APPLICATION OF GEOPHYSICS FOR MINERAL EXPLORATION IN SMALL-SCALE MINING

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ABSTRACT

In every mining venture, it is necessary to determine ore reserves to support the business feasibility analysis and the investment plan. However, the process of calculating reserves, especially due to diamond drilling campaigns, can be costly and time-consuming, thus often prohibitive in small-scale mining. In this work, we developed a methodology to minimize the cost of mineral exploration in small-scale mining, using geophysics techniques to generate a target-oriented, low-risk, cost-efficient drilling plan. This methodology has been applied and evaluated in a small manganese deposit in the state of São Paulo, Brazil.

Small-scale mining; geophysics; geological modeling;

INTRODUCTION

Many of the world-class deposits in operation are close to exhaustion, and new discoveries of this kind have been increasingly rare (Laznicka, 2001; Seccatore et al., 2013). Therefore, small-scale mining is likely to play a bigger role in mineral production in the future. For this reason, it has become increasingly important to study methods and technologies for small-scale mining.

In this work, we developed a methodology relying on geophysics for mineral exploration in small-scale mining. This methodology has been applied to a small manganese deposit at Fazenda Santana, in the town of Itapira, São Paulo state, Brazil.

METHODOLOGY

Figure 1 below represents the methodology that was developed and applied in this work.

