Tridimentional Modelling and Resource Estimation of the Mining Wastepiles of São Domingos Mine, Iberian Pyrite Belt, Portugal

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INTRODUCTION

Located in the Portuguese sector of the Iberian Pyrit Belt, the São Domingos Mine was exploited in the roman period, and between 1857 and 1966 by the Mason & Barry Company. The mining activity produced an amout of 25 Mm³ of mining residues (Álvarez-Valejo *et al.*, 2007), all of them with high metal contents (Mateus *et al.*, 2011).

This work aims at evaluation of some of these wastes, namely those located in the mine northern sector (Fig. 1), considered as high economic potential, due to the high Au and Ag contents. These materials are characterized by gossan, volcanic and sedimentary ore host rocks, and were mapped in detail by Matos (2004) and evaluated by the spanish mining company Compañia Nacional de Piritas, S.A.(CONASA), between 1990 and 1991. The residues are heaped in wastepiles (Figs. 1 and 2) and as landfill, as part of the mining residues were used for the construction of the Mina de São Domingos village and industrial areas earthworks (Fig. 1).

Tridimentional individual volumes were modeled for the sampled wastepiles, aswell for the sampled landfill areas, and Au and Ag resources were estimated in each model.

GEOCHEMICAL DATA

The waste modelling and resource estimates were based on a data set from LNEG archives (Portuguese Geological Survey), comprised by an historical drilling and sampling campaign by CONASA (Malavé and Mora, 1991), detailed mine waste mapping (Matos, 2004), and a digital elevation model of the area (Quental et al., 2003).

The CONASA sampling was carried out in four different waste classes: gossan (W1), felsic volcanics (W2), shales (W3) and in some landfill areas (W4) (Fig. 2), by means of reverse circulation drilling (RC) for sampling, and pitting for size fraction sampling and precise waste thickness measurements. The dataset contains 160 boreholes (total of 1,884 m) and 162 pits (total of 1,307 m), totaling 1148 samples assayed for Au and Ag.

The individual pit samples were sorted into 4 size fractions of >40 mm, 40-9 mm, 9-5 mm and <5 mm, and assayed for Au and Ag. Size fraction analysis revealed that an overall increase in Au correlates with an increase in size fraction (Fig. 2). The average grade in the coarser fraction (>40 mm) had grades greater than 1.20 g/t Au in all classes, with exception of W3 class (shales), where the Au grades were consistently low (<0.25 g/t Au) in all size fractions. There seems to be no apparent correlation between Ag grades and size fraction, being the average grades of size factions very proximate.

