



HAL
open science

Gold and silver extraction in Alburnus Maior mines, Roman Dacia (Rosia Montana, Romania). Dynamics of exploitation and management of the mining space,

Béatrice Cauuet

► To cite this version:

Béatrice Cauuet. Gold and silver extraction in Alburnus Maior mines, Roman Dacia (Rosia Montana, Romania). Dynamics of exploitation and management of the mining space,. coord. ed. Luís Fontes. Paisagens Mineiras Antigas na Europa Ocidental. Investigação e Valorização Cultural, p. 81-104., 2014, Paisagens Mineiras Antigas na Europa Ocidental. Investigação e Valorização Cultural, 978-972-97695-7-3. halshs-02130709

HAL Id: halshs-02130709

<https://shs.hal.science/halshs-02130709>

Submitted on 13 Dec 2019

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

Atas do Simpósio Internacional
Boticas, 25/26/27 julho 2014

PAISAGENS MINEIRAS ANTIGAS NA EUROPA OCIDENTAL

Investigação e Valorização Cultural

**Gold and silver extraction in Alburnus Maior mines,
Roman Dacia (Rosia Montana, Romania). Dynamics
of exploitation and management of the mining space.**

Béatrice Cauuet (Chercheur CNRS)

Laboratoire TRACES - UMR5608, Université Toulouse 2, France





Resumo

O objetivo da Missão Francesa em Rosia Montana foi completar o estudo arqueológico preventivo dos vestígios de mineração anteriores ao século XX que se conservam e que permanecem acessíveis com segurança. Rosia Montana é um depósito epitérmico de ouro e prata, no Noroeste da Romênia, no qual se individualizam os seguintes sectores mineiros: Cetate, Cârnic e Cârnicel, Tarina, Orlea, Paru Carpeni, Cos, Jig-Vaidoia. Na vertente sudeste do Maciço de Cârnic, todos os sítios acessíveis de mineração romana (do século II a meados do século III), bem como algumas áreas significativas datáveis da Renascença (finais do século XV aos inícios do século XVII), foram prospectadas, escavadas, datadas e interpretadas. Adicionalmente foi completado o estudo geológico da maioria dos vestígios existentes à superfície.

Na zona nordeste, nos Maciços de Tarina e de Orlea, as investigações iniciadas recentemente já permitiram identificar um grande número de sítios de mineração romana semelhantes aos do Maciço de Cârnic. As últimas descobertas localizam-se no Maciço de Paru Carpeni e na mina Catalina Monulesti (Maciço de Cos), onde se identificaram inúmeros sistemas hidráulicos de drenagem, com rodas de elevação de água em madeira datáveis de meados do século II. Na mina Catalina Monulesti (inacessível desde meados do século XX), foram igualmente encontrados inúmeros e diversificados equipamentos de madeira de época romana, bem conservados, tais como escadas, vigas, plataformas, caleiras e carrinhos de mão. A prática da arqueologia em ambiente de mina subterrânea implica a adequação das técnicas de prospecção e de escavação, em parte adaptadas da espeleologia. A metodologia usada no nosso estudo arqueológico das minas romanas de ouro e prata de Rosia Montana será apresentada em detalhe.

Para acesso ao subsolo, os mineiros romanos preferiram longas galerias inclinadas escavadas a partir da superfície, em vez de poços verticais. Independentemente do âmbito dos trabalhos de mineração, as obras romanas têm seção trapezoidal. Os locais de exploração resultaram de várias galerias trapezoidais que seguiram os filões de minério, com cruzamentos verticais, horizontais ou inclinados, originando assim desmontes verticais e inclinados, bem como câmaras horizontais e pilares, com um ou dois níveis.

O estudo da rede subterrânea preservada permite a reconstrução da organização espacial das minas romanas. O tamanho das galerias subterrâneas, desmontes e câmaras (altura e largura), bem como a abundância de equipamentos de madeira descoberta no interior das minas, indica que os mineiros da época romana em Rosia Montana beneficiaram de espaços convenientes para o trabalho. A qualidade das obras e as soluções de engenharia identificados nas minas indicam uma alta eficiência, um ritmo rápido de avanço e uma excelente prática de mineração.

Palavras-chave Mineração Romana. Dinâmicas de Exploração. Equipamentos Subterrâneos de Madeira

Abstract

The aim of the French mission in Rosia Montana was to complete the preventive archaeological study of the mining remains dating back before 20th century, preserved and still safely accessible. The Rosia Montana is a gold and silver epithermal deposit. Rosia Montana site (NW Romania) comprises the following individual mining sectors: Cetate, Cârnic and Cârnicel, Tarina, Orlea, Paru Carpeni, Cos, Jig-Vaidoia. In the southern slope of Cârnic massif, all accessible Roman mining works (2nd to mid-3rd c. AD) as well as few significant areas dating back to the Renaissance period (end of 15th century to early 17th century) were surveyed, excavated, dated and interpreted. An additional geological study was also completed for most of the uncovered remains.

In the northern part of the site, in Tarina and Orlea massifs, the exploration has just been started and shown a great number of Roman mining works similar to those from Cârnic massif. The latest discoveries were made in Paru Carpeni massif and in Catalina Monulesti mine (Cos massif) and are represented by several hydraulic drainage systems with wooden water wheels dating back to mid-2nd c. AD. In Catalina Monulesti mine (inaccessible since mid-20th c.) a great diversity and number of well conserved Roman wooden equipment were also found, i.e. ladders, props, platforms, channels, handbarrows. The practice of archaeology in mining environment implies exploration and digging techniques adapted to the underground, partly taken from speleology. Our methodology used to study the gold and silver Roman mines of Rosia Montana will be presented in detail.

