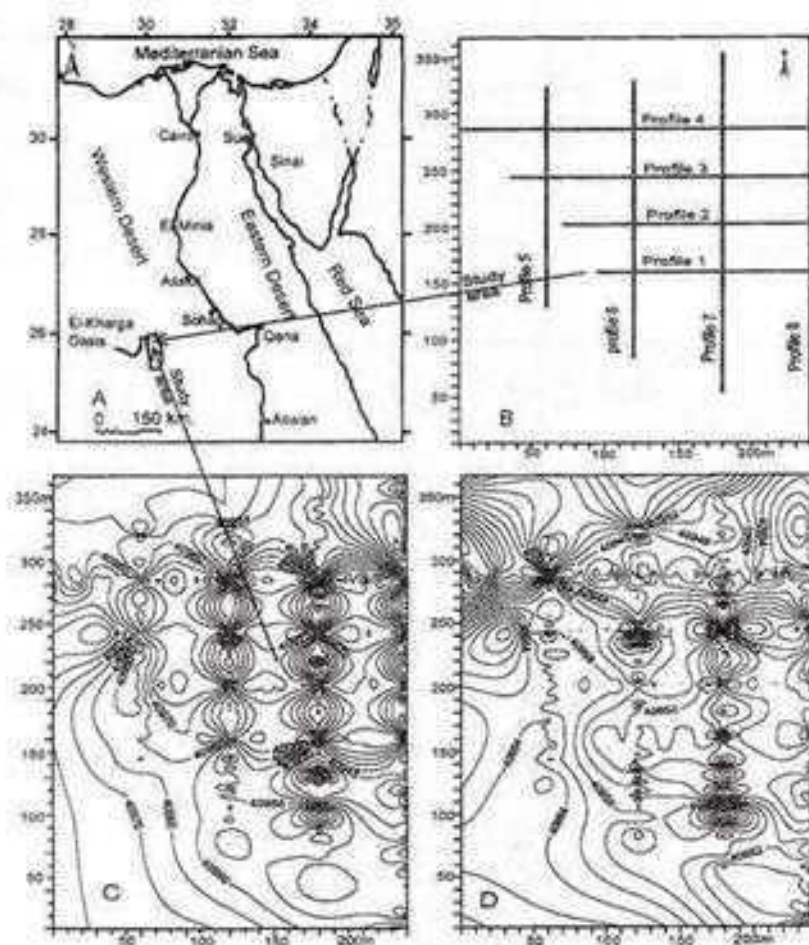


Fig. 1: A) Location map of the study area, B) Location map of the measured profiles, C) Total intensity magnetic anomaly map, and D) The reduced to the pole (RTP) map

Results and discussion

Analytic signal analysis

The results of the analytic signal calculations of the residual magnetic data are presented as contour map (Fig. 2B) and 3D orthographic view (Fig. 2C). The analytic signal contour map showed that, circular, semi-circular and rectangular anomalies occupy the eastern, middle and northern parts of the study area. The outer lines of these analytic signal anomalies are denoting to the edges of the expected cemeteries. Therefore, it is easy to calculate the horizontal dimensions

(length and width) of the cemeteries from short and long axes inside the outer contour lines of the analytic signal anomaly. From measuring the short and long axes of the analytic signal anomalies, it can be seen that most of the predominance cemeteries have horizontal dimensions (length and width) ranging from 3 to 10m. However, some large cemeteries are distributed all over the area, particularly at the middle and northern parts (marked by dense and large closed contours) having dimensions ranging between 10 and 25m. These features can be easily seen very well on the 3D orthographic view (Fig. 2C). In this figure the narrow cemeteries are represented by short and small peaks, however, the large cemeteries are seen as long and wide peaks. The high and sharp peaks indicating to cemeteries of vertical walls, however, the wide ones denoting to either cemeteries of inclined walls or connected small cemeteries at different depth levels as those observed in the middle and northern parts of the study area. This type of cemeteries is called here step cemeteries.

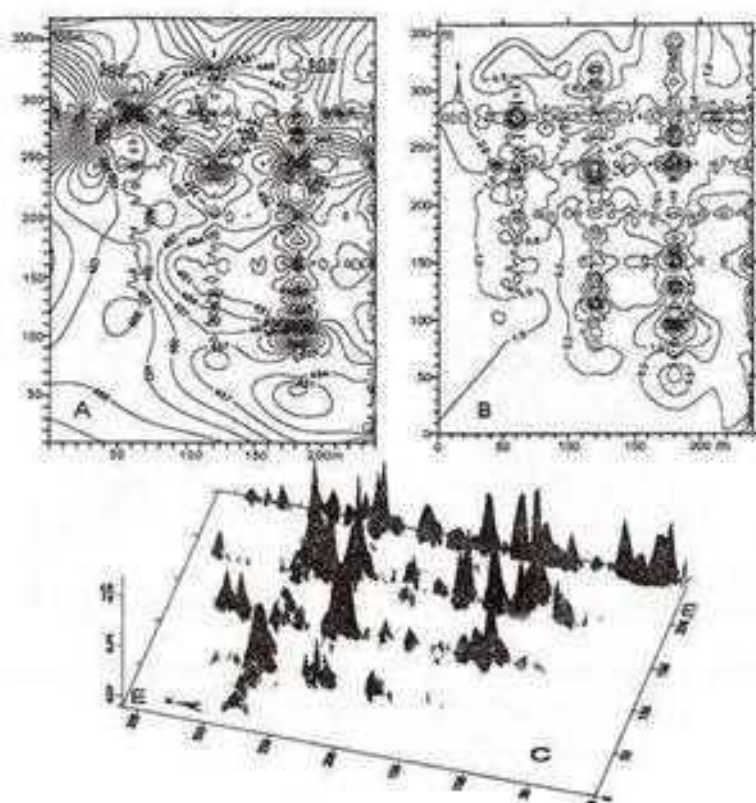


Fig. 2: A) The residual magnetic anomaly map, B) The analytic signal contour map, and C) The 3D orthographic view of the analytic signal results

Euler de-convolution analysis

The Euler solutions were conducted by structure index 2 & 2.8 and window size 3 & 5. The results of the solutions were presented as squares (Fig. 3A), the edges of the squares represent the location of the cemeteries however, the diameter of these squares pointing to depth of the cemeteries. Figure 3A represents all detected cemeteries in the study area. Euler solutions were

separated according to the depths of the cemeteries into six levels. Level 1 shows the cemeteries situated at depth ranges form 0 to 2m, level 2 from 2.0 to 4.0m, level 3 from 4.0 to 6.0m, level 4 from 6.0 to 8.0, level 5 from 8.0 to 10.0. Figures 3B&C show the cemeteries that situated at depth 0.0-2m and 2-4m respectively as an example.

Conclusion

From the above mentioned discussions it can be concluded that the studied archeological site have a large number of buried cemeteries. The cemeteries are concentrated in the eastern, northern and middle parts at depths beginning from the surface to depth 12m below the ground level. Step cemeteries are dominated at depths from 8.0 to 12.0m especially in the middle and northern parts. Some of the detected cemeteries are empty, however some others contain metallic relics or stones of crystalline rocks. The later ones are present in the northern parts of the area. All cemeteries were constructed away of the major N-S Tarief-Ter fault and its related minor faults. This indicated that, the Pharaonien were aware very well by the geologic features prevailing in the area. The excavation of these cemeteries is very important to bring out the buried relics, stones and mummies which have historical values.

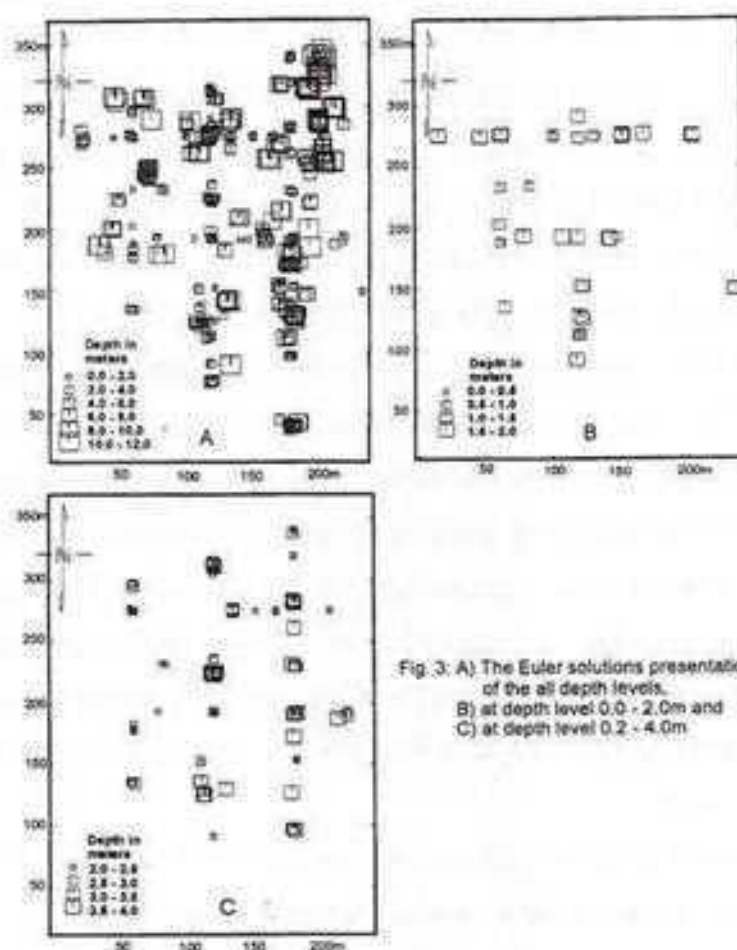


Fig. 3: A) The Euler solutions presentation of the all depth levels.
B) at depth level 0.0 - 2.0m and
C) at depth level 2.0 - 4.0m

EXPLORATION PROGRESS ON BUCIUM RODU FRASIN GOLD DEPOSIT

C. SZENTESY¹, A. MINUT¹, G. O'CONNOR¹

¹S.C. Rosia Montana Gold Corporation S.A., 321, Piata Str., Rosia Montana, Alba County, Romania,
cecilia.szentesy@rmgc.ro, adrian.minut@rmgc.ro, gary.oconnor@rmgc.ro.

