Geophysical Investigation of the Pb-Zn Deposit of Plombières, Belgium

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Abstract. The new ore deposits discoveries are more and more complex: lower grades, smaller size, higher depth, complex mineralogy and geometry… Geophysical prospecting methods should be adapted and improved in order to respond to the current needs of the mining industry. The Pb-Zn deposit of Plombières (Eastern Belgium) has produced more than 220 kt of Pb-Zn concentrate during the 19th century and was one of the biggest mine of Belgium. The mine has ceased its activities since 1880, but some unexploited ore are still present under old mining works. The deposit of Plombières is classified as a Mississippi Valley type deposits. It consists mainly of Pb-Zn-Fe sulphides and oxides veins/lodes hosted in a transverse fault crosscutting Visean carbonated rocks and Namurian detritic rocks (Dejonghe and Jans 1983). Three geophysical techniques are used to inspect the MVT ore deposits: electrical, gravimetric and magnetometric techniques. The data obtained will then be combined using innovative inversion techniques and constrained with drill-hole information allowing better detection and targeting the Pb-Zn deposits.

Keywords. Geophysics, MVT deposit, 3D modelling, Plombières.

1 Introduction

The deposit of Plombières is a MVT ore deposit located in Eastern Belgium near the German and Dutch borders (Fig.1). This deposit was already extracted from historical time until 1881 but Pb-Zn mineralization is still hosted in the basement, under the old mining works as reveal by a hole-drilling campaign in the 90's. A 3D modelling of the Pb-Zn mineralization has been achieved in order to target the deposit and to better understand its genesis. This step enables to target the deposit using geophysical investigation techniques (electrical, magnetic and gravity methods). The geophysical 3D model will further be used to build a geologically-constrained multi-geophysics inversion model.

2 Geological Context

The Pb-Zn deposit of Plombières is located in the mining district of the Verviers synclinorium. This mining district is the most important of Belgium and has produced the overwhelming majority of the Belgium Pb-Zn concentrates (2Mt) from historical time until the beginning of the 20th century (Fig.1). The deposit of Plombières was one of the most productive mine of the district with a production of more than 220kt during the 19th century. This production is weaker than the annual production of the biggest Pb-Zn mines in operation such Boliden Tara Mine (Ireland) (Boliden 2015) or Lisheen (Sesa Sterlite 2015). Statistically, the exploited Plombières deposit can be situated between the 25th percentile and the median in term of size and Pb-Zn grades comparing to other MVT deposits (Table 1).

Table 1. Summary statistics of MVT deposits (USGS 2010; data from Taylor et al., 2009). [Min: minimum value; 10th: 10th percentile; 25th: 25th percentile; 75th: 75th percentile; max: maximum value].

	Min	10th	25th	Median	75th	90th	Max	n
MVT deposits (113 deposits)								
Size (Mt)	0.06	0.65	1.90	7.00	18.1	42.4	394	113
Pb (Mt)	<0.01	<0.01	0.02	0.11	0.36	0.98	6.30	108
Zn (Mt)	<0.01	0.03	0.11	0.33	0.95	2.44	16.6	108
Pb (%)	0.18	0.75	1.10	1.90	3.60	6.27	13.0	101
Zn (%)	0.11	1.89	3.56	6.00	9.94	12.5	24.0	107
Cu (%)	0.10	0.14	0.17	0.23	0.33	0.44	0.52	8
Ag (g/t)	3.40	10.2	17.8	32.5	54.8	88.0	485	34

The deposit hosts in a transverse fault crosscutting the Namurian shales/sandstones in its Northern part and the Visean limestones in its Southern part. The mineralizing process is similar for all the MVT deposits of the district of the Verviers synclinorium: the mineralizing fluids-originated from seawater evaporation during Givetian to Carboniferous era-percolated to the Cambro-Silurian basement causing a dolomitization of the crossed limestones (Dewaele et al. 2004). Mineralized dense brines were then expulsed during the Jurassic via transverse faults generated by the Rhine graben extension (Muchez et al. 2000). The fluids have then precipitated in Pb-Zn sulphides mainly within the carbonated formations (Fig. 2) (Dejonghe et al. 1993: Dewaele et al. 2004).