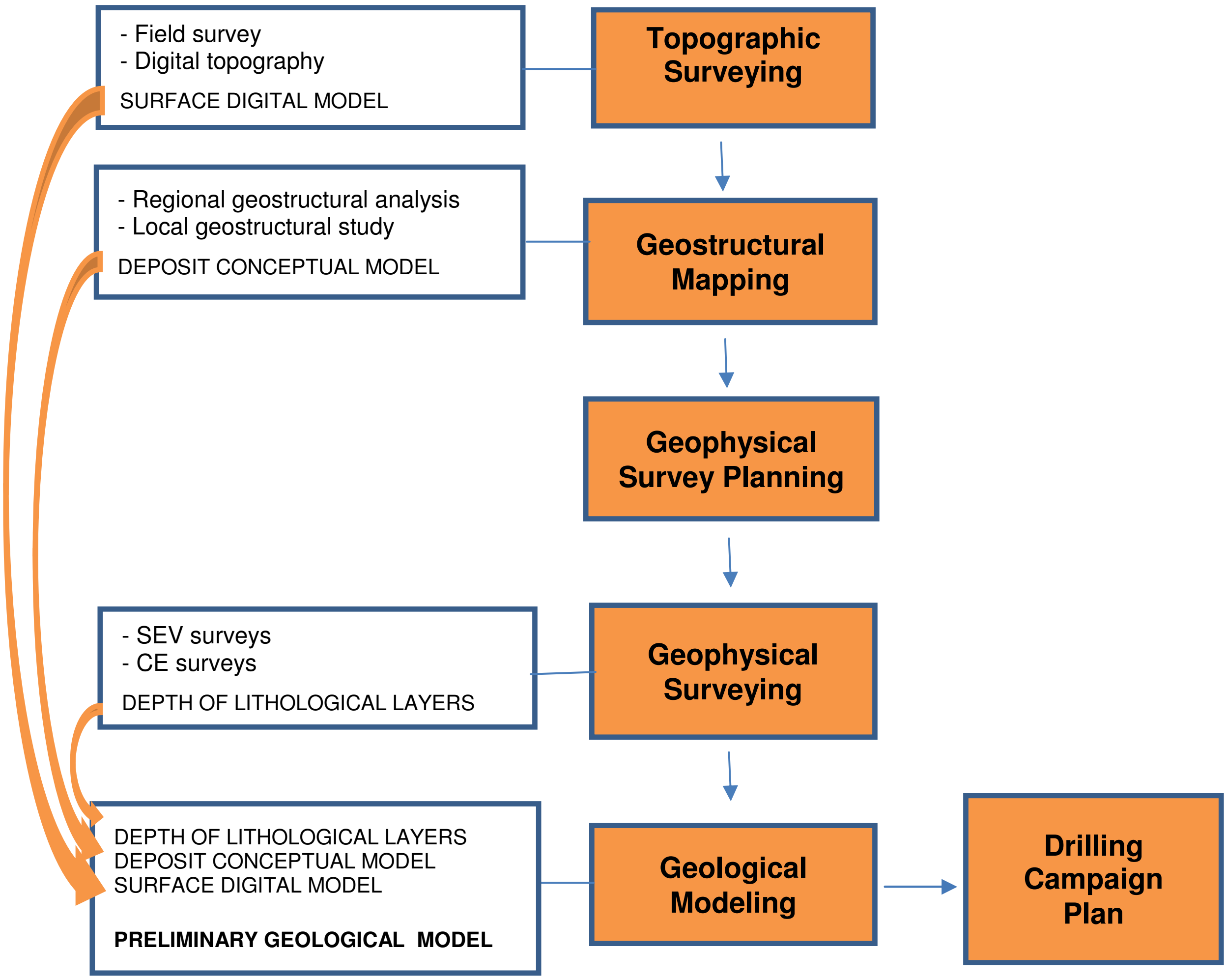

Figure 1: Diagram of the methodology carried out.

The works were conducted at Fazenda Santana because of the existence of outcrops of manganese rocks, old mining works, and agreement with land owners. Topographic surveying, geostructural mapping and geophysical surveying works were executed. Interpretation of the data obtained resulted in a preliminary geological model and a drilling plan.

The Figure 2 below shows an aerial image of the surveying target at Fazenda Santana.