The Rodu and Frasin prospects are interpreted to occur in a maar – diatreme complex of Neogene age emplaced into a sequence Cretaceous sediments. The dominant lithologies mapped in the project areas comprise Cretaceous sediments, phreato-magmatic polymictic breccias (locally termed “vent breccia”) and dacitic intrusive.

The Rodu-Frasin diatreme complex occurs along a regional north-northwest structural trend extending from north of Rosia Montana to the south end of the Bucium tenement area. The location of the diatreme complex along this structure is interpreted to be controlled by dilation due to a cross cutting structure interpreted to be steeply dipping northeast trending faults.

The gold-silver mineralization outlined at Bucium is interpreted to represent a shallow level, low sulphidation epithermal system. The mineralization is located within an extensive zone of strong hydrothermal alteration and is dominantly disseminated, with associated stockwork and breccia hosted gold-silver mineralization. Gold-silver mineralization at Bucium is predominantly hosted in Frasin dacite and Rodu vent breccia.

The Frasin area is dominated by a shallow dacitic intrusive of Neogene age, intruded sub-vertically through the Cretaceous sediments, with significant brecciation along the contact. In areas of weaker hydrothermal alteration the dacite contains phenocrysts of quartz, feldspar, biotite and hornblende with accessory apatite and zircon in a very fine groundmass.

Gold-silver mineralization is associated with pervasive adularia – clay (illite-smectite) – carbonate +/- silica alteration, disseminated pyrite and associated quartz-carbonate-sulphide veining and brecciation. Most of the mineralization occurs within a single north-south trending zone, which dips moderate to steeply towards the east in the north, and becomes more vertical to the south.

It is also noticed a vertical zonation with the best grades bellow level +800m and low grades above this level. This vertical zonation is interpreted to be due to a distinct boiling

horizon, producing a well-mineralised horizon and with only poorly mineralised dacite above this.

A significant hydrothermal breccia pipe occurs at the south end of Frasin at the interpreted intersection of the main north-south trend and the northeast trending structure. The breccia pipe contacts with the dacite are sharp and the alteration around the pipe quickly becomes propylitic. This is one of the few locations where the majority of mineralization is hosted by open space infill (breccia matrix) style mineralization rather than by altered dacite.

Based on the ordinary kriged gold and silver estimates for blocks measuring 40m east by 40m north by 10m RL, and using a cut off grade of 0.6 g/t, a resource estimate (indicated plus inferred categories) of 16.2 million tonnes at 1.4 g/t gold and 4.3 g/t silver was calculated for Frasin.

Flanking the Frasin dacite intrusive to the west is a massive, unsorted, matrix supported polymictic breccia of phreato-magmatic origin, which is locally referred to as a "vent breccia" from Rodu area. This is dominated by clasts of Cretaceous sediment, which include shale, sandstone, conglomerate and limestone and clasts of dacite.

Significant gold-silver mineralization is associated with silicic, carbonate and adularia alteration with finely disseminated pyrite and infrequent veining. Veins are generally narrow (up to 1m) and strike north-northwest for up to 300m and have a moderate to steep westerly dip.

Based on the ordinary kriged gold and silver estimates for blocks measuring 40m east by 40m north by 10m RL, and using a cut off grade of 0.6 g/t, a resource estimate (inferred category) of 21.3 million tonnes at 0.78 g/t Au and 2 g/t Ag was calculated for Rodu.

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SIMPLIFIED ECONOMIC FILTERS FOR GOLD DEPOSITS

Sorin TAMAS-BADESCU, Gabriela TAMAS-BADESCU

GEOEXPERT S.R.L., Deva, geoexpert@smart.ro

Keywords

Discounted cash flow (DCF), net present value (NPV), sensitivity analysis, Monte Carlo simulation, economic filter, risk profile.

Introduction

The economic viability of any mining or exploration project depends on the reserve/resource quantity and quality and relies on certain relationships between production capacity, capital and operating costs and returns.

The aims of this paper are to present some simple tools, based on DCF analysis and Monte Carlo simulation, for estimating the economic viability of the gold projects in the earliest stages of exploration.

Analysis of the production records

In order to establish the above-mentioned relationships, data for over 110 projects developed worldwide (fig. 1) have been collected from various sources. Data from 2003, are plotted in fig. 2 to 7.

The deposits belong to all metallogenetic types, excepting placers. Most of the deposits are mined or are planned to be mined exclusively for gold, excepting few cases, in which Ag, Pb, Zn, Cu are also extracted. The deposits are mined in open pits or/and underground. The ores are processed mainly by cyanide leaching.

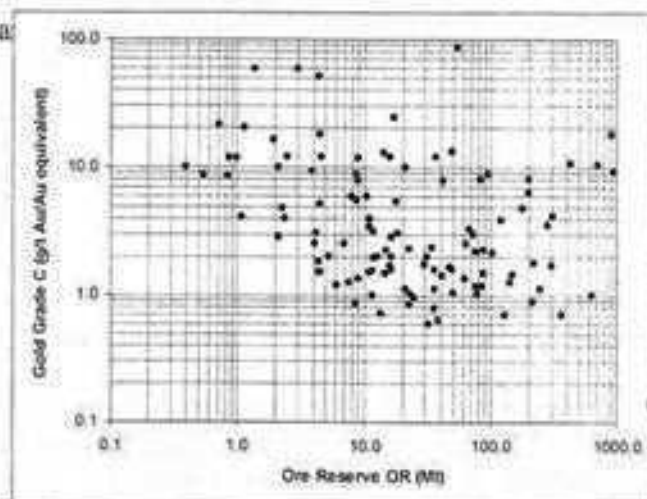


Fig.1. Grade and tonnage of the deposits used in the analysis.

Simplified DCF model

The regression equations from fig. 2 to 7 could be used for estimating the main economic parameters (optimal production rate and the average correspondent capital and production costs) of a project, starting from the deposit's resource data.

A simplified discounted cash flow model (table 1), using a Microsoft Excel spreadsheet, could be built for a broad evaluation of the economic viability of the project in the early stage of knowledge. The analysis results could be plotted as in fig. 8.