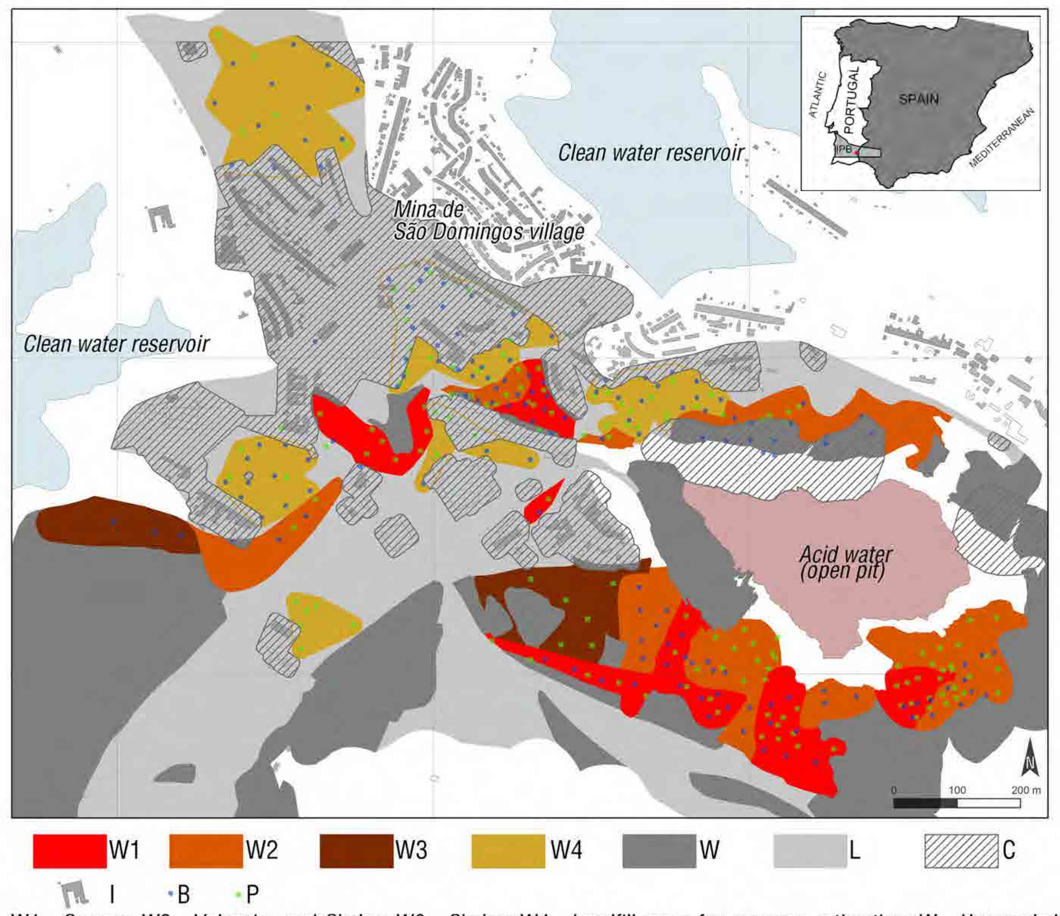
MINE WASTE VOLUME MODELLING

The waste volume modelling was performed by defining a group of boundaries for each waste pile: the present terrain surface (upper boundary); the original terrain surface, before the waste heaping (lower boundary); and a polygon representing the extent of the pile (lateral wastepile boundary) (Fig.3).

The upper boundary was extracted from a digital elevation model (DEM). The lower boundary was interpolated with a spline function in a GIS environment (ArcMap) from the coordinate points of the bottom of the pits (true waste thickness) and the boreholes. Due to the large extent of the lower surface boundary and the small survey dataset, the quality of the model was assessed by modelling its drainage network, and comparing it with the one mapped in a 19th century (Ribeiro, 1857), prior to waste dumping. The result results revealed a high correlation between the two networks, and thus the surface model was considered as representative of the original terrain surface.

The lateral boundaries were created in ArcMap from the mining and geologic map of the São Domingos mine (Matos 2004), and from the sample distribution in the landfill areas. During this process was considered the fact that a part of the wastes are under the São Domingos mine village (Fig. 1), and near protected sites (roman galleries and slags, mining infrastructures), meaning that part of the area occupied by the wastes is conditioned for exploration, and the waste removal will be either impossible, or will have negative socio-economic impacts that need to be thoroughly assessed beforehand. Having this possible restriction in mind, a second set of polygon boundaries was defined, corresponding only to the non-conditioned part of the waste areas, where waste remobilization is possible (Fig. 1). A total of 23 waste models were created (Fig. 4).

Figure 1 - Sampling locations in the norther São Domingos mine sector



W1 - Gossan; W2 - Volcanics and Shales; W3 - Shales; W4 - Landfill areas for resource estimation; W - Unsampled wastepiles; L - Unsampled landfill; C - Conditioned exploration areas; I - Infrastructures; B - Borehole; P - Pit.