The Roman miners preferred long sloping galleries dug from the surface instead of vertical shafts as access into the underground. Irrespective the scope of the mining works, the Roman works have trapezoidal cross section. The exploitation sites were created by several trapezoidal adits joined vertically, horizontally or inclined following the ore bodied and creating thus vertical and inclined stopes, as well as horizontal chambers and pillars with one or two levels. The study of the preserved underground network allows the reconstruction of a spatial organization of the Roman mines. The size of the underground adits, stopes, and chambers (height and width) as well as the abundance of wooden equipment discovered inside the mines indicates that the miners from Roman time in Rosia Montana had a convenient space for work. The quality of the works and the engineering solutions identified in the mines indicate a high efficiency, a rapid rhythm of advancement and an excellent practice of mining.

Key-words Roman Mining. Dynamics of Exploitation. Underground Wooden Equipment.

Gold and silver extraction in Alburnus Maior mines, Roman Dacia (Rosia Montana, Romania). Dynamics of exploitation and management of the mining space.

1. Introduction

From 1999 to 2013, preventive mining archaeology research has been carried out in Rosia Montana (ancient *Alburnus Maior*), NW Romania. The archaeological research was coordinated by a French team (B. Cauuet Director) from TRACES Laboratory, Toulouse 2 University in the frame of a planned large scale re-opening mining project proposed by Rosia Montana Gold Corporation SA mining company (Cauuet *et al.*, 2003; Cauuet 2004 and 2011; Cauuet and Tamas 2012). The aim of the archaeological mission was to complete the preventive archaeological study of the mining remains dating back before 20th century, preserved and still safely accessible. Rosia Montana site comprises the following individual mining sectors: Cetate, Cârnic and Cârnicel, Tarina, Orlea, Paru Carpeni, Cos, Jig-Vaidoia. In 1999 and 2001 the research was carried out in Cetate massif. From 2000 to 2006, the study focused on Cârnic Massif, particularly on the ancient underground mining remains (2nd and 3rd centuries AD) located in the southern slope of the massif (**fig.1**). From 2005 to 2007, Paru Carpeni, Orlea and Tarina massifs started to be explored and studied, but for these perimeters the archaeological diggings must continue. Finally, from 2011 to 2013, a large programmed research was initiated in Cos massif, in the so-called Catalina Monulesti Roman and modern mine in the perspective of the creation of a new underground mining museum in the future.

In the southern slope of Cârnic massif, all accessible ancient mining workings as well as few significant areas dating back to the Renaissance period (end of 15th century to early 17th century) were surveyed, excavated, dated and interpreted. An additional geological study

was also completed for most of the uncovered remains. Moreover, an overall topographical survey of all accessible networks, i.e. ancient, medieval, modern (end of 17th century to beginning of 20th century) and recent, was completed in order to develop a synthesis map of the accessible underground works within the entire massif. Using the plans and detailed cross-sections realized during the investigations, a 3D multimedia presentation of three ancient mining networks from Cârnic massif, i.e. Cârnic 1, 2 and 3 is currently under completion. In the northern part of the site, in Tarina and Orlea massifs, the exploration has just been started and shown a great number of Roman mining works similar to those from Cârnic massif. The latest discoveries were made in Paru Carpeni massif and in Catalina Monulesti mine (Cos massif) and are represented by several hydraulic drainage systems with wooden water wheels dating back to mid-2nd c. AD. In Catalina Monulesti mine (inaccessible since mid-20th c.) a great diversity and number of well conserved wooden equipment were also found (Roman and modern).

After the Antiquity, Rosia Montana deposit was subjected to a continuous exploitation starting with the end of Middle Ages (15th-16th c.), with an important development during 18th-19th centuries. Underground mining works largely developed from 1960-1980s facilitated a detailed underground survey of the entire mining site. 35 km of mining works out of 110 km visited mining works have been mapped. Almost 7 km of Roman works are now known at the site scale. Prior to our study, the information concerning the extent of ancient works were unclear being mostly limited to the data supplied by Posepny, i.e. the geological and mining map of Rosia Montana from 1868. At the beginning of



Exploration

The exploration of large underground mines like those from Rosia Montana site which contains ancient, modern and recent works must be done according to a speleological progression through the accessible cavities. The progression within the underground works is carried out using an all-gas detector. The stability of the mining works must be checked by highly specialized personnel in order to comply with the safety regulation in mines and to protect the integrity of the people involved. The vertical mining works are equipped with cords or ladders. The topographical survey of the networks is conducted before and during the program of archaeological excavation. The accesses to the surface are located by GPS and/or theodolite with laser. The exploration topographic maps are based on horizontal, vertical and inclined linear measurements combined with additional drawings of the cavities made in underground. The distances are measured with tape measure or laser distance meter, while the stations are marked with painting. The directions and the dips are taken with the compass (integrated compass and clinometer). The precision of the advance is increased by frequent loops (error lower than 1%). The scale chosen for the plan is usually 1:200.

These plans and ground data (x,y,z topographical values) are transferred to a data base which afterwards is processed with dedicated software (Limelight – Toporobot) with realization of outputs of the measurement axes in plans, cross sections and 3D views. These layouts are then used as basic documents for the drawing of the mining works which is carried out in the underground using additional measurements. After control, the graphic documents are redrawn using drawing software (Adobe Photoshop and Adobe Illustrator). The documents and data needed for 3D output are treated under Geo3D which allows animations of the topographic advance. These

synthetic plans of the accessible mining networks are used as general maps for the underground works. The exploration topographic data is regularly corrected and developed in accordance with the progress of the excavations.