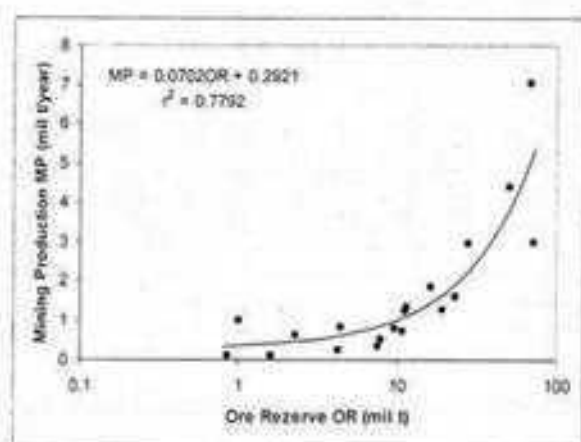


Fig. 2. Ore reserve – mining production correlation

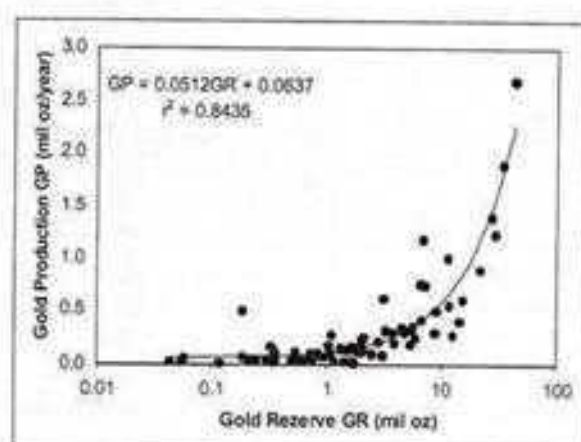


Fig. 3. Gold reserve – gold production correlation

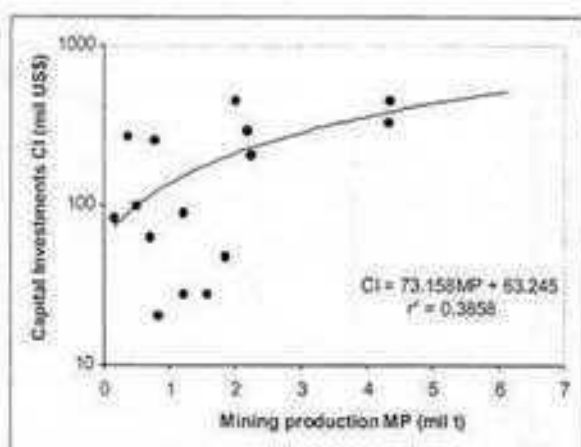


Fig. 4. Mining production – capital investments correlation

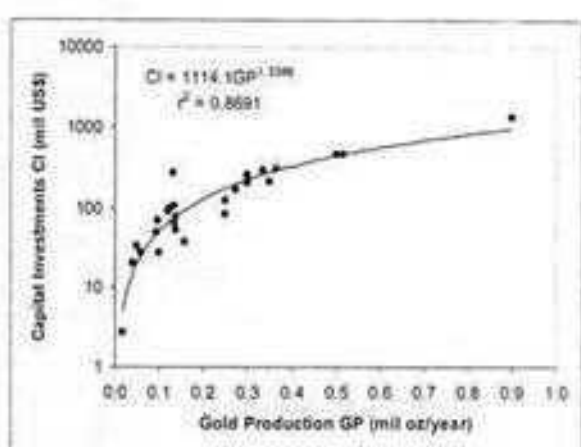


Fig. 5. Gold production – capital investments correlation

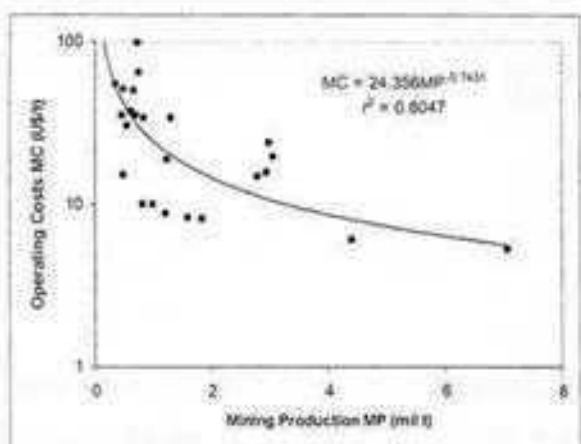


Fig. 6. Mining production – operating costs correlation

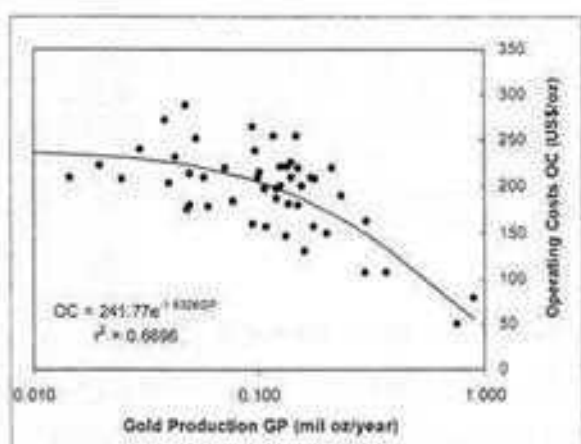


Fig. 7. Gold production – operating costs correlation

Table 1. Discounted cash flow model

		Pre-production	1	2	3	4	5	6	7	8	9	10
Gold production	$GP = 0.0512GR + 0.0637$		0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.07
Mining production ($C=3.5g/t$)	$MP = (GP \cdot 31.10)/C$		1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	0.7
Income @ 400 US\$/oz (mil US\$)	$I = GP \cdot 400$		50	50	50	50	50	50	50	50	50	30
Capital investments (mil US\$)	$CI = 1114.1GP^{1.356}$											
Operating costs (mil US\$)	$OC^* = (24.356 \cdot MP^{0.7425}) \cdot PM$	69	25	25	25	25	25	25	25	25	25	25
Cash flow (mil US\$)	$I - OC^*$	-69	25	25	25	25	25	25	25	25	25	15
Discounted cash flow (mil US\$)	@ 15%	-69	25	22	19	16	14	12	11	9	8	4
DCF criteria												
NPV (mil US\$)		73										
IRR		34%										

In any stage of a project, there is a degree of uncertainty regarding the estimated technical and economical parameters used in the DCF analysis. The Monte Carlo simulation (fig. 9) allows estimating the risk given a certain range of variation of the DCF's input parameters.

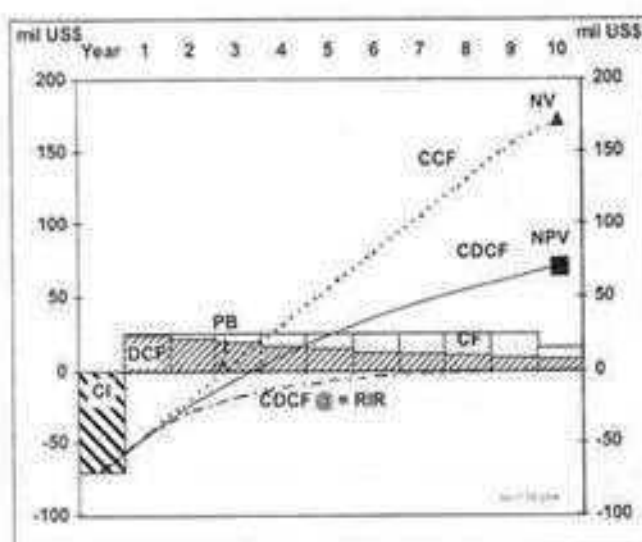


Fig. 8. Graphical representation of the DCF model (@ 15%)
CI - capital investments, *CF* - annual cash flow, *DCF* - discounted annual cash flow, *CCF* - cumulated cash flow, *CDCF* - cumulated discounted cash flow, *CDCF @ = RIR* - cumulated discounted cash flow at a discount rate equal with the internal rate of return (34%), *NV* - net value, *NPV* - net present value, *PB* - payback period

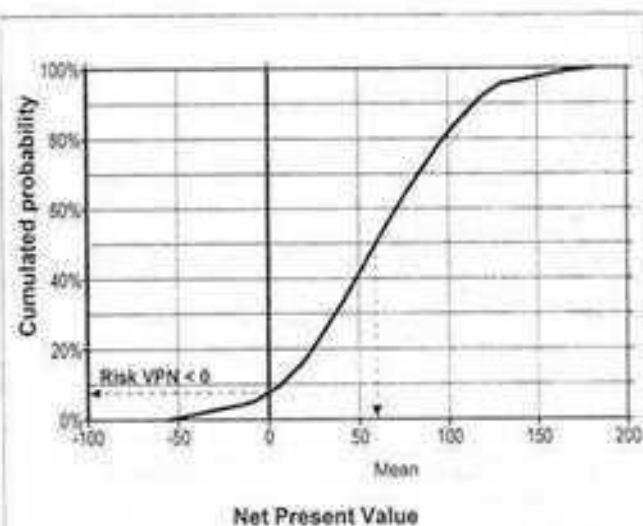


Fig. 9. Results of the Monte Carlo simulation (gold price, capital and operating costs varying with $\pm 30\%$ from the base case)

Minimal reserve/ resource

The net present value of a deposit represents the discounted difference between the incomes and costs (including capital and operating costs). As the total income is function of gold reserve quantity and price, it is obvious that at a certain gold price, the deposit should have a minimal gold reserve to be economic. Using a series of DCF models, the minimal gold reserves/ resources requirements for various gold prices have been calculated (fig. 10 and 11).

Monte Carlo simulations have been performed for certain points along the grade/ ounces regression line (fig. 11). Fig. 10 and 11 represent economic filters that could be used in targeting the exploration.

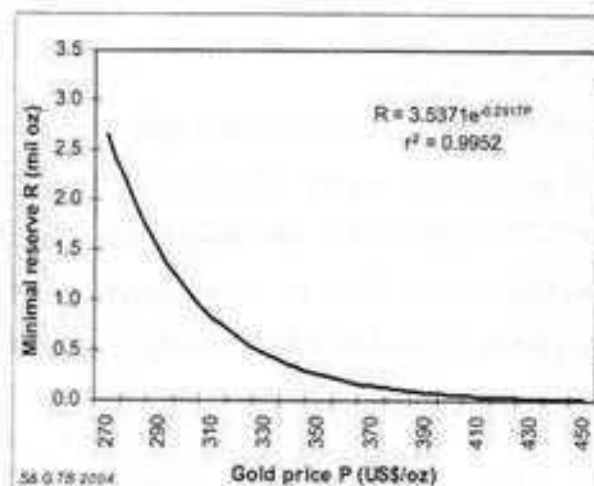


Fig. 10. Minimal gold reserve/ resource requirements (VPN ≥ 0 @ 15%) for different gold prices.

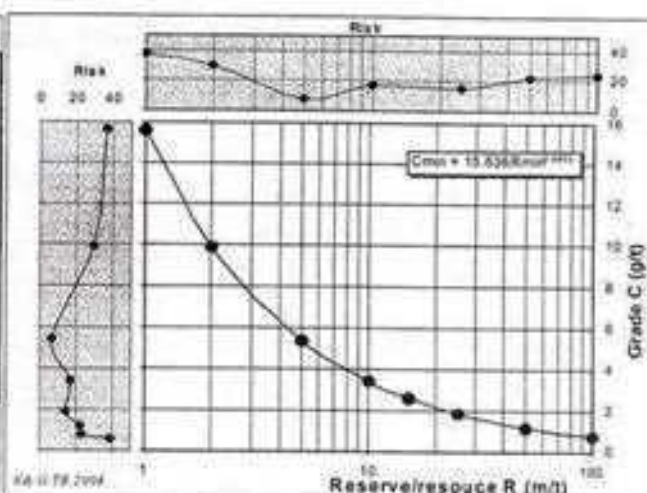


Fig. 11. Economic filter based on the minimal reserve/ resource requirements (VPN ≥ 0 @ 15%) at different gold prices completed with risk profiles

Risk adjusted economic filter

Risk profiles for a wide range of gold resource/ reserve quantities and grades (fig. 12) were drawn using the Monte Carlo simulation technique, considering the gold price varying between 270 and 450 US\$/oz and the ranges of variation of the mining and economical parameters resulted from fig. 2-7. Based on these profiles, a risk-adjusted filter was drawn (fig. 13). It could be used in the early stage of exploration to evaluate the probability of a deposit to be economically viable.