In Plombières, the mineralization is closely linked to the transverse fault: in the Namurian shales/sandstones, the mineralization is strictly hosted in the fault presenting a vein shape. While in the limestone part, the mineralization is less structurally controlled and is spread within the limestone presenting lode shapes (Dejonghe et al. 1993).

Figure 1. Location of the Pb-Zn deposits in Belgium (Dejonghe et al. 1985)

The Pb-Zn mineralization is mainly composed of sphalerite and galena but calcite, pyrite, marcasite, chalcopyrite and Zn and Pb oxides are also present.

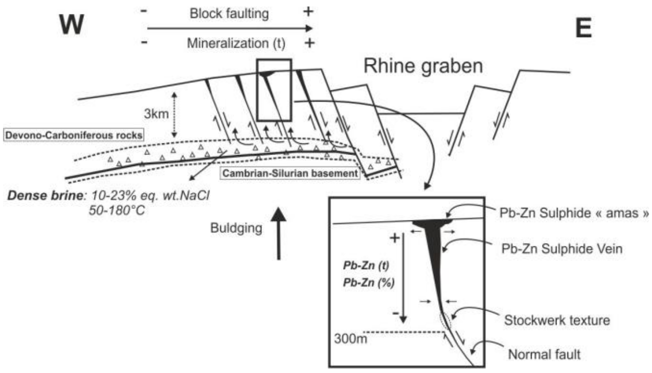

Figure 2. Genesis of the Belgian MVT deposits (mineralization zone is not at scale)

3 Methods and results

3.1 3D geological modelling

During the 90's a drill hole campaign has been led in Plombières to explore the root of the Pb-Zn vein under the old mining works. The purpose of this campaign was to evaluate its potential resources. The drillings have crosscut Pb-Zn mineralization at depth between 90 and 220m (Fig. 3).

A 3D modelling has been achieved with Micromine using the data of the 52 drillholes (Fig.4). The geometry of the orebody has been drawn manually through connection of the drillholes.

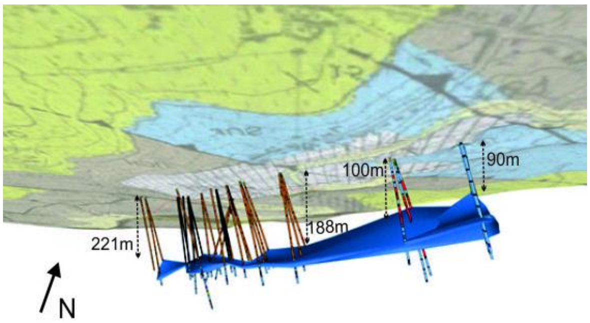

Figure 3. Modelling of the Pb-Zn vein and depth of the mineralization (view from the bottom)

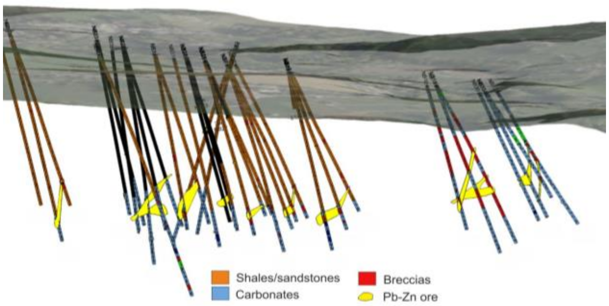

Figure 4 : Representation of the Pb-Zn mineralizaed interval. The lithological contrast between the Namurian shales/sandstone and the visean limestone give an horizontal direction to the mineralization while the transversal fault give an oblique direction of the mineralization

This geological model provides many information about the deposit: size, length, depth, width, shape of the mineralization and a better understanding of the genesis. This large extensional fault generated by the Rhine graben extension is clearly visible in the core rocks and its role in the mineralization process is evidenced in both Namurian and Visean rocks. The upper mineralized zone, which is controlled by the normal fault, is composed of Pb and Zn sulphides while calcite is much more abundant at depth (Fig. 5). Most of the Pb-Zn mineralization cut by the hole drillings are hosted in limestone and presents a breccia texture. The biggest majority of the Pb-Zn veins present a thickness of 0-2 m with a median Zn grade around 5-6 %. The volume of the modelled Zn-Pb vein has been estimated to 647491.7m^3, which corresponds to 2.26Mt (using a density of 3.5) with average grade of 10.4%Zn, 1%Pb and 13 g/t Ag. These figures have to be taken carefully due to the weak density of hole drilling in some places and the irregular shape of the vein.

