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Determination of the spatial organization of the lead-silver mining chaîne opératoire at Le Minier - contribution of surface geochemistry

Study carried out within the framework of the PCR Le Minier : histoire et archéologie des entreprises argentifères médiévales



Where to search?

Texts mentioning medieval mining activities are abundant for the Minier valley. However, if certain place names are well known, it is rare to be able to locate precisely the places of production.

Indeed, if the mines can be located thanks to geological clues, topographical anomalies and the heaps they generate, the mineralurgical (sorting, crushing, grinding, washing) and metallurgical workshops can remain discrete, even invisible on the surface.



Portable X-ray fluorescence analysis coupled with a differential GPS

Following the example of studies conducted in Ariège (Térygeol et al., 2010) and in Tuscany (Volpi et al., 2019), a systematic geochemical survey was organized to detect surface metal anomalies in the territory of the Minier community. This area was occupied and exploited in the Middle Ages. The sectors suggested by the medieval archives were privileged, as well as the surroundings of the Amalou river.

The measurements were made with an X-ray fluorescence device, by direct contact with the soil. A scraping with a trowel was carried out to remove the vegetation beforehand.

Each chemical quantification was accompanied by the taking of coordinates using a differential GPS operating in RTK whose precision in x,y,z was of the order of about fifteen centimeters in clear ground.

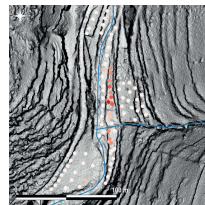
Quantified elements

A calibration designed for the study of soils was used. Some elements such as silver and antimony that do not fix in soils were not quantified. The presence of silver measured with another calibration indicates less than 9ppm of silver in the soil.

The acquisition times were fixed in order to accurately measure copper, zinc, lead and arsenic.

Element	Mn	Fe	Ni	Cu	Zn	Ga	As	Se	Rb	Sr	Y	Zr	Nb	Ba	Pb	Th
average error (%)	3,6	0,5	11	3,3	1,2	4,3	1,0	16	3,5	4,7	3,2	3,2	46	7,5	0,7	4,8

Element	Mg	Al	Si	P	S	K	Ca	Ti	V	Cr
average error (%)	65,7	26,9	2,6	52,5	8,2	1,3	3,6	2,8	50,4	42,2



5m grid pattern

The measurement points were spaced about 5 m apart. However, the impossibility of picking up a GPS signal in certain wooded or bushy areas did not always allow us to respect this distance.

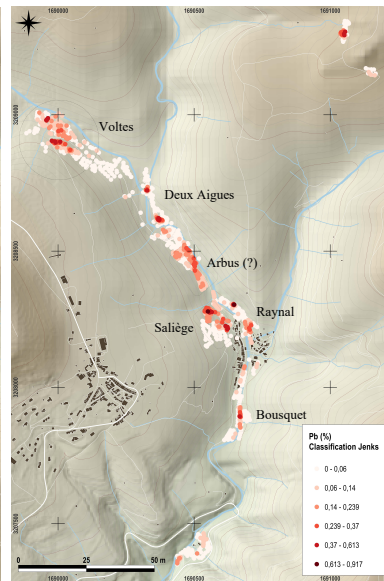
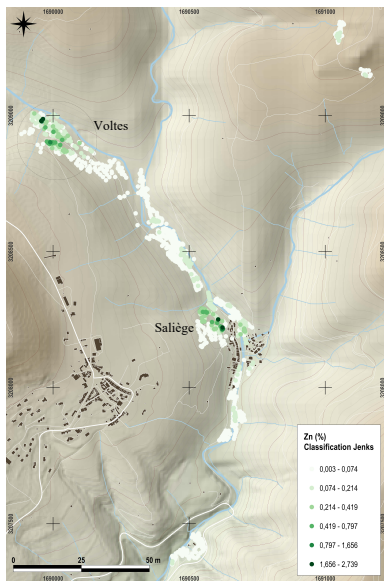
As soon as a concentration higher than the natural geochemical background was detected, a tighter grid was made to verify the presence of an anomaly and to delimit its contours.

Finally, the analyses performed were superimposed on a LiDAR DTM to refine the interpretations according to the topography (slopes, terraces, etc.).

Natural geochemical backgrounds

Beforehand, controls were recorded in several locations to define the natural geochemical background.