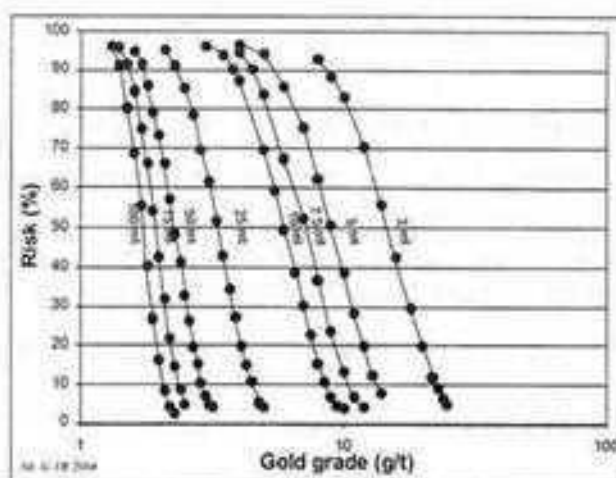


Fig. 12. Risk profiles (VPN ≤ 0 @ 15%) for different resources/ reserves

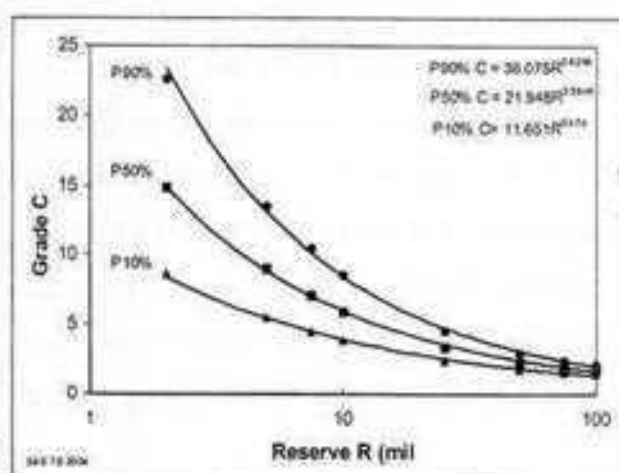


Fig. 13. Risk adjusted economic filter (VPN ≥ 0 @ 15%)

Reference

Singer D.A., Menzie W.D., Long K.R., 1998 - A simplified economic filter for open-pit gold-silver mining in the United States; *U.S.G.S. Open-File Report 98-207*

NATIVE PLATINUM AT PIANU, SEBES COUNTY, ROMANIA

UDUBASA¹ Gheorghe, POP² Dana, COSTEA¹ Constantin

¹Geological Survey of Romania, 1 Caransebes street, Bucharest, Romania

²Babes-Bolyai University, Cluj-Napoca, 1 Kogalniceanu street

The alluvial heavy mineral concentration at Pianu is mainly known as a gold occurrence. Gold washing was nearly continuously undertaken in the last century. More details about this occurrence are given in the papers of Marincas (1965), Hadnagy¹ (1969) and Galcenco et al. (1995). A nice "gold snake" of about 1mm is shown in Ramdohr's book (1955) in an association including magnetite, ilmenite, titanomagnetite, monazite and garnet. Other minerals occurring in the Pianu alluvial sands were described by Saulea (1934-1935). The whole mineral association is given in the table.

The first mention of native platinum at Pianu (so far the only occurrence in Romania) appeared in the book of Ackner (1855), who gave the following, partly amazing information "Nach der Wiener Zeitung (?) sind Spuren des Platins (Eisenplatins) im Goldseifenwerke von Olahpian mit Titan, Nigrin u.v.a. vergesellschaftet, entdeckt worden"². Afterwards the information was taken over by Zepharowich (1859, 1893), Bielz (1889), Koch (1888), Poni (1900), Cadere (1925-1928), Radulescu & Dimitrescu (1966), Udubasa et al. (1992).

In the mineralogical collection of the Babes-Bolyai University in Cluj-Napoca there is a small (very old) sample of alluvial sand from Pianu, labelled "Platina". Investigation of the sample led to the identification of several grains, mostly rounded and zoned, showing minute inclusions of iron oxides and sulphides (Figure). EPMA¹ on most homogeneous parts of the grains gave the following results (wt %): 90.63-93.92 Pt and 6.08-9.37 Fe.

The platinum from Pianu is thus a ferroan variety named "polyxene" in the older papers (3-11 per cent Fe). It is the first analytical proof of the existence of the mineral, some 150 years after the first mention. Further work is now in progress in order to obtain other data on this unique platinum occurrence in Romania, including also some thoughts on gold and platinum source(s). Anyhow, it is already shown that the gold source at Pianu is multiple, both FeTi oxides in association with kyanite and chromian spinel in ultramafics (Udubasa et al., 1992a).

¹ Hadnagy reported that a gold nugget weighting 467g should have been found in 1837.

² "According to the Wiener Zeitung (?) traces of platinum (iron platinum) have been found (discovered) in the alluvial gold workings at Pianu, in association with titanium, nigrin and many others".

Table
Mineral species identified at Pianu

Native elements	Sources
Gold	1; 2; 3; 4; 5; 6
Platinum	1; 7
Copper	1; 6
Iron	1; 6
Lead	1
Graphite	6
Sulphides	
Pyrite	6
Pyrrhotite	6
Chalcopyrite	6
Oxides	
Magnetite	2; 4; 6; 8
Ilmenite	2; 4; 6; 8
Rutile	1; 2; 6; 8
Titanomagnetite	4
Hematite	6
Cr-spinel	6
Corundum	1
Fergusonite (?)	9
Goethite	6
Phosphates	
Apatite	8
Monazite	4; 8
Silicates	
Garnets	4; 6; 8
Olivine	1
Zircon	8
Titanite	6; 8
Sillimanite	10
Kyanite, andalusite, staurolite, tourmaline, actinolite, tremolite, hornblende, epidote-zoizite, muscovite, serpentine minerals, talc and chlorite were also described by Saulea (8).	

Sources

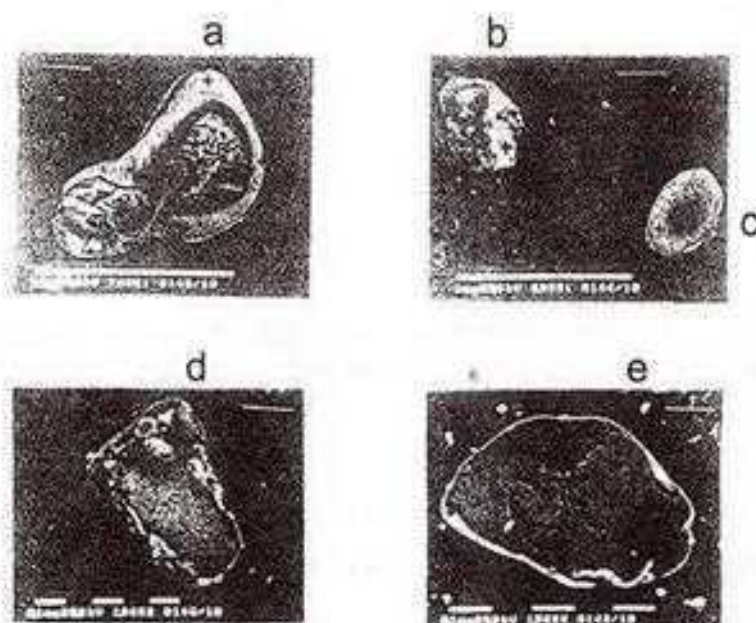
1 Ackner (1855); 2 Hadnagy (1969); 3 Galeenco et al (1995); 4. Ramdohr (1955); 5. Poni (1900); 6. Udubasa (1987, unpubl. report); 7 This study; 8 Saulea (1934-1935); 9 Koch (1888); 10 Radulescu & Dimitrescu (1966).

Note: Copper, lead and iron may be considered artifacts, as the copper and the iron were observed by Udubasa (1987) in association with magnetic spherules of industrials origin. Globular copper, iron and even gold occur in a matrix of olivine, magnetite, may be wustite too.

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¹ Working conditions: SEM PHILIPS 515, accelerating voltage 25KV, equipped with EDAX; correction programme PV.9900.

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SEM micrographs of platinum grains from Pianu

The scale bar is 0.1mm

	A	B	C	D	E
Pt	93.92	91.15	91.41	90.87	90.63
Fe	6.08	8.85	8.59	9.13	9.37

PARAGENESES AND GEOCHEMISTRY OF GOLD FROM VALEA LUI STAN AND COSTESTI ORES, SOUTHERN CARPATHIANS, ROMANIA

UDUBASA Sorin Silviu

University of Bucharest, Faculty of Geology & Geophysics; 1, Nicolae Balcescu Blvd., Bucharest, Romania;
e-mail: udubasa@geo.edu.ro.

Valea lui Stan (Brezoi) and Costesti (Horezu) mineralizations are two examples of shear zone related gold mineralizations within the Getic-Supragetic Realm of the Southern Carpathians in Romania. The two mineralized structures are localized in the eastern part of the Capatanii Mts., west of Olt River. The ore bodies are both discordant and concordant to the fabric of the metamorphic rocks.

The mineralization from Valea lui Stan (Brezoi) occurs mainly in the Sibisel Group metamorphics, in connection with N-S brittle-ductile shear zones related to the Getic-Supragetic Alpine nappe stacking. The protore of the mineralizations is considered the amphibolitic sequences of the Sibisel Group, argued by the higher Au content in respect to other (similar) rocks in the area (Udubasa & Hann, 1988).