Systematic diggings

The archaeological excavation widens the space for exploration and allows to date the mining vestiges. It provides an overall vision for the interpretation of the dynamics of exploitation. It consists in removing obstructions from the mining works represented by old and/or modern backfilling as well as collapse material. In the case of mining networks situated far away from the surface (more than 100 m), it is necessary to store the excavated waste material underground within the modern mining works close to the zones of excavation. The strategy of underground archaeological intervention consists in choosing the zones of excavation, the areas for the storage of waste material and the circulation paths. It also comprises various setting up adjustments to ensure security (timbering, casings, parapets, etc.) and of assistance (chutes, ladders, handrail, wooden floors or platforms, pipes for water drainage, etc.). All these preparatory works are essential for starting the excavations but for their achievement it is necessary to dispose of qualified personnel, materials and time. The initiation of the diggings may be significantly delayed until the completion of preparatory works, especially when security or material storage problems occur.

Supplementary devices for diggings

The particular conditions from the underground mines, *i.e.* the presence of water or harmful gases (containment, lack of ventilation) imply the installation of heavy devices. For example, during the mission Rosia Montana 2003, the water from the descending

adit G31 (Cârnic 2 Upper) was lifted 35 m using three different pumps connected one above another. The fresh air needed in the confined zones (all-gas detector permanently present in the underground), was supplied by ventilation systems (ventilator and extensible aluminum sheaths). The electric power for pumps and ventilators was supplied by mobile power generators, or in special cases when the excavation sites are far away from the surface and the natural ventilation is weak the power supply was made by electric cables connected to the surface and installed and verified constantly by the specialized personnel of the mining company. During the archaeological diggings the use of electric power increases work output by use of electric tools, *i.e.* power drills, pumps, ventilation, electric chainsaws and facilitates a better lighting of the working sites. It is clear that the presence of a mining company offering the logistical and financial support for excavations in old mines constitutes a crucial factor to carry on ambitious operations from human resources and scale points of views.

Plans, sections and 3D restitution for the network topography

During the excavation are drawn up stratigraphic cross sections (scale 1:20, sometimes 1:50). At the end of excavation detailed topographic drawings *i.e.* plans, longitudinal and transversal cross sections are also done (details at scale 1:20 or 1:10, cumulative drawings at scale 1:50). This work is done using horizontal and/or vertical axes in the cavities (axes and measurements made with the laser meter, tape measures, level with the bubble and plumb line; orientation taken with compass). These axes materialized by strings and tape measure/decameters are evidenced on the drawings carried out underground because they constitute the spinal column of the topographic reproduction, similar with the network of points used by the team in charge

with exploration. The dimensions and the orientations are transcribed later in Excel tables. These X, Y, Z values are then treated by the software Visual Report which restores views in plans, cross sections and animation 3D. The axes are used for connecting different underground works in cumulative views (plans, cross sections) and at the completion of the topographical representations they are removed and are shown only the traces of the walls, basements, ceilings, steps, and other details of the mining works. The first description of the mining works is made *in situ* in the underground, thus being certain that all the peculiarities of the cavities are well registered. The excavation tracking is done through photographic coverage which shows the various stages of the work and constitutes an important database.

Dating and analysis of discovered objects and materials

After treatment, the archaeological objects, usually scarce in a mining context remain in Romania in the collections made up on the site of Rosia Montana. The organic remains, *i.e.* wood pieces (props, boards, and various other fragments) and charcoals are sampled for radiocarbon and dendrochronological analyses (partnership with Archeolabs Laboratory, France) and remained inside the underground mine in protected storage areas. Special analyses required by the remarkable objects are entrusted to qualified laboratories; for example, a litharge roll (derived product of the metallurgy of silver-bearing galena) discovered in underground has been studied through ICP-MS chemical and isotopic analyses (Baron *et al.* 2011; Tamas *et al.*, 2009).

Geological survey, sampling and ore analyses linked to archaeology

The geological and ore deposit investigation



of the ancient mines is used to identify in detail the types of mineralization exploited by the Ancients and the composition of the exploited ores which still occur in the face lines. The first step is to accomplish the geological mapping (plans and cross sections) of the mining works. The geological mapping is using the topographical representations (plans, cross sections) done during exploration and at the end of archaeological diggings. Representative rock and ore samples are picked up from the underground works and are further on studied in laboratory by diverse methods of mineralogical analyses. The laboratory mineralogical studies of the ancient mines from Rosia Montana were done by geologists from Romania, Germany and France and provided important new data concerning Rosia Montana geological context and ore deposit.

4 - Dynamics of exploitation and characteristics of the Roman mining works

Three major types of mining works, all opened in the same way, were outlined in the mining networks of Rosia Montana, as follows: exploration works (adits and incipient adits, sloping adits, sloping and vertical shafts), exploitation sites (stopes, vertical shafts, sloping shafts, chambers on pillars, inclined sites dug in successive benches) and support workings (access adits or sloping adits, sloping shafts, circulation, ventilation, junction adits and drainage rooms and adits). Among the particularities of Rosia Montana, we may mention that Cetate massif was widespread mined by deep opencast mining works, but these remarkable large Roman open pits or so-called Roman Courts, are known only from old pictures, movies or drawings because they were destroyed by the Romanian State mining company Minvest open cast exploitation (1972-2006) without any previous archaeological study.

Tool marks and fire setting

95% out of the 7 km of ancient works known to date were dug by tools (chisel and hammer or pick), technique attested by the tool traces on the walls. Systematically, all the mining works possess a trapezoidal cross section and usually have flat ceiling and basement or sometimes the basement is equipped with steps dug directly in the rock (**fig.2**). The general progression and exploitation were done either through adits, descending adits, vertical and horizontal stopes, few shafts and some large chambers on pillars with two or three levels (Cauuet and Tamas, 2003). In the case of very hard rocks (silicified dacite) the advancement of the miners was possible only using the fire setting; however this technique was used for less than 5% of the total mining works.