Figure 2 - Sampled waste materials

Figure 3 - Average Au and Ag grades in the sizes fractions

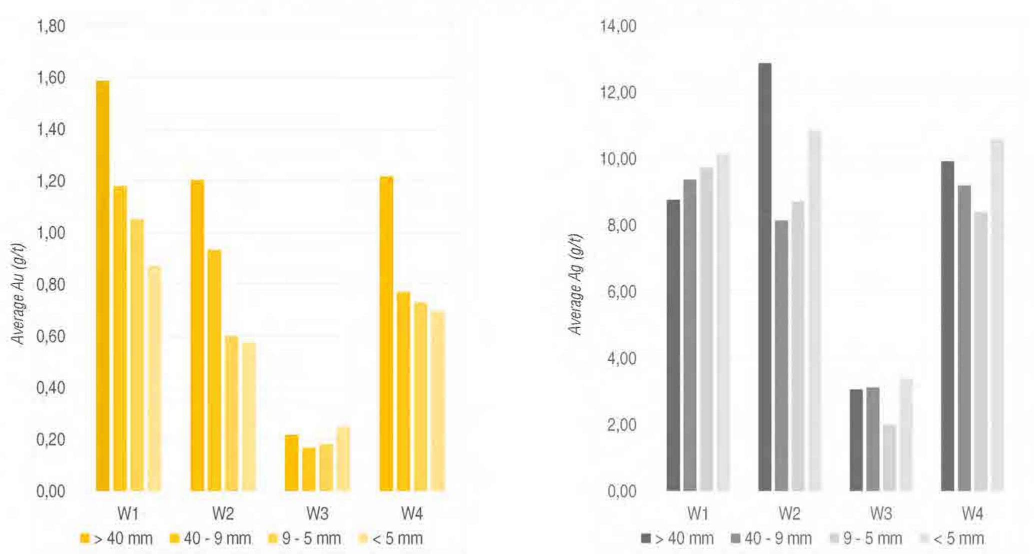


Figure 4 - Waste tridimentional modeling scheme.