In the case of Costesti (Horezu) mineralization, the ore bodies are located in the Vaideeni Formation (Apostoloiu et al., 1990), along the possible eastward extension of the pre-Alpine "Ramesti blastomylonitic zone" described W of Costesti Valley by Viorica Iancu (in Hartopanu et al., 1988). Here, the biotite blastomylonites sequences are considered the protore for the mineralization, the geochemical analyses pointing out higher Au content for this kind of rocks in respect to others (Hartopanu et al., 1991).

Although similar, the two shear zone related gold mineralizations show distinctive geochemical spectra (Udubasa, 1993; Udubasa & Udubasa, 2002) in respect to other occurrences with same genesis in the Southern Carpathians:

Valea lui Stan	Au - As - Cu
Costesti	Au - As - Bi
Valiug	Au - As - Sb
Jidostita	Au - As - Pb

The difference could be mainly the effect of the protore composition, e.g. amphibolites for Valea lui Stan and biotite blastomylonites for Costesti (Udubasa & Hann, 1988; Hartopanu et al., 1988).

The geochemical spectra could be completed by the secondary (minor) elements (Udubasa, 2004):

Valea lui Stan	Cr - Ni - Pb - Zn
Costesti	Cr - Ni - Se - Cd

At Valea lui Stan the paragenesis is dominated by pyrite, chalcopyrite, arsenopyrite, which are also the main host minerals for gold; quartz is the main gangue mineral. Other metallic minerals have been also described by previous authors (Petrulian, 1936; Udubasa & Hann, 1988): pyrrhotite, sphalerite, galena, tetrahedrite-tennantite, native gold, bornite, magnetite, ilmenite, hematite; as secondary minerals are cited: marcasite, goethite, covellite, chalcocite, malachite, azurite, anglezite, cerussite, scorodite. Calcite occurs sometimes as gangue mineral too. Possible new minerals for this occurrence have been identified by qualitative analysis – SEM (Udubasa, 2004): Sb minerals (secondary) on the arsenopyrite cracks and a Cu-Bi-Hg-Pb-Fe-S compound in association with chalcopyrite and arsenopyrite.

The mineral paragenesis of the Costesti occurrence is larger as the one from Valea lui Stan. Here, pyrite and arsenopyrite prevail in the ore minerals association. Quartz, carbonates (calcite, ankerite) and chlorite are the main gangue minerals. Other ore minerals known in the paragenesis are as follows (Apostoloiu et al., 1990; Hartopanu et al., 1991): chalcopyrite, bismuthinite, tetrahedrite-tennantite, sphalerite, jamesonite, greenockite, pyrrhotite, galena, native gold, native silver, native bismuth, wittichenite, unidentified Bi sulfosalts (containing Bi, Pb, Ag, As, S), magnetite, marcasite, arsenolite. New entries for the mineral association can also be cited (Udubasa, 2004): cubanite, "Zwischenprodukt", Ca-bearing pyrrhotite, ikunolite (?), "schreibersite"-like minerals, "merumite" compounds.

Gold occurs in both mineralizations as inclusions in sulfides or in gangue minerals.

In the Valea lui Stan ores the native gold occurs as inclusions in arsenopyrite, chalcopyrite pyrite, quartz, and sometimes in goethite. Petrulian (1936) has separated two frequent associations for gold: Au-arsenopyrite and Au-chalcopirite-arsenopyrite ($\pm$ sphalerite). New electron microprobe analyses performed on different gold grains reveal several peculiarities (Udubasa, 2004). The gold grains show significant Ag content and Cu, Ni, Mn and Bi are also present. The gold fineness varies from 246.51 to 835.92 ‰. Two distinctive compositional fields can be observed for the gold grains plotted on a ternary diagram Au – Ag – Cu*10 (Fig. 1), corresponding to different host minerals of the gold grains:

- Au alloy with low Ag content (25-40 at.% Ag) for the Au grains included in chalcopyrite;
- Au alloy richer in Ag (close to "electrum"; 45-60 at.% Ag) for the Au grains included in arsenopyrite.

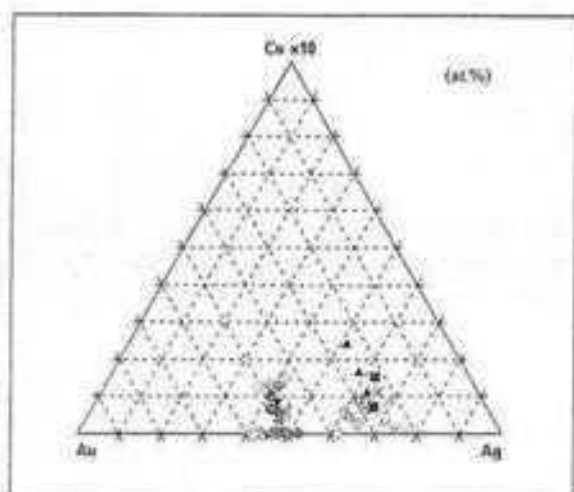


Fig. 1. Plot of the gold grains composition (at.%) from Valea lui Stan ores in the ternary diagram Au – Ag – Cu*10.

As for the other elements present in the gold grains, they usually do not exceed 4 at. %. Only Bi shows some enrichment in the grains with greater amount of Ag (Fig. 2).

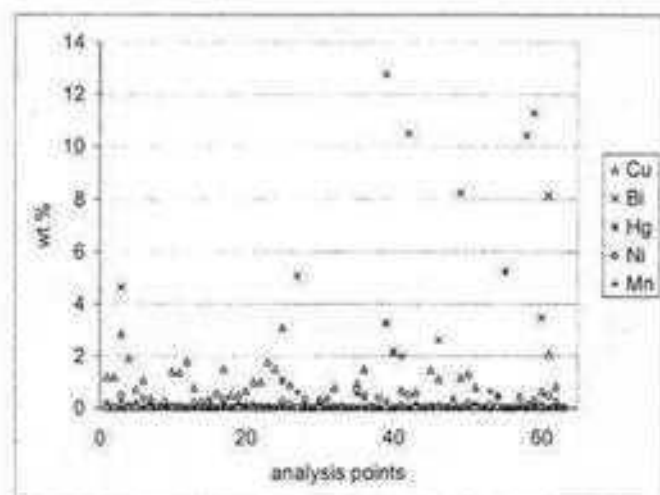


Fig. 2. Minor elements present in the gold grains from Valea lui Stan ores.

The Au from Costesti ores occurs mainly in arsenopyrite, sometimes associated with native Bi and other Bi minerals (sulfosalts), and sporadically in gangue minerals (quartz). Several Au grains have been observed as inclusions in pyrrhotite (Udubasa, 2004). As revealed by microprobe analyses, gold contains variable amounts of Ag, also Cu, Bi, Ni, Mn. The gold fineness varies between 448.29 and 743.42 ‰. In some of the analysed grains, Ag enrichment towards the rims can be observed. Here, there exists also for gold two compositional fields which can be observed on a ternary plot Au – Ag – Cu*10 (Fig. 3).

These two fields can be correlated, as in Valea lui Stan, with different host minerals of the gold grains:

- Au alloy with low Ag content (40-50 at.% Ag) for the Au grains included in pyrrhotite;
- Au alloy with high Ag content (close to “electrum”; 55-60 at.% Ag) for the Au grains included in arsenopyrite.

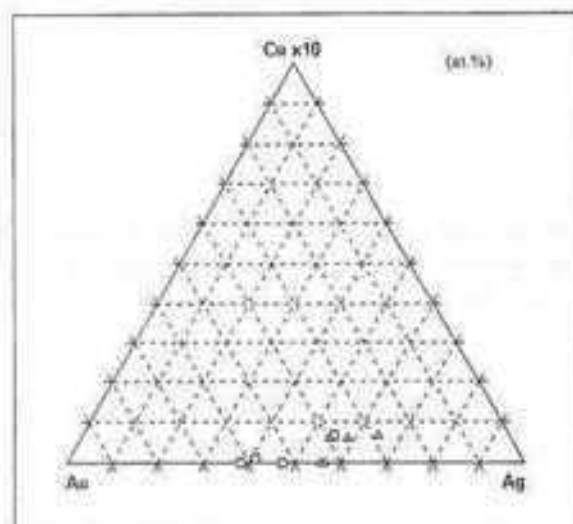


Fig. 3. Plot of the gold grains composition (at.%) from Costesti ores in the ternary diagram Au – Ag – Cu*10.

These features are similar to Valea lui Stan, especially the preference of the Au-Ag alloy to be richer in Ag in the grains included in arsenopyrite. The other elements present in the gold grains do not exceed 1 at. %, and only Cu shows enrichment in the Ag-rich gold grains (Fig. 4).

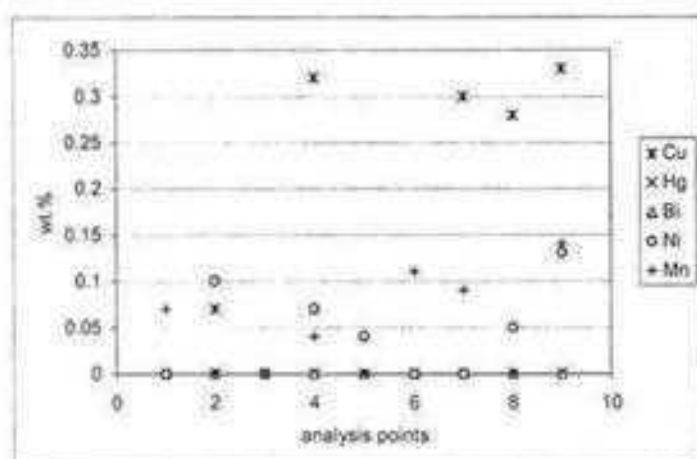


Fig. 4. Minor elements present in the gold grains from Costesti ores.