There are only two sectors with ancient workings opened up by fire setting, namely Gauri sector located on the southwestern slope of the Cetate massif and Piatra Corbului sector on the east side of the Cârnic massif. The fire setting works from Cârnic were dated to the Roman period (2nd c. AD) based on charcoals, *i.e.* scrap wood from the fire setting technique. Moreover, in the eastern sector of Cârnic, a gallery opened up partly by tools and partly by fire, depending on the nature of the country rock, was discovered. This situation confirms that the two mining techniques were employed simultaneously in the same area depending on the rock hardness. The fire setting technique posed significant ventilation problems for the work sites located far away from the surface and in addition it was a big wood consumer.

Stopes and chambers for exploitation works with trapezoidal cross section

Most of the ancient works opened up by tools have a general trapezoidal cross section. This even includes incipient adits showing a trapezoidal cross



Figure 2
Intersection of galleries with trapezoidal sections in the lower level of Cârnic 3 network (Photo: J.-F. Peiré).



Figura 3
Working face and connection adit with trapezoidal section in lower level of Catalina Monulesti mine (Photo. C. Tamas).

section from the first centimetres. The face lines of the abandoned adits always show evident angles of a trapezium (**fig.3**).

The general shape of the exploitation sites is imposed by the morphology of the ore bodies. In the case of flatly dipping veins and breccia bodies the exploitation developed in room and pillars, preserved in place to ensure the security of the mining space. The chambers correspond to a row of trapezoidal adits dug one beside the other of which common walls were also mined. The traces of these different primary adits may sometimes be preserved in ceiling, basement or face lines of the exploitation chamber where a sequence of adjacent trapezoidal-shaped mining faces is preserved. Depending on the ore body width, the exploitation developed on two or three levels maintaining safety pillars between levels; in this case the passage from one level to the other is done through short rising shafts or small sloping galleries with steps.

The exploitation works developed in the shape of steep vertical workings when the miners followed steeply dipping veins and breccia bodies. These works are opened as stopes and generally began as a simple trapezoidal-shaped adit which is next widened and deepened downwards in the initial floor, eventually forming large vertical works like the central stope of Cârnic 5 which is 2 m wide, 7 m high and 15 m long. In some other cases, the works consist of a superposition of at least four levels of trapezoidal-shaped adits dug with a slight unevenness between them. They are positioned one beneath the other and are consolidated by a dense wooden propping placed in the ceiling and floor of each level. This particular type of site was so far identified only in the Paru-Carpeni sector of the Carpeni massif. On the other hand, an entire mining network from the Cârnic massif known as Cârnic 10 is formed of three large sloping sites, dug in benches within a breccia dyke inclined at about 45°. These stopes are also formed from trapezoidal-shaped adits opened one

close to another, following the dip of the mineralized structure. The walls between adits were subsequently mined out resulting finally a large network descending in benches.

Rare vertical shafts and inclined shafts

We did not find any surface access to the underground through vertical shafts. Few short vertical shafts were recognized inside the mines, generally connecting one level to another. They are usually associated with a descending adit indicating that the miners preferred circulation through sloping adits not through vertical shafts. However, we found a lot of wooden ladders abandoned within vertical shafts or large stopes. In absence of drainage devices, we noticed in Cârnic massif as well as in Catalina Monulesti mine that some deep works end in a large inclined shaft with large steps which seems to be used as collecting pit for water (**fig.4**).

Complex imbricated networks in Cârnic massif

With the exception of the fire setting exploitation sector in Piatra Corbului, the original character of the Cârnic massif consists in the considerable development of the mining works. They are situated in the southern side of the massif, covering an area of about 13,600m² (**fig.5**). This ensemble is made of seven ancient mining networks, Cârnic 1-2-3-4-8-9-10, which we called the Big Network. It counts a cumulative length of about 3 km of ancient works, spread on 98 m height (from +921 m to +1019 m elevation). This Network comprises exploitation and exploration sites as well as auxiliary works for circulation or ventilation and followed in fact a complex breccia dyke ore body and its related quartz vein branches.

The Big Network was dug through a descending progression towards the interior of the massif starting



Figure 4
Large inclined shaft with steps dug at the bottom of Cârnic 3 network as an exploitation work and finally used as a collecting pit for water (Photo. J.-F. Peiré).