3.2 Geophysical survey

Three geophysical techniques are used in this project to inspect this MVT ore deposits: electrical, gravimetric and magnetometric methods. The data obtained will then be combined using innovative inversion techniques and constrained with drill-hole information allowing better detecting and targeting the Pb-Zn deposits.

An electrical campaign (electric resistivity and induced polarization) has been achieved in the southern part of the Pb-Zn vein in order to target the vein at its lower depth; but the mineralization was not detected despite the 600m long profile (Fig 6.). Nevertheless, the fault zone between the Visean limestones and the Namurian shales/sandstones crossed by the profile is clearly visible and can be more precisely positioned (Fig. 6).

A gravity campaign has also been achieved using the Scintrex CG-5 AUTOGRAV gravimeter. Three gravimetric profiles have been made in the southern part of the deposit but the results are still in progress. A magnetometric campaign is scheduled in the future months.

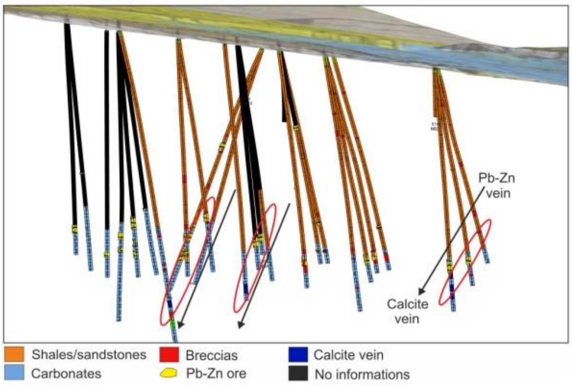

Figure 5. Mineralogical evolution of the Pb-Zn vein with depth

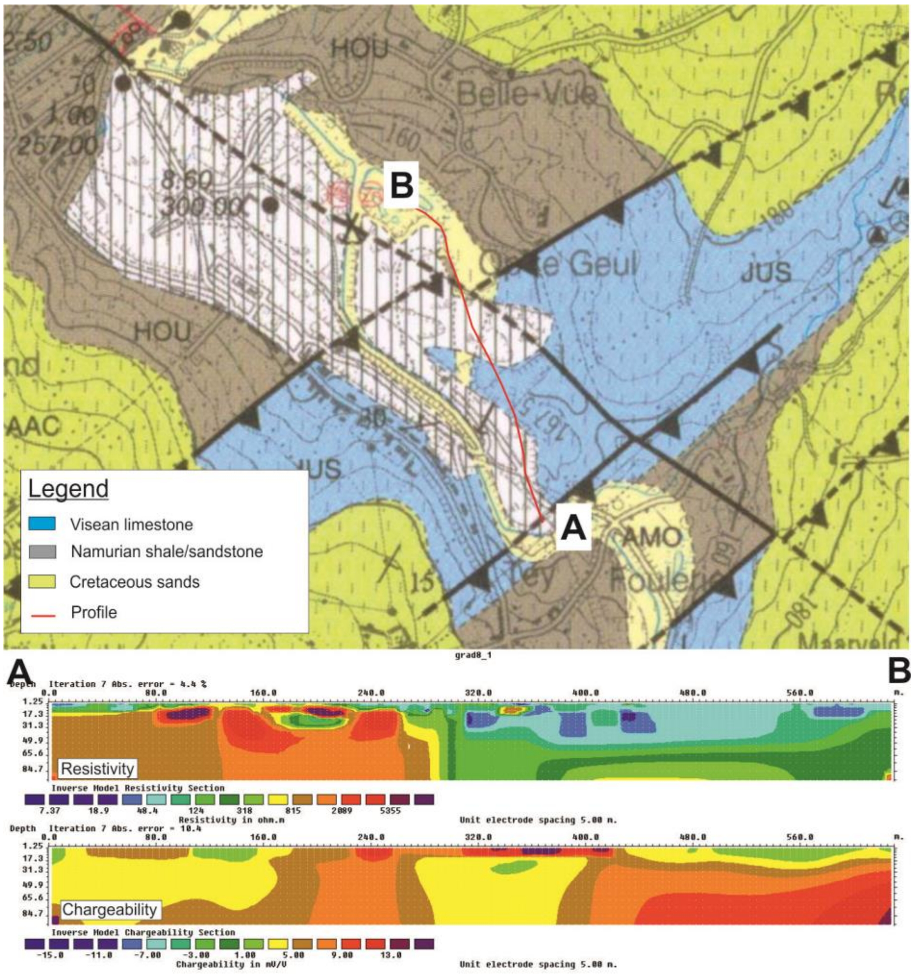

Figure 6. Electrical profile. The resistivity profile (top) and chargeability profile (bottom)

4 Discussion

The mineralization is clearly lithologicaly and structurally controlled. Indeed, the contact between Namurian shales/sandstones and the Visean carbonates creates a high permeability contrast zone which hosts a part of the mineralization while the other part of the Pb-Zn mineralization is structurally controlled and hosts in the transversal fault. In this normal fault, a zonation can be observed in the mineralization (Fig. 8) with massive galena and sphalerite occurring mainly at low depth and disseminated sphalerite and massive calcite vein at depth. The mineralization was then formed by at least two mineralizing fluids: a first one has crystallized galena and sphalerite in the upper part, and a second one has crystallized calcite at depth. Indeed, the carbonate doesn't co-precipitate with the sulphides due to the acid generated during their deposition (Anderson 1983).