In conclusion, the native gold is associated mainly with arsenopyrite at Valea lui Stan, and with arsenopyrite and chalcopyrite at Costesti. In both cases there is a silver-rich natural alloy, sometimes with the “electrum” composition. Bi, Cu, Ni and Mn are other elements usually present in the alloy. At Valea lui Stan the natural Au-Ag alloy is usually richer in Au than at Costesti. There are compositional differences between the gold grains in respect to the associated/host mineral. Generally, when Au is included in chalcopyrite (Valea lui Stan) or pyrrhotite (Costesti) the Ag content of the natural alloy is lower than the case in which the arsenopyrite (in both occurrences) is the host of the gold grains (composition close to “electrum”). One can assume that in the case of inclusions in arsenopyrite, some of the Au probably enters the arsenopyrite structure (proven by some electron microprobe analyses, Fig. 5). In other cases such as Au inclusions in chalcopyrite and

pyrrhotite there is the possibility to explain the presence of gold as "trapped" in their structure. Further work will be undertaken in order to get a deeper insight into the geochemistry of gold in sulfides.

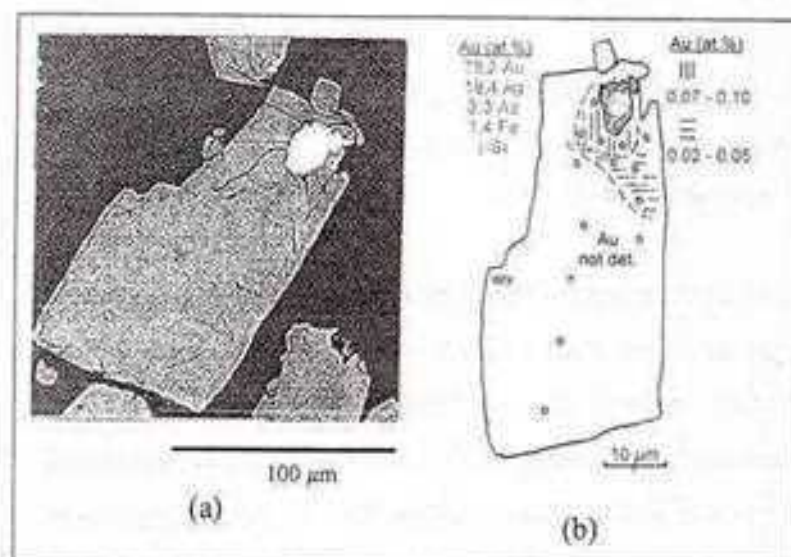


Fig. 5. Gold content variation around a gold inclusion in arsenopyrite from Costesti ores (Izvoru Neteu Galery).

- (a) BSE image of the arsenopyrite grain with the gold inclusion (white);
(b) Sketch of the gold content variation around the gold inclusion in arsenopyrite (apy).

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THE CRYSTAL STRUCTURE DETERMINATION AND CATION ORDERING ANALYSIS OF Mn-ILVAITE FROM DOGNECEA, SOUTH-WESTERN BANAT

Alexandru VIZITIU, Gheorghe ILINCA, Ioana STANCIU

University of Bucharest, Department of Mineralogy, Bd. N. Balcescu, 1, RO-701111, Bucharest, e-mail:

ilinc@geo.edu.ro

Mn-ilvaite is a minor but ubiquitous component of the skarn deposit at Dognecea, where it is associated mainly with Mn-hedenbergite and magnetite. Detailed microprobe and X-ray studies have been carried out within present study in order to: (1) determine the polymorphic state (orthorhombic or monoclinic) of Mn-ilvaite, and the ordering of Fe^{2+} and Fe^{3+} in the crystal lattice; (2) characterize the isomorphous substitutions of Mn-ilvaite (especially $\text{Mn}^{2+} \leftrightarrow \text{Fe}^{3+}$); (3) establish the structural location(s) of manganese ions, and (4) examine the possible genetic implications of such crystal-chemical features.

A number of 41 EDS microprobe chemical analyses of Mn-ilvaite resulted in the following ranges of variation: (in weight percents; parentheses read as average values and standard deviation, respectively): **Si**: 12.52-14.21 (13.68;0.38), **Al**: 0.00-0.33 (0.10;0.1), **Fe**: 31.73-37.31 (34.87;1.16), **Mn**: 4.63-9.17 (6.58;1.27), **Mg**: 0.00-0.33 (0.13;0.13), **Ca**: 9.01-10.64 (10.04;0.35). Atomic proportions of Fe^{2+} and Fe^{3+} for a chemical formula unit normalized for 12 cations, were calculated as $\text{Fe}^{2+} = 4 - \text{Mn}^{2+}$ and $\text{Fe}^{3+} = \text{Fe}_{\text{total}} - \text{Fe}^{2+}$. The variation domains of Fe^{2+} , Fe^{3+} and Mn^{2+} atomic proportions were the following: 2.68-3.30 (average 3.04; standard deviation 0.17), 1.89-2.09 (1.99; 0.05) and 0.7-1.32 (0.96;0.17), respectively. The only reversed correlation suggesting isomorphous substitution was observed for the pair Fe^{2+} - Mn^{2+} (Figure 1).

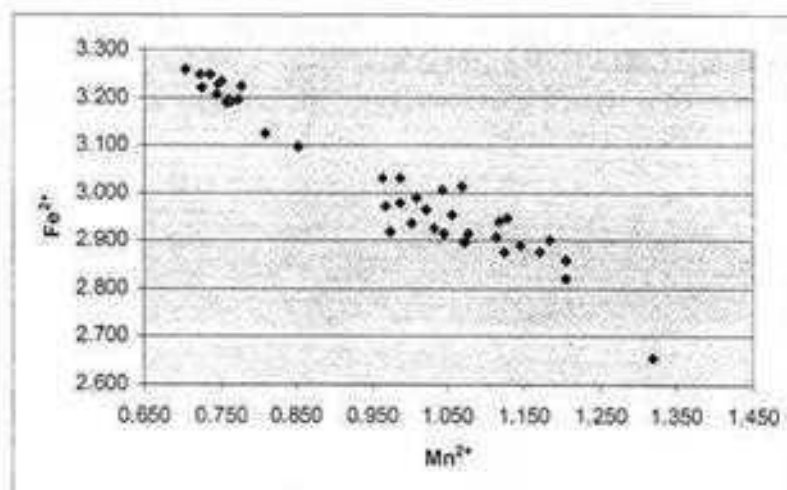


Figure 1. Reverse correlation between Fe^{2+} and Mn^{2+} in Mn-ilvaite (atomic proportions).

Mn-ilvaite from Dognecea is a $P 2_1/a$ polymorph with significant ordering of Fe^{2+} and Fe^{3+} among Fe11 and Fe12 structural sites (Figure 2). The single crystal structure determination of Mn-ilvaite – based on 1509 unique reflections, with final $R=5.51\%$ – allowed the calculation of interatomic and per-polyhedra average distances for all relevant cation-oxygen pairs and the evaluation of Fe^{2+} and Fe^{3+} occupancies in Fe11 and Fe12 structural sites. Statistical Fe^{x+} occupancies were calculated on the basis of two classic atomic radii models, i.e. Ghose (1966) – (G) and Shannon (1967) – (S). Thus, Fe11 structural site is 66% (G) or 74% (S) occupied by Fe^{2+} . Fe^{3+} occupancy in Fe11 and Fe^{2+} occupancy in Fe12 site are complementary to these values. The corresponding ordering parameter (Takeuchi et al., 1983) was 0.34 (G) or 0.47 (S). Same calculations concerned Fe2 structural site and allowed indirect evaluation of Mn^{2+} occupancy vs. complementary Fe^{2+} . The calculated occupancy was 37% Mn^{2+} , in agreement with the chemical analyses results, and suggesting that Mn^{2+} is confined to the Fe2 structural site.

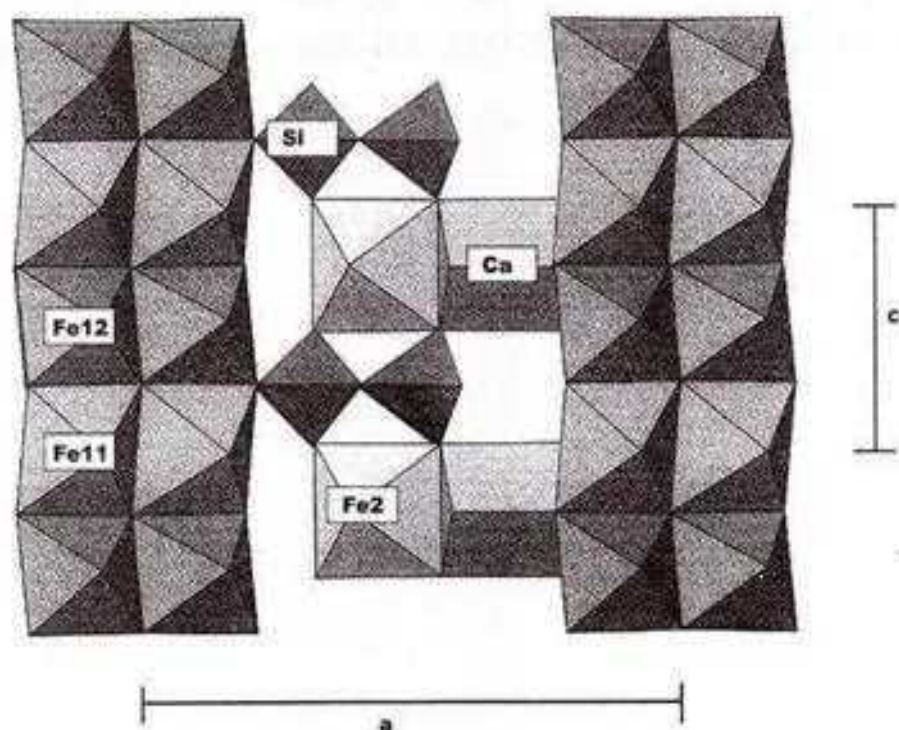


Figure 2. Simplified projection of the crystal structure of monoclinic (ordered) Mn-ilvaite, along b axis. The Fe11 structural site is prevalently occupied by Fe^{2+} and Fe12 by Fe^{3+} . Fe2 is mixed Fe^{2+} and Mn^{2+} .