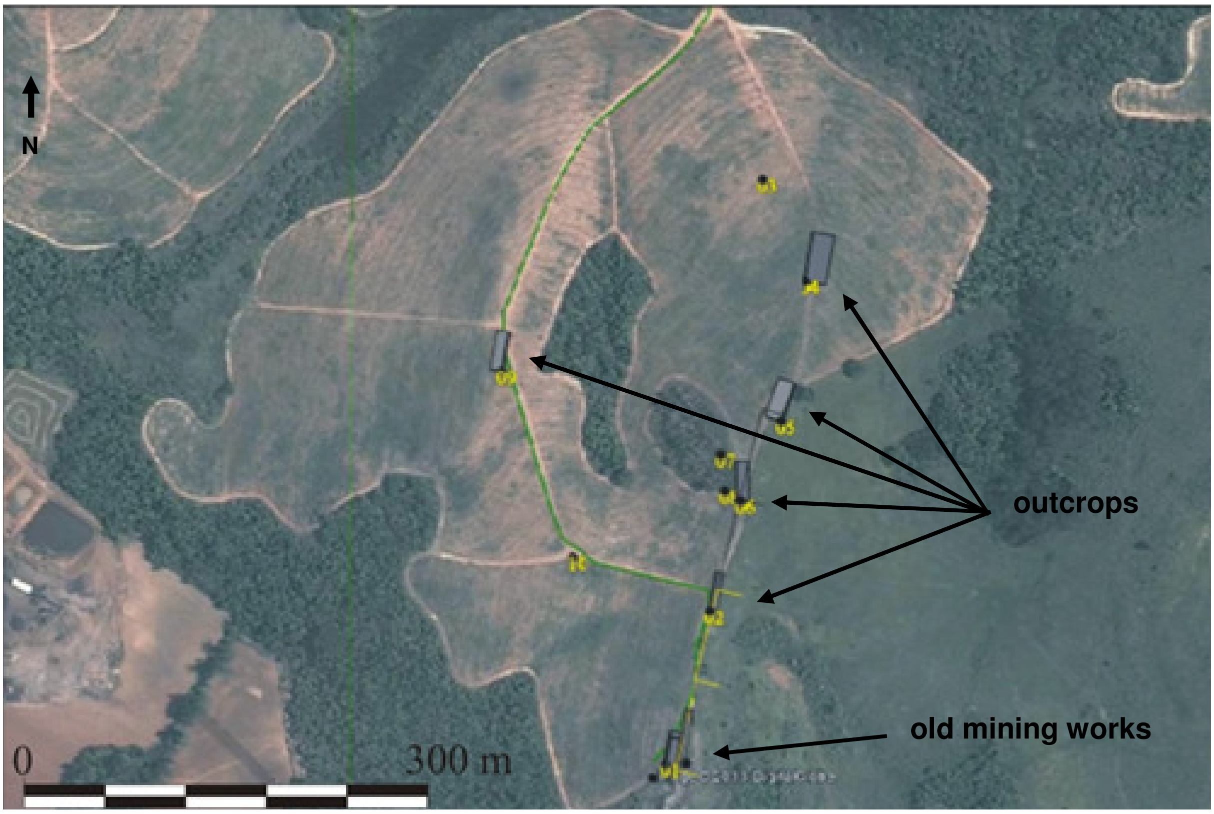

Figure 2: Survey area.

Topographic Survey

The field survey at Fazenda Santana, combined with additional data from the “Carta IBGE Mogi Guaçu” (Id: SF-23-Y-A-III-3) (IBGE, 2014), generated a digital topographic model, illustrated in Figure 3.

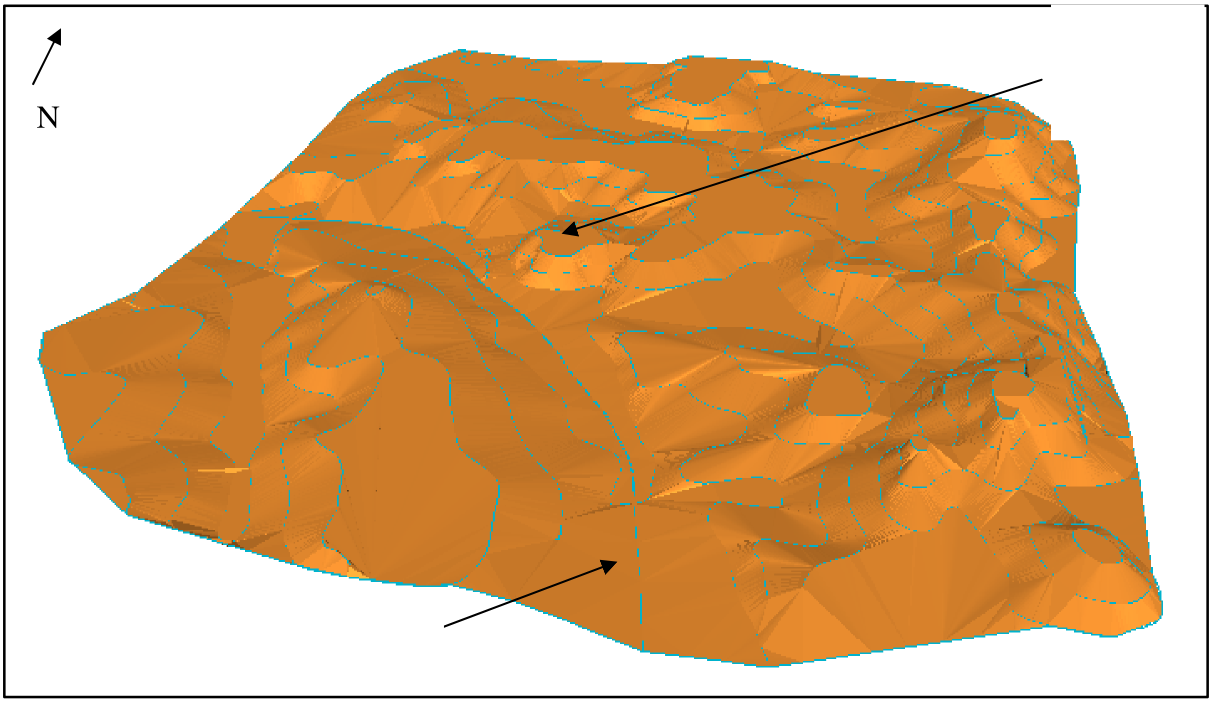

Figure 3: 3D view of the surface digital model at Fazenda Santana.