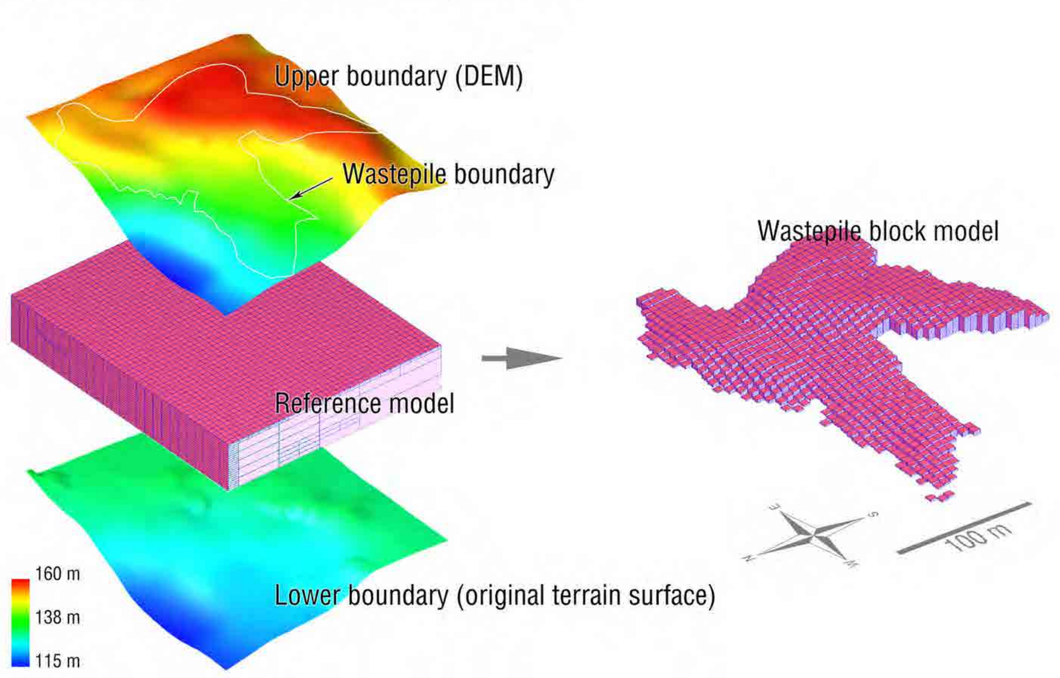


Figure 5 - Wastepile and landfill block models

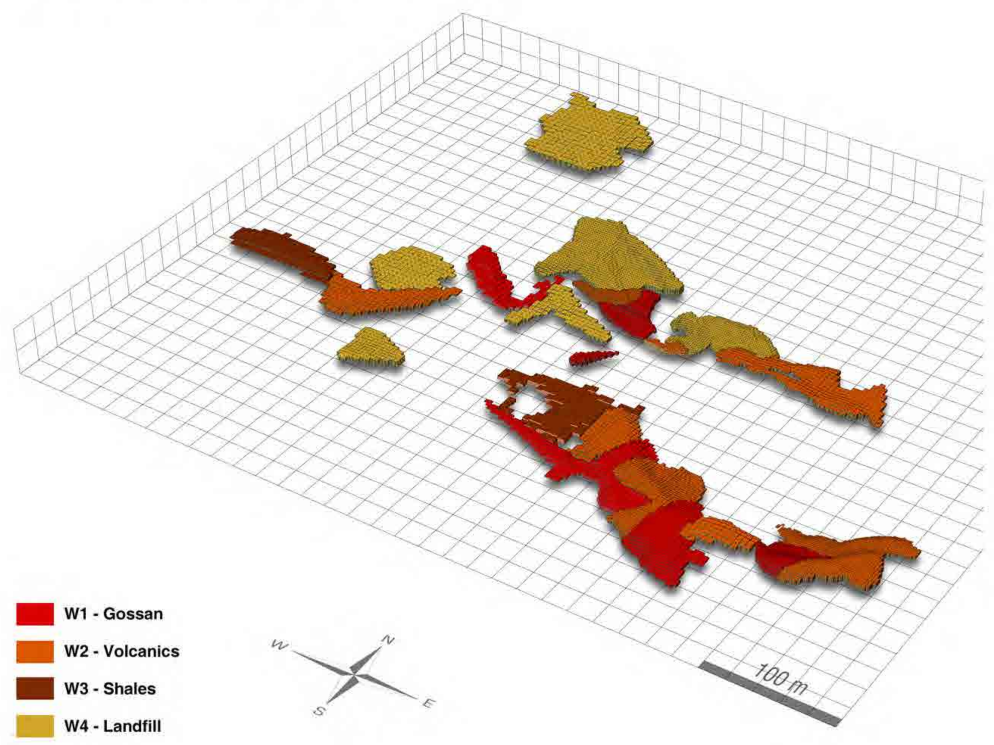


Figure 6 - Distribution of Au (a) and Ag (b) grades in a Volcanics and shales block model.

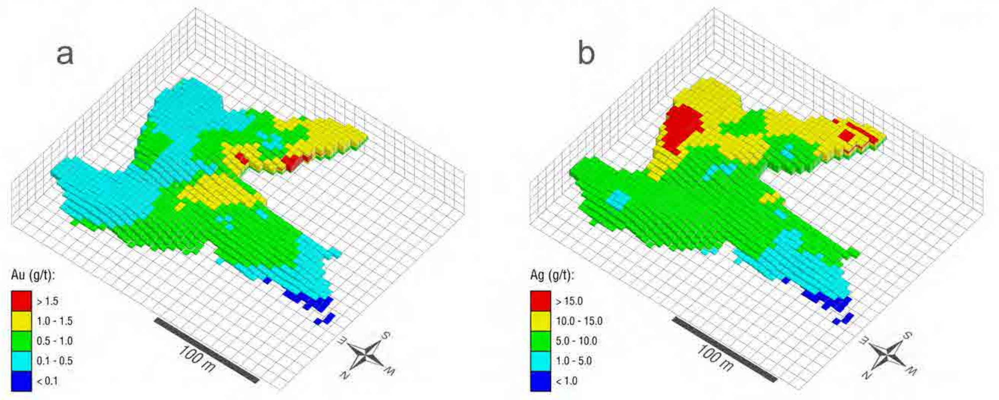


Figure 7 - Gold grade distribution in the wastepile and landfill models.