The cell parameters determined from the single crystal structure analysis were the following: $a = 13.014 \text{ \AA}$, $b = 8.846 \text{ \AA}$, $c = 5.848 \text{ \AA}$ and $\beta = 90.34^\circ$. The experimental β value was slightly discrepant with regard to the ones calculated on the basis of correlated ordering parameter and degree of monoclinicity (Takeuchi et al., 1983 (T); Finger and Hazen, 1987 (FH)): 90.16° (T)

and 90.27° (FH). In addition to the crystal structure determination, three sets of cell parameters were calculated based on accurately measured X-ray powder diffraction patterns: (1) $a = 12.997 \text{ \AA}$, $b = 8.802 \text{ \AA}$, $c = 5.859 \text{ \AA}$, $\beta = 90.27^\circ$; (2) $a = 13.004 \text{ \AA}$, $b = 8.805 \text{ \AA}$, $c = 5.862 \text{ \AA}$, $\beta = 90.31^\circ$; (3) $a = 13.000 \text{ \AA}$, $b = 8.803 \text{ \AA}$, $c = 5.857 \text{ \AA}$, $\beta = 90.40^\circ$. Reversed calculation of ordering parameter from β angles, based on T and FH correlations, yielded values between: 0.592-0.877 (T) and 0.443-0.656 (FH). The degree of Mn^{2+} - Fe^{2+} substitution in ilvaite does not appear to have any influence on its degree of monoclinicity.

Local paragenetical relations and various published correlations between the ordering parameter and the temperature of formation, suggest that Mn-ilvaite from Dognecea represents a reaction product of $6 \text{ hed} + 4 \text{ mgt} + 3 \text{ H}_2\text{O} \rightarrow 6 \text{ ilvaite} + \frac{1}{2} \text{ O}_2$, formed at temperatures not exceeding 300° C , and in conditions of relatively low $f\text{O}_2$.

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OUTCOMES OF BOREHOLE MEASUREMENTS TO ASCERTAIN REGIONAL STRESS DISTRIBUTION WITHIN THE TERRESTRIAL UPPER CRUST OF THE TRANSYLVANIAN BASIN

ZUGRĂVESCU Dorel, POLONIC Gabriela, NEGOIȚĂ Victor

"Sabba S. Ștefănescu" Institute of Geodynamics of the Romanian Academy, 19-21,
J.L. Calderon St., 70201-Bucharest, Romania, e-mail: dorezugr@geodin.ro

The Transylvanian Basin located on the Romanian territory represents a intensively explored region for hydrocarbon resources in which during the last 50 years a lot of gas reservoirs have been discovered. More than 2000 boreholes drilled in this region investigated the entire Pliocene and Miocene sedimentary fill from the ground surface to 5 km deep.

Nevertheless, the geodynamic information related to the present day-stresses acting within the terrestrial upper crust of the Transylvanian Basin is very scarce and the few data coming from earthquake focal mechanisms have not been included in the World Stress Map (WSM).

That is why in the last five years the research programs of the Geodynamic Institute of the Romanian Academy were directed on topics concerning a better understanding of various geodynamic processes taking place in this zone.

A brief presentation needs to say that the Transylvanian Basin is located in the Eastern part of the Alps – Carpathian – Pannonian system. It has a roughly circular shape and a Cretaceous to Miocene sedimentary fill, up to 8 km thickness. The basin margins are represented by the East Carpathians, the South Carpathians and the Apuseni Mountains.

As a result of its tectonic evolution, the Transylvanian Basin is characterized by the following peculiar features: normal thickness lithosphere (100 km), low heat flow (30–60 mWm⁻²) and a crustal thickness of 33–36 km, increasing from the central area to the basin borders.

Our stress study was entirely based on borehole geophysical measurements existing in Romania, and consequently, without any extra-cost.

For that purpose, the available well log suites coming from 53 exploration boreholes whose bottom holes-depth were less than 3.5 km have been selected, collected and finally processed. All these boreholes have been geophysically investigated with Schlumberger equipments, including always the Stratigraphic High-Resolution Dipmeter Tool.

The field data processing was performed according to the Schlumberger instructions, the interpretation method devised in our institute was based on the "breakout technique", both of them being finally coupled in a such way to comply with the requests of the World Stress Map.

The results of our stress orientation determinations have been presented in two variants:

1.- a graphical one, in which all stresses are plotted on the regional map as arrows, showing at the base of arrow the geographical co-ordinates.

2.- a second one, displaying the so called "stress data file" prepared and stored in the Stress Data Bank of the Geodynamic Institute. This stress data file comprises a lot of data regarding: well geographical co-ordinates, borehole intervals with continuous measurements, the recorded type of well logs, lithology of geological formations passed through, their ages and boundaries, physical and chemical characteristics of drilling mud, borehole deviation, pressure and bottom hole maximum temperature. On the basis of different physical measurements acquired during the well logging operations (Gamma Ray, Neutron/Density, Sonic Log, Electric resistivity/conductivity and Dipmeter) the following types of information were established and reported in the data stress file:

- the azimuth of maximum horizontal principal stress;
- the azimuth of least horizontal principal stress;
- the magnitude of the above mentioned stresses for some "in house studies".

In our breakout inferred stress study of the Transylvanian Basin upper crust we consent with the linear, isotropic poroelastic stress-strain theory assuming the strain plane orthogonal to the borehole axis. On these terms the ellipsoid of stresses was defined by giving the directions of its three axes and the corresponding stress magnitude values S_1 , S_2 , S_3 , known as principal stresses.

Roughly speaking within depositional basin, whether tectonically inactive or undergoing extension, the maximum stress (S_1) is represented by the geostatic load/overburden, both intermediate stress (S_2) and the least stress (S_3) being located in the horizontal plane.

The combination of extensional and strike-slip regimes existing in the Transylvanian Basin supported our assumption to consider that the principal stress is oriented vertically ($S_1=S_v$), the greater horizontal stress as being ($S_2=S_H$), and finally, the least horizontal stress to be ($S_3=S_h$).

The last horizontal stress was expressed as a fraction of the geostatic load (S_1) using a variable coefficient whose value was calculated on the basis of Poisson's ratio. Both, rock elastic parameters (Poisson's ratio and Young's modulus) have been derived in our study from wave velocities and bulk volume densities recorded by well logging measurements.

Because the results of our study were provided by the open hole-geophysical measurements performed during the drilling period of gas producing-wells, we have been constrained to present the distribution of stress orientation within the Transylvanian Basin in a closed relation to the framework of gas-geological activity. According to the official reports, the gas bearing-geological structures of the Transylvanian Basin are joined, making up five gas producing – structure groups: the northern, the western, the southern, the eastern and the central.

We are aware of the differences existing between the gas bearing – sedimentary sequence

framework and the stress orientation – geodynamic framework, but this connection has been chosen solely for a better interpretation and localization of stress determination-points.

The main characteristics of stress orientation in the five groups of gas producing-geological structures are discussed below:

1. Northern group

The approximate areal is situated on the northern part of the Mures river, being enclosed between the following localities: Cluj – Dej – Bistrița – Grebeniș – Luduș – Turda.

Among the most representative gas producing-geological structures we mention: Sarmășel, Buza, Strugureni, Delureni.

The extreme values of stress orientation are $80^{\circ} - 130^{\circ}$.

The average value of stress data is 106° .

2. Western group

The approximate areal is situated between Mureș and Târnava Mare rivers, being enclosed between the following localities: Turda – Luduș – Târnăveni – Tăuni – Blaj.

Among the most representative gas producing-geological structures we recall: Bogata, Iernut, Deleni, Tăuni.

The extreme values of stress orientation are $92^{\circ} - 112^{\circ}$.

The average value of all stress data is 102° .

3. Southern group

The approximate areal is situated between Târnava Mare and Olt rivers, being enclosed between the following localities: Luduș – Sibiu – Ucea – Agnita – Sighișoara.

Among the most representative gas producing-geological structures we mention: Alămor, Ruși, Noerich, Ilimbav and Săsăuș.

The extreme values of stress orientation are $10^{\circ} - 40^{\circ}$.

The average value of all stress data is 25° .

4. Eastern group

The approximate areal is situated near the Eastern Carpathians, being enclosed between the following localities: Agnita – Rupea – Odorhei – Sovata – Sighișoara.

Carrying on, some of the representative gas producing-geological structures are listed:

Daia, Bunești, Feliceni, Lupeni, Porumbeni, Șoimuș.

The extreme values of stress orientation are $60^{\circ} - 135^{\circ}$.

The average value of all stress data is 104° .

5. Central group

The approximate areal is situated between the following localities:

Sighișoara – Măgherani – Reghin – Crăiești – Medias.