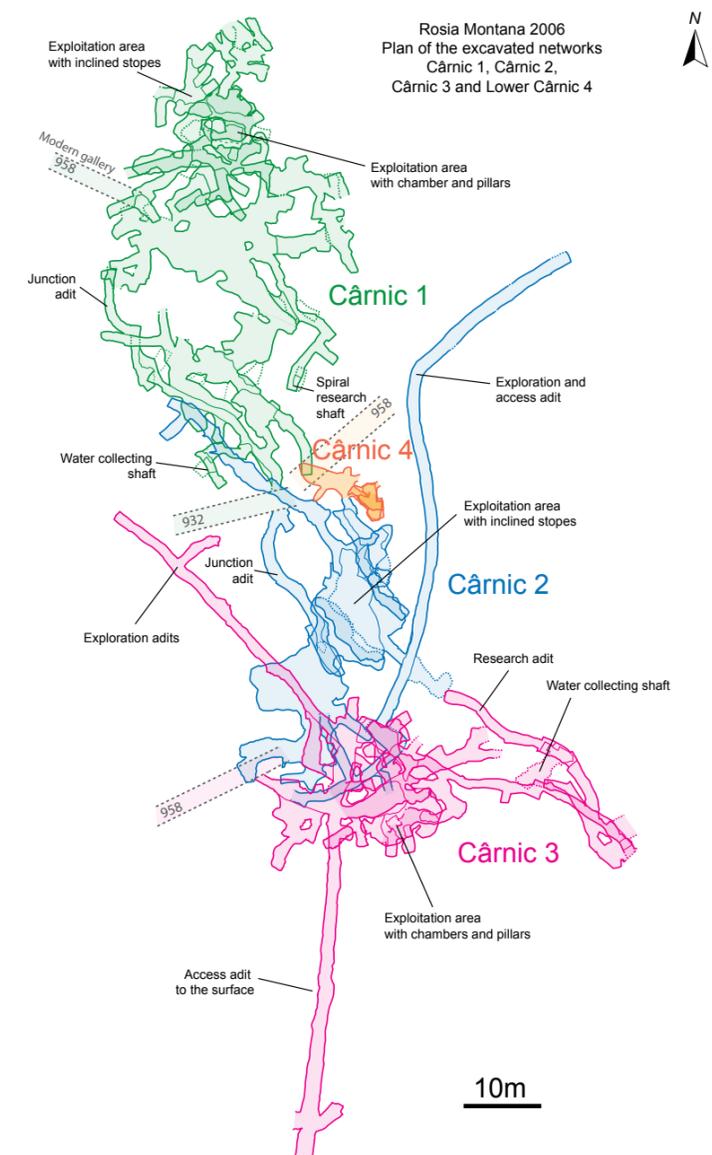


Figure 5
The complex ensemble of several antique networks in Cârnic massif (Ill. A. Constans).



from long sloping galleries coming from the surface. Certain types of mining works from Cârnic massif such as rooms with pillars, inclined working sites with benches, spiral sloping shafts with steps and long research adits with steps were not identified yet in other mine sectors from Rosia Montana. On the other hand, within the Cos sector we discovered successions of trapezoidal research adits, very deep vertical stopes and several shorter sloping galleries, provided with steps, similar with the same type of workings known from Cârnic massif.

5–Underground installations and technical equipment

Timbering and wooden devices

Different Roman wooden equipment as ladders, beams, boards, props, channels, handbarrows, were well preserved in the humid environment and constant temperature environment from the northern part of Rosia Montana mine. The vertical passage between two adits, sometimes nearly 2 m high or more was equipped with a monoxyle notched ladder. We have already discovered more than dozen ladders of this type, including a long one of about 5 m length (**fig.6**). These ladders have been dated by dendrochronology to the second half of the 2nd c. AD. They were made out of very large squared trunks, with carefully cut steps which gives all the appearance of a staircase.

The narrow trapezoidal section of the galleries helped avoid timbering in most Cârnic mining works. In the case of tall workings, there are notches in the walls confirming the previous presence of timbering or even suspended wooden bridges. In one case at Catalina Monulesti, a wooden platform used for circulation was discovered still standing in place in a vertical work being supported by carrying beams and made out of boards. In other cases elements of the timbering are found

collapsed or in secondary positions. In the Catalina Monulesti adits, different propping techniques were discovered, *i.e.* simple props (**fig.7**), half frames, frames and closed frames. The assemblage among different wood pieces (cap and posts) is made from mortise and an elongated tenon. The wood frames were placed at intervals in the adits or in a contiguous manner and in this latter case were created fully timbered adits.

Similar or even more complex systems forming frames with three or five pieces were also found in water drainage chambers from Paru Carpeni and Catalina Monulesti presenting the same mortise and tenon jointing (Cauuet, 2008). The propping system of the chambers from Paru Carpeni consists of two squared carrying beams which could be fixed either on the rock basement, either being embedded in the walls. Each carrying beam supports one row of posts. The posts are fixed at each 50 cm in a squared mortise dug in the supporting beam by a tenon (inferior tenon). The other tenon of the post (the superior one) is fit in a mortise of the cap which is supporting the ceiling of the water wheel chamber. Wooden logging covers the walls behind the timbering.

Ventilation

Few devices have been found to justify of a ventilation system for the underground. The important height of the adits and sloping adits, frequently up to 2 m, may have left the possibility to emplace a secondary ceiling made of a fabric or a skin leather sheet or even with boards that could created an air circulation inside the network. Meanwhile such installations did not left remarkable marks on the walls. Only one special work was discovered in Tarina area. It consists in one long lateral narrow adit, branched and then continuing parallel to one main access from the surface.

We also observe in several sectors in Cârnic that many exploitation areas are served by two access ways



Figure 6
A monoxyle notched ladder of 4.90 m length found perfectly conserved inside the backfilling of a vertical stope in Catalina Monulesti mine (Photo. B. Cauuet).



Figure 7
Two props with an assemblage made from mortise and an elongated tenon
found still up in one gallery of Catalina Monulesti mine (Photo. C. Tamas).

(sloping adits, high stopes, and chamber with pillars) which certainly facilitated the natural ventilation inside the network as well as the circulation of the miners/transport in the underground without interfering with the digging of the ore.

Lighting underground

The presence of lamp notches dug in the upper part of the walls confirms Roman illumination arrangements in the galleries. In the filling of the mining works from Cârnic and Catalina Monulesti were discovered three almost complete Roman lamps as well as numerous lamp fragments (elements of more than 70 lamps altogether). We found three different sizes of lamps with channel, all *Firmalampen* of Loeschke X type, datable to 2nd century AD. They are marked FORTIS, however they are only castings of lamps originating from the Italian Fortis pottery shop. Torches with long wooden laths were also used for illumination in parallel with the use of oil lamps. A great number of such partly carbonized sticks were found during the diggings in Cârnic and especially in Catalina Monulesti mining works. They could have also served to light the lamps put at strategic points while the laths and torches were current individual lighting for the miners.