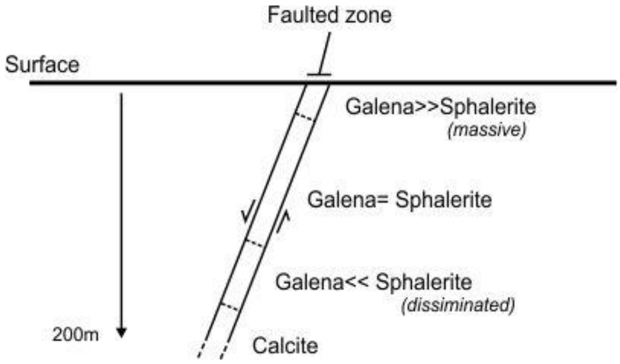

Figure 8. Mineralogical zonation with depth in the normal fault of Plombières

The stratigraphic core log shows that the Pb-Zn vein becomes more disseminated in depth (as confirmed by Dejonghe et al. 1993) and is even substituted by calcite. Nevertheless, the thickness of the mineralized zone is not decreasing with depth and the grades are still high contrary to the digger observation (Dejonghe et al. 1993). The lateral extension of the Pb-Zn vein is hard to estimate. Indeed, in the northern part the shape of the vein become really irregular and does no longer follow the lithostrucural control as it is shown in the Fig.7. Several hole drills don't intercept the mineralized vein while it seems to extend in that direction. This observation is only valid for the Northern part of the deposit because all the hole drills localized in the Southern part (where the Visean limestone outcrop) cut the mineralization. It is extremely difficult to predict the lateral and longitudinal extension of the Pb-Zn vein in this context.

The electrical survey don't reach the mineralization depth despite a 600m length, but it enables to localize precisely the fault zone and to measure the resistivity and chargeability values of the rock.

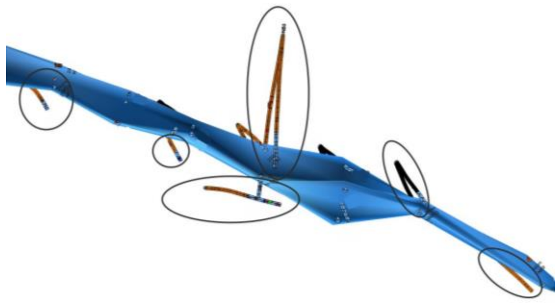

Figure 7. Several bore hole doesn't cut the Pb-Zn veins despite the predictive extension of the fault (view from the bottom).

5 Conclusion

A 3D model of the Pb-Zn mineralization of Plombières has been made with Micromine based on a drillhole campaign achieved in the early 90's. This model is the first step of this project and has led to the better understanding of the Pb-Zn mineralization genesis. This model will be further use to constrain the geophysical inversions.

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