Carrying on, some of the representative gas producing-geological structures are listed: Corunca, Tg. Mureş, Eremieni, Sângeorgiu de Pădure, Măghirani, Petrilaca, Filitelnic and Nadeş.

The extreme values of stress orientation are $100^{\circ} - 175^{\circ}$.

The average values of all stress data is 150° .

As a general observation, in the Transylvanian Basin most of the variations related to stress orientations follow a normal (perpendicular) direction against the Carpathian mountainous chain. The stress orientations found on some geological structures (Sărmăşel 118° , Bogata 112° , Alţâna 20° , Nocrich 8° , Săsăuş 38° , Buneşti 86° , Feliceni 132°) are relevant in this respect.

Yet, some characteristic behaviours of stress orientations on the Transylvanian Basin areal need to be remarked and discussed.

The first one is represented by the "Central group" where the average stress azimuth of 150° is equivalent to the general stress orientation trend found in the Central and Western Europe (the so called Midplate stress domain) with average stress orientation values of 145° .

The second one, is represented by the most south-western zone of the Transylvanian Basin where an obvious N-S direction of stress orientation was pointed out, more or less equivalent to the stress orientations noticed in the south of Poland as well as in the eastern part of the Slovakian territory. In addition, for this south-western part of the basin we suppose the existence of some deep local fault processes generating the perturbations of stress field.

The quality data resulted from our 53 determinations of stress orientations, assigned according to the "World Stress Map - ranking quality scheme" may be placed between A and C. We have to mention that WSM quality scheme starts with the best ranking quality A and ends with ranking quality E.

Our 53 stress orientation-determinations may be integrated in the ranking scheme as follows: A = 7, B = 22, C = 24 and therefore, the specific percentages related to the data quality are: A = 13.2%, B = 41.5%, C = 45.3%.

Stress magnitudes have also been calculated on the basis of well logging data and pressure measurements. Generally, the vertical stress increased with depth taking for the vertical stress gradient values between 22 MPa/km and 24 MPa/km. Formation fluid pressure gradient in the Miocene and Pliocene formations seldom exceed 13 MPa/km, few occurrences of 15–16 MPa/km in the Filitelnic – Corunca – Tg. Mureş areal being recorded.

In such circumstances the least horizontal stress gradients, estimated on the basis of Poisson's ratio and vertical stress gradient indicated values of 13 – 15 MPa/km, confirming several leak-off tests carried out during the drilling period of boreholes.

Finally, the analysis of stress magnitudes established that maximum principal stress is vertical, while the minimum horizontal stress is approximately 62% of the vertical stress magnitude. The average values of these two stress gradients are respectively 23 MPa/km and 14.2 MPa/km.

LIFE Environment Project

A POSSIBLE ENVIRONMENTAL SOLUTION FOR SUSTAINABLE DEVELOPMENT BY COAL PROCESSING

Georgeta PREDEANU¹⁾, Petre ALBĂSTROIU¹⁾, Silviu LAMBESCU¹⁾, Valerica SLĂVESCU¹⁾, Nicolae ȚICLEANU²⁾, Ioan VACARCIUC³⁾, Ștefan ANGELESCU³⁾, Ion GURAN⁴⁾, Oprea SCORTĂRIU⁴⁾, Eugen BELU⁴⁾

1) Metallurgical Research Institute SA, Bucharest, Romania e-mail: gpredeanu@metal.icem.ro

2) Faculty of Geology and Geophysics, University of Bucharest, Bucharest, Romania, e-mail: Nticleanu@yahoo.com

3) IPROCHIM SA Bucharest, Romania, e-mail: ivacarciuc@iprochim.ro

4) SNLO SA Târgu Jiu, Gorj County, Romania, e-mail: opreas@cnlo.ro

The project is focused on the development of a clean technology based on the recovery of xylite waste from brown coal, in order to obtain a new ecoproduct - *xylite activated carbon* - with an increased utilization area in the purification processing.

For the reason that activated carbon processes that use vegetal raw materials are rather expensive and mainly because of the diminishing resources involved by the need of forest protection, in the last decades, with the expanding market for activated carbons and the enlarging environmental applications, great interest has been developed towards vegetal waste materials. Those generate cheaper precursors for activated carbon reducing the wastes and disposal costs. In this category are included xylites due to their chemical composition (low rank and ash content), structure and texture that can develop on activation a highly porous system, fig. 1.



Fig.1. Cellular textinite with lignite impregnation in LR (a) and LF (b) and cellulose (c) in xylite, oil im., 250x

In Romania, because of the impact of technological development on the environment and of the insufficient activated carbon internal supply obtained only from dried hard wood, it is assumed that the future necessary will overlap the present estimations.

The xylite reserves from Oltenia mining basin, sufficient for a long-term exploitation, can assure:

- the widening of raw materials supply for activated carbon manufacturing;
- the diminishing of the currency effort necessary for activated carbon imports;
- a promising solution for economical and social growth of the area.

At the same time, our target is to provide the innovative development and realization of a demonstrative installation focused on the elaboration of improved thermal treatment processes integrated in the world new context research program of identification the clean technologies [1-9].

The demonstration character consists in developing of a coherent strategy in which local community interests – identification of heat recovery resources for local domestic use – and industrial developments – based on promotion of modern clean technologies and manufacturing of eco-products - represents the key of progress and economic development at national level.

The ratio of primary to secondary xylite resources indicates how well the project area is moving up the sustainability scale of waste avoidance/waste minimisation/waste reuse/waste recycle/waste disposal continuum.

The ratio of secondary materials (especially steam, CO₂) that are used for some beneficial purpose, for example as activation agents and than as heat or power, thereby replacing other non-renewable and perhaps global climate change resources, now and in the future, provides a measure of the path to sustainability.

A key characteristic of our technology involves the sustainable development of the environment, fig.2.

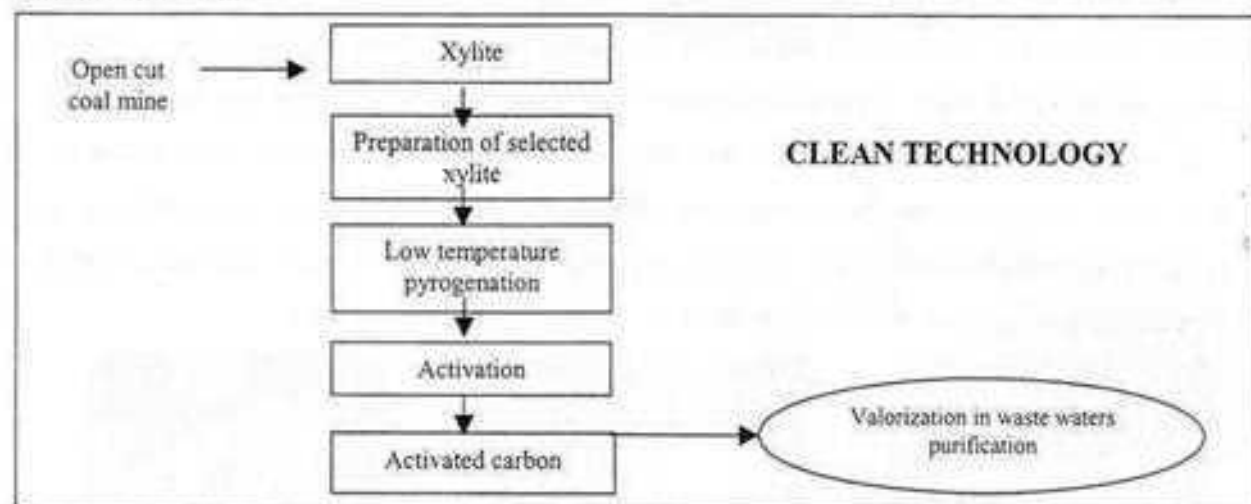


Fig.2. General scheme of xylite processing through a clean technology.

The procedure of activated carbon manufacturing using xylite charcoal represents a clean technology because of the ecologically and technique-economically advantages offered both of the quality of the raw material and the adequate processing solution of combustion and heat treatment adopted, such as:

1. prevention of the air and soil pollution: with flying ashes resulted from the burning process of coals with high xylite content - in the power plants and with waste xylite resulted from the usual exploitation of the productive seams;

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- appraising of forest exploitation, that has direct consequences on the prevention of the "greenhouse effect" and the diminishing of atmospheric CO₂ by the recycling of xylite waste which has a detrimental effect on the coal grinding and burning yield in the power plants;
 - the use of activated carbon in the purification processing: the removing of bad taste and odorous from the drinking waters; treatment of waste waters; the removing of oil from wastewater from the petroleum processing; the purification of different products resulted from the food industry; filters for gas masks.
 - the products quality, comparable or higher than of classical adsorbents;
 - clean technology with a strong recycling component and burning of the gases and vapors;
 - low energy, low raw material supply costs and low production costs because of the recycling of the thermal agents on carbonization and activation;
 - applicability with the same production yields to other vegetal raw materials as fruit pits and waste wood, etc.

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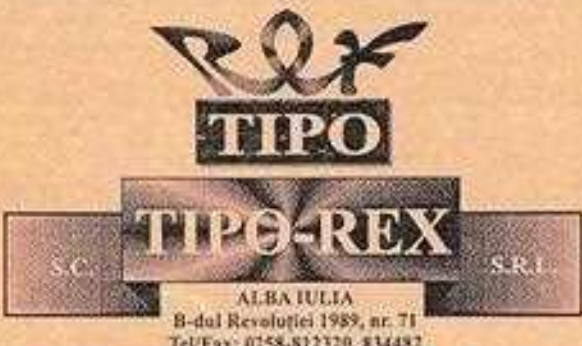
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