Underground sampling vestiges

No pumping or drainage equipments were found in Cetate and Cârnic massifs situated in the southern part of Rosia Montana site. The only drainage arrangement is a narrow ditch dug in the basement of a horizontal junction gallery located at a fairly high elevation in the massif. This ditch prevented water runoff from this gallery to a sloping gallery and shaft which together form an ensemble of exploration works in Cârnic 1. In this massif were observed sometimes rectangular-shaped channels dug in the basement

of galleries or exploitation chambers. These negative forms could serve as water collector basins out of which water could be evacuated by buckets or maybe as small water stocks in the underground.

This water supply could have been used to preliminarily concentrate the raw ore in the process of checking out the ore grades in the working face lines. We must mention also the discovery of a sort of wooden pan abandoned in one of the water basin and dated to Roman times by dendrochronology (Cauuet and Tamas, 2012). In 2013 in Catalina Monulesti mine, a broken mortar was found inside the backfilling of a tall stope. It is similar to those found in the ore treatment workshop discovered in 2003 in Piciorag site situated in the northern part of Rosia Montana site (Simion *et al.*, 2003). In relation to the monitoring of the ore grades, it is worth to mention that on some of the remaining working faces are preserved deep parallelepiped-shaped areas corresponding to about 50 liters or 120 kg of extracted ore. In this case, it could involve the minimum amount required to estimate in the underground the grades of the ore occurring in the working faces.

Mechanical drainage system

The ancient mining networks located in the eastern and northern part of the site, *i.e.* Cos, Tarina, Orlea and Carpeni were partly situated under the hydrostatic level from the Roman times. This is the reason why the Roman mining sites from these sectors were equipped with mechanical drainage systems that ensured a proper water evacuation during the mining works (**fig.8**). This involved chambers equipped with wooden hydraulic wheels (diameter 3.90 m, 27 buckets), wooden channels (**fig.9**) and drainage galleries fitted with channels dug in the basement. Presently, there are four drainage rooms known in the Paru-Carpeni sector of Carpeni massif belonging to the same hydraulic system (Cauuet, 2008, 2011).

In the Cos massif, two chambers equipped with

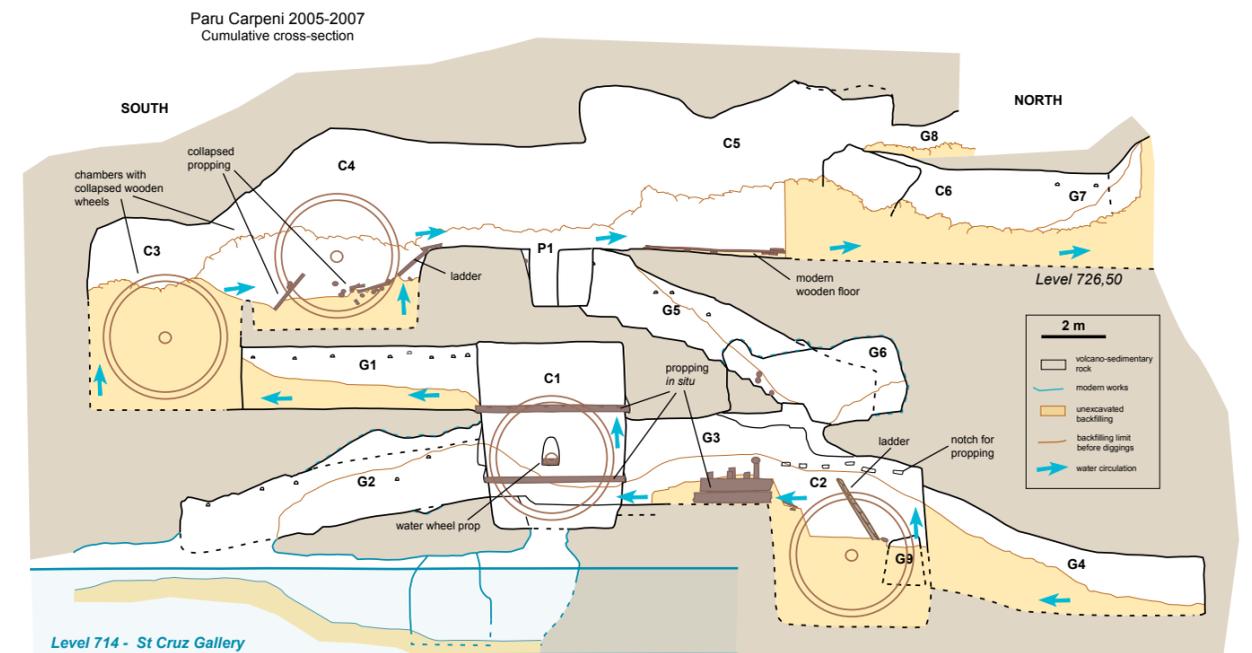


Figura 8
Cumulative cross-section of the two levels with four water wheel chambers for drainage from Paru Carpeni massif. Ongoing diggings from 2007 (Ill. B. Cauuet).

the same mechanical drainage systems were found in 2013 in the Catalina Monulesti Roman mine. In one of the chamber, two wooden wheels were discovered, positioned one upon the other (diameter 3.20 m, 24 buckets). The downer one is better preserved having its hub still *in situ* (**fig.10**). Moreover, in the western part of Orlea massif, a water evacuation crosscut has been partly recognized. It should have drained all the mining works from this massif through several drainage galleries and we suppose that it served also the drainage system from Paru Carpeni.