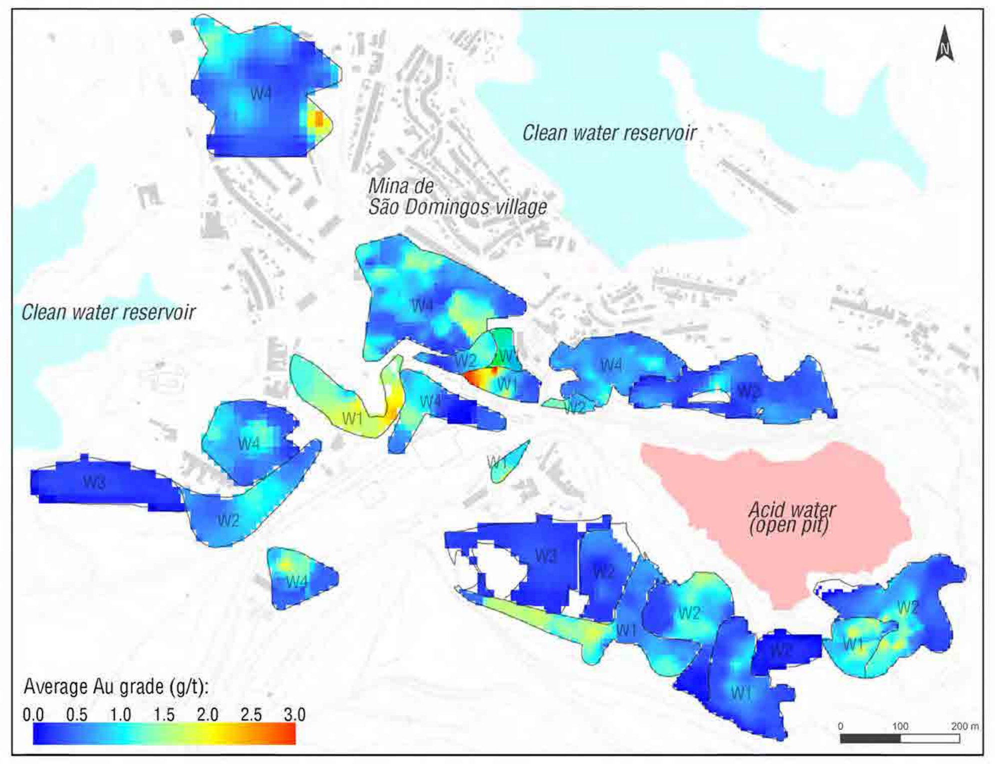
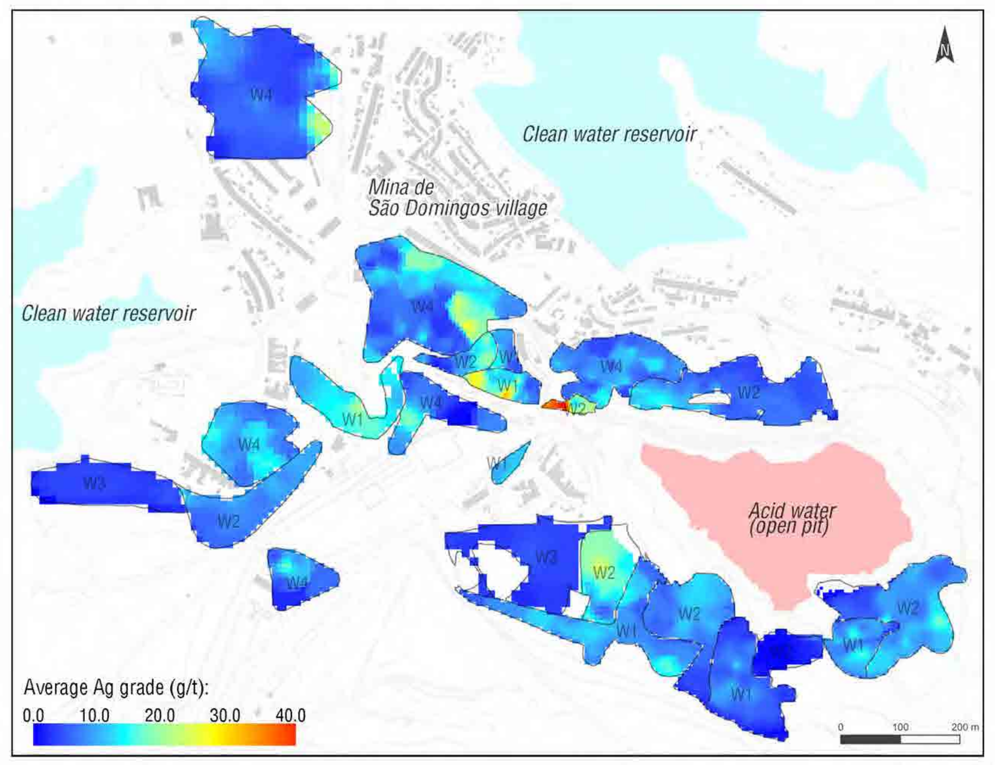