Geostructural Mapping

The mapping carried out shows that the outcrops of manganese rocks at Fazenda Santana present folds and plans generally aligned to the NE-SW axis. The outcrops attitudes are consistently close to 285º of azimuth, with sub-vertical dip. Shearing zones may indicate discontinuity in the occurrences of manganese ore.

The field work allowed for the identification of an outcropping manganese rock that presents stretched portions, as shown in Figure 4. These stretched portions indicate the proposed conceptual model for geological investigation, as in Figure 5.

Figure 4: Stretched portions in manganese rock indicating the conceptual deposit model.

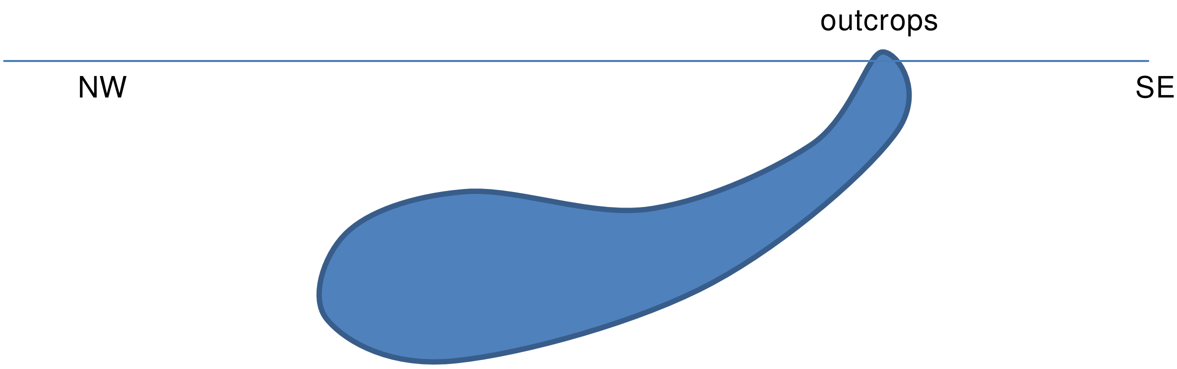

Figure 5: Conceptual model for the manganese deposit at Fazenda Santana.

Geophysical Surveying

Geophysical surveying works were conducted to identify the depth of subsurface layers, thus generating information for the preliminary model of the deposit and the drilling plan. The targets for geophysical surveying were determined based on the information obtained through topographic and geostructural analysis.

The methods used in the geophysical surveying were those of resistivity and induced polarization, and the data were obtained through two complementary techniques, vertical electrical sounding ("VES"), with Schlumberger array, and electrical profiling, with dipole-dipole array. While VES surveys produce vertical and relatively deeper data, profiling generates information of layers in sections and relatively lower depths (Braga, 2001; US EPA, 2014).

These methods and techniques were chosen based on relatively low cost, ease and speed of mobilization and application, good response to low depths, and efficiency to individualize manganese layers.

The Schlumberger array is the most widely used in VES because of the quality of field data, ease and speed of execution, and low sensitivity to lateral variations of resistivity and natural or artificial noises that exist underground, such as natural soil currents, interference from power lines, etc.

Investigations by electrical profiling are conducted along lines, and the results are related to each other to generate sections showing the depths of subsurface layers. The dipole-dipole array was used due to the detail and precision of the results obtained.

VES surveys were carried out on four points, and horizontal profiling along five lines, as shown in Figure 6.