6 - Conclusion and perspectives

Rosia Montana perimeter was licensed by the Romanian state for mining activities in late 1990. According to Romanian Patrimony law, archaeological diggings should take place before mining operation. For this reason the Romanian state created the *National Research Program Alburnus Maior* (preventive archaeological diggings). While the Romanian archaeological teams studied the surface sites (buildings, temples, necropolis...) the French mining archaeological team was in charge only with the study of the underground. This is the reason why we could not look for ore treatment or metallurgical



Figure 9
The wooden channel that collected the water from the upper water wheel in Catalina Monulesti mine still at its place along the wheel (Photo. C. Tamas).



Figure 10
The hub of the lower water wheel from Catalina Monulesti mine still in connection with the spokes of the wheel in its lower part (Photo. C. Tamas).



workshops. Meanwhile our colleagues from MNIR museum (National Historical Museum from Bucharest) had found a small ore treatment workshop, partly covered by the extension of a Roman necropolis (Simion *et al.*, 2003). From this site located at Piciorag on the Jig-Vaidoiaia massif (NE of the valley) were discovered several crushing mortars. All of them present a deep and narrow shape with gripping lugs at the opening. The broken one found in Catalina Monulesti mine shows a similar form (nature of the stone still to be determined by analyses). The presence of this mortar underground as well as the water collector basins found in certain chamber in Cârnic mine indicates the monitoring of the ore grades in direct link with the progression of the mining extraction. Due to the huge development of the underground network it appears much more adapted to do some ore grade tests during mining than waiting a feedback from the ore treatment workshops located at the surface to be sure that the working face is still worth to be extracted.

The French expertise in the large Rosia Montana mining complex allow us to propose a new interpretation of the development of mining practices underground in the 2nd c. AD in NW Roman Dacia. After more than twelve years of mining archaeological research in the Rosia Montana underground sites it is now possible to do a review on the nature, importance and preservation state of the mining vestiges from this site. While for Cârnic and Cos massifs and what is left of Cetate massif we have a synthetic view, for Carpeni, Orlea and Tarina massifs, where the investigation are just preliminary our scientific opinion is still fragmentary. However we consider extremely useful to compare the mining vestiges from all the different investigated massifs located along the Rosia valley for an overall and synthetic view on a large gold-silver Roman mining site. Despite a still incomplete view upon the site it may be noted that for most of the Roman mining works there is a consistent repetition of the shape and distribution

of the workings investigated in the entire underground mining park. At the same time there are certain types of work sites that are specific to a certain sector or massif, a feature which is dependent on the morphology, size and dip of the ore bodies (veins, breccias, stockworks, impregnations), on the nature of the host rocks, their higher or lower hardness, respectively (more or less intensely silicified dacite, soft volcano-sedimentary rocks) or on the topographical position of the mining works in relation to the groundwater table.

The Roman miners preferred long sloping galleries dug from the surface instead of vertical shafts as access into the underground. Irrespective the scope of the mining works, the Roman works have trapezoidal cross section. The exploitation sites were created by several trapezoidal adits joined vertically, horizontally or inclined following the ore bodied and creating thus vertical and inclined stopes, as well as horizontal chambers with pillars with one or two levels. The joint geological studies carried on during the archaeological excavations proved that the Roman miners followed very closely the high grade mineralization and extremely rarely they work in barren rocks, excepting of course the auxiliary works (junction, access, transport, ventilation). However, we observed that the Roman miners organized the progression of the mines digging even auxiliary works in mineralized zones if possible. Well organize transport paths from underground to the surface, *i.e.* stair floor, ramps or ladders suggest that the ore and waste material were removed from the underground to the surface by individual transport by carrying on back. Heavy or bulky loads might have been carried on wooden handbarrows as we had found underground parts of two, one in Tarina (Cauuet, 2011) and another one in Catalina Monulesti.

The Roman miners strengthened their underground mining works either preserving rock and ore pillars or by propping, as they built up solid timbering frames (still in place today) as well as platforms at dif-

ferent levels in vast stopes to ensure an easy underground circulation (Cauuet, 2008). The drainage was solved either by simple arrangements, like drainage channels cut directly in the basement of an adit, either by complex works when necessary, *i.e.* complex water-wheel lift system with several chambers one up onto the other one. They linked to another system by a short adits like those from Paru Carpeni mine (Cauuet 2011) were mined parallel veins or even inside large works as those from Catalina Monulesti site. The water lifted by the water wheels was then driven by wooden channels inside large stopes or through adits equipped with channels up to a main drainage adit going out towards the surface. The size of the underground adits, stopes, and chambers (height and width) as well as the abundance of wooden equipment discovered inside the mines from Rosia Montana indicates that the Roman miner had a convenient space for work. The quality of the mines and the engineering solutions identified in the mines indicate a high efficiency and a rapid rhythm of advancement which contrasted with some dramatic description of the activity in underground mines during antique time (*i.e.* Diodorus, History, 3, 12).

The study of the preserved underground network allows the reconstruction of a spatial organization. We can imagine that the Roman mine administration was carefully supervising the development of such mining works of 30 to over 70 m long adits. This is the consequence of a production planning imposed by the Roman tax authority to best serve the state finances. The study of the mining workings from Rosia Montana requires the study of its logic development as it is conditioned by the nature of the deposit and the type and number of concessionary entities that had to work according to a program regulated by the Roman law (Cauuet, 2004). The gold and silver mines from *Alburnus Maior* certainly represent one of the largest mining complex of Roman age and the archaeological research that have been recently carried out represent

the largest preventive archaeological research of a mining site ever realized in Europe.