Figure 8 - Silver grade distribution in the wastepile and landfill models.



RESOURCE ESTIMATION

Grades for gold and silver were interpolated into the models by the inverse distance squared method (Fig. 6). Bulk density values between 1.83 and 1.30 were applied to all blocks within the models, considering the average specific gravity of the main lithological constituents and a void ratio of 0.30.

Considering the fact that the resource estimates are for the mining waste piles, no cut-off grade was applied to the reported resource, as any practical recovery of the precious metals will probably require the processing of all the materials in the piles. However, in order to determine an amount of material with reasonable prospects for eventual economic extraction, *i.e.*, *high grade* materials with no removal restrictions, only the piles with an average gold grade above 0.50 g/t were considered for reporting (Table 1).

Table 1 - Resource estimates in the non-conditioned volumes of the wastepile and landfill models with an average Au grade above 0.5 g/t.

Waste class		W1	W2	W4	total
Quantity (t)		613,208	667,150	1,105,121	2,385,479
Grade (g/t)					
	Au	1.07	0.71	0.65	0.77
	Ag	10.01	8.61	7.08	8.26
Contained metal (oz t)					
	Au	21,145	15,266	23,078	59,489
	Ag	197,443	184,581	251,464	633,488

These criteria excluded all the wastepiles of the shales class (W3), in which the average Au and Ag grades for all modelled are very low, averaging between 0.19 to 0.21 g/t Au and 2.70 to 2.83 g/t Ag. Three of the eight piles composed of felsic volcanic and shales (class W2) were also excluded, with average grades ranging from 0.08 to 0.40 g/t Au and 0.60 to 5.76 g/t Ag. Only one model of the gossan wastes class (W1) was excluded, averaging 0.43 g/t Au and 5.08 g/t Ag. None of the landfill models (class W4) were excluded.

CONCLUSIONS

The results revealed an inferred mineral resource of 2.38 Mt in the non-conditioned volumes of the *high grade* waste piles and landfill models (Au >0,5 g/t), with an average grade of 0.77 g/t Au and 8.26 g/t Ag, totalling a metal content of 59,489 oz t gold and 633,488 oz t silver. If the conditioned part of the volumes were to be considered, the mineral resource increases to 2.94 Mt with an average grade of 0,77 g/t Au and 8,27 g/t Ag, corresponding to 72,871 oz t Au and 781,531 oz t Ag. If all the 17 waste piles and 6 landfill volumes modelled in this investigation were to be considered, *i.e.*, including both high and low grade models, and the portions with probable conditioned exploitation (edified and protected areas), the mineral resource could be increased to 4.0 Mt with an average grade of 0.64 g/t Au and 7.30 g/t Ag, corresponding to a metal content of 82,878 oz t gold and 955,753 oz t silver.

In possible future mine extractive projects, a further detailed knowledge is needed, complementary to the existing data. The characterization of the fine vertical zonation of the mining wastes will be essential to define high grade levels within the wastes. In future land use plans of the São Domingos mining area, the balance between economic mine profit and negative impacts of the waste exploitation must be done, and a re-mining phase must be properly planed considering the mine rehabilitation plan and current heritage promotion projects. In this balance, is essential to improve the knowledge related to the existing geological resources. The present evaluation work is a contribution to the understanding of the São Domingos mining potential.

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