Sector	Type	Pb	Zn
Voltes	Mineralization zone	270 ppm	460 ppm
Saliège	Mineralization zone	310 ppm	470 ppm
Le Minier	Valley (not alluvial)	325 ppm	335 ppm
Deux Aigues	Valley (not alluvial)	225 ppm	150 ppm
Voltes	Non mineralized zone	240 ppm	130 ppm



Results: different anomalies in the hillsides and in the valley bottom

The main chemical elements detected in the soils that may be related to mining activities are lead, zinc and arsenic. If the presence of lead and arsenic (here associated with the oxidation of sulfides) is not surprising because of their increased fixation in the acidic soils of the area, the presence of zinc in large quantities indicates a significant saturation of the soils.

Relative mobility	Ph		Redox potential	
	Neutral-alkaline	Acid	Oxidizing	Reducing
High	As	Zn, Cd, Hg, Co, Ni, (Mn)	Mo, Se	
Medium	Mn	Cu, Al, Pb, Cr	Cu, Co, Hg, Ni, Zn, Cd	Mo
Low	Pb, Fe, Zn, Cd, Ti	Fa(III), Ti	Pb, Ti	Fe, Zn, Co, Ni, Ti
Very low	Al, Cr, Hg, Cu, Ni, Co	Mo, Se, As	Al, Cr, Fe, Mn	Al, Cr, Hg, Co, Se, B, Mo, Cd, Pb

Mobility of metallic trace elements in soils, source: Föstner, 1985.

Particularly high zinc contents exceeding 1000/2000 ppm and often reaching 5000 ppm have been detected on the hillsides of the Voltes sector to the north and the Saliège sector to the south. These anomalies are not localized in the vicinity of the mining structures but in their surroundings and seem to be associated with the presence of tailings heaps. In the valley bottom, however, zinc concentrations are lower and rarely exceed 600/1000 ppm.

Lead concentrations are more abundant. The center of the various anomalies generally reaches 3000/5000 ppm lead and its edges 1000 ppm. Lead has been detected in the hillsides area where zinc is present, but also in the valley bottoms where zinc levels are low. Finally, it should be noted that some sectors (in particular near Arbus) have been reworked by cultivation terraces after the mining activity. The anomalies are therefore spread out and do not have a marked core.

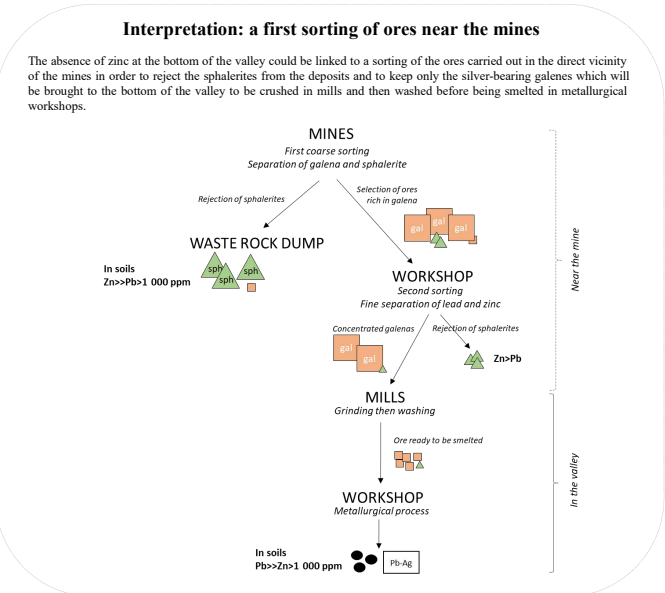
Conclusions and perspectives

Prospecting has allowed the identification of clear anomalies in several places, and therefore the presence of rejects related to silver production. The results obtained are rich in potential. They may allow us to identify treatment workshops, whether for the preparation or smelting of ores.

These prospecting also allow to outline a spatial organization of the work:

- mining sectors on the hillsides that seem to be dedicated to the sorting of ores rich in galena and sphalerite;
- other sectors much more enriched in lead that seem to be dedicated to the end of the process, probably to crushing, washing and metallurgy.

To go forward, it will first be necessary to improve the representation of the data by using a spatial interpolation of the kriging type. This will allow the geochemical analyses to be linked to the topographic context. These maps will then have to be compared with the information contained in the medieval production archives. The hypotheses of location will then be consolidated, and surveys and excavations can be undertaken.



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