Presently, the large mining project planned at Rosia Montana seems to vanish due to strong opposition so one can expect that the rich vestiges discovered there and belonging to a long mining tradition will be protected as they have been excavated. However, the emptied underground space was weakened by the removal of the supporting backfilling and should be reinforced and not abandoned as such. Furthermore, the study of the site is not finished and different orientations of new research could still be launched underground in the northern part of the site but also to be completed elsewhere, like at the surface concerning ore and metallurgical workshops or miners' dwellings. These villages should be found and studied with the perspective of a protection and valorization program of all archaeological discoveries and sites for future conservation and public access.



References

BARON, S., TAMAS, C.G., CAUUE, B., MUNOZ, M. (2011). Lead isotope analyses of gold-silver ores from Rosia Montana (Romania): a first step of a metal provenance study of Roman mining activity in *Alburnus Maior* (Roman Dacia), *Journal of Archaeological Science*, vol. 38, Nr 5, p.1090-1100.

CAUUE, B. (2004). Apport de l'archéologie minière à l'étude de la mise en concessions des mines romaines aux IIe et IIIe siècles. L'exemple de *Vipasca* (Aljustrel, Portugal) et d'*Alburnus Maior* (Rosia Montana, Roumanie), *V Mesa Redonda sobre Lusitania Romana: las comunicaciones*, J.-G. Gorges, E. Cerrillo et T. Nogales Basarrate (eds), Caceres 7-9 nov. 2002, Caceres, p. 33-60.

CAUUE, B. (2005). Mines d'or et d'argent antiques de Dacie. Le district d'*Alburnus Maior* (Rosia Montana, Roumanie), *Les Nouvelles de l'Archéologie*, Editions Errance, N°100, Paris, p. 38-43.

CAUUE, B. (2008). Equipements en bois dans les mines d'or protohistoriques et antiques (Gaule et Dacie romaine), *Archéologie et paysages des mines anciennes. De la fouille au musée*, Dir. M.-C. Bailly-Maitre, C. Jourdain-Annequin, M. Clermont-Joly, Editions Picard, p. 57-73.

CAUUE, B. (2011). L'espace minier romain. Le cas des mines d'or et d'argent d'*Alburnus Maior* en Dacie romaine (Roşia Montană, Roumanie), *Actas del V Congreso Internacional sobre Minería y Metalurgia Historicas en el Suroeste Europeo. Homenaje a Claude Domergue. Leon – 2008*, Madrid, p. 345-382.

CAUUE, B., ANCEL, B., RICO, C., TAMAS, C.G. (2003). Ancient mining networks. The French archaeological missions 1999-2001 (Rosia Montana, NW Romania), *Alburnus Maior I – Chapter V, Mining Archaeology*, P. Damian (éd.), Bucharest, p. 465-526.

CAUUE, B., TAMAS, G.C. (2003). Dynamics of exploitation and types of mining workings in *Alburnus Maior* ancient mining site (Rosia Montana, NW Romania), *Studia – Geologia, 6th International Symposium on Mineralogy*, Cluj-Napoca (Romania) – 18-21 Sep. 2003, University of Babes-Bolyai, p. 31-33.

CAUUE, B., TAMAS, C.G. (2012). Les travaux miniers antiques de Rosia Montana (Roumanie). Apports croisés entre archéologie et géologie. In Orejas, A., Rico, C., Sánchez Palencia, J. (dir.). *Mineria antigua: estudios regionales y temas de investigacion actual*, Colloque International 28-29 novembre 2005, Casa de Velazquez, Madrid, 2012, p.219-241.

GHITULESCU, T.P., SOCOLESCU, M. (1941). Etude géologique et minière des Monts Métallifères (Quadrilatère aurifère et régions environnantes). *An. Inst. Geol. Rom.*, vol. 21, Bucharest, p.181-465.

MANSKE, S.L., HEDENQUIST, J.W., O'CONNOR, G., TAMAS, C., CAUUE, B., LEARY, S., MINUT, A. (2006) - Roşia Montană, Romania: Europe's largest gold deposit. *SEG Newsletter*, 64, p. 1, 9-15.

SANTIMBREANU, A. (1989). *Muzeul Mineritului din Rosia Montana*, Bucuresti, 220 p.

SANTIMBREANU, A., Wollmann, V. (1974). Aspecte tehnice ale exploatarei aurului in perioada romana la *Alburnus maior* (Rosia Montana), *Apulum XII*, Bucuresti, p. 240-279.

SIMION, M., BALAN, G., DUMITRASCU, E., VLEJA, D., NEAGU, C.M., BOCAN, I., CLESIU, S. (2003). Jig – Vaidoiaia, Rosia Montana. *Cronica Cercetarilor Arheologice din Romania Campania 2002*, CIMEC – Institutul de Memorie Culturala, Bucarest, p. 262-264.

TAMAS, C.G. (2010). (2010). Structuri de breccii endogene (*breccia pipe – breccia dyke*) si petrometalogenia zacamentului Rosia Montana (Muntii Metaliferi, Romania). Editia a 2-a, Editura Mega, Cluj Napoca, 168 p.

TAMAS, C.G., BARON, S., CAUUE, B. (2009). Minéralogie et signature isotopique du plomb des minerais auro-argentifères exploités durant l'époque romaine à *Alburnus Maior* (Rosia Montana, Roumanie), Actes du Colloque international *AURUM Authentication and Analysis of Gold Work*, Paris, 11-13 mai 2009, *Archeosciences - 33*, p. 83-90.

WOLLMANN, V. (1999). Contribution à la connaissance de la topographie archéologique d'*Alburnus Maior* (Rosia Montana) et à l'histoire des techniques d'exploitation romaines en Dacie, *L'Or dans l'Antiquité de la Mine à l'Objet*, B. Cauuet (éd.), *Supplément 9 Aquitania*, Bordeaux, p. 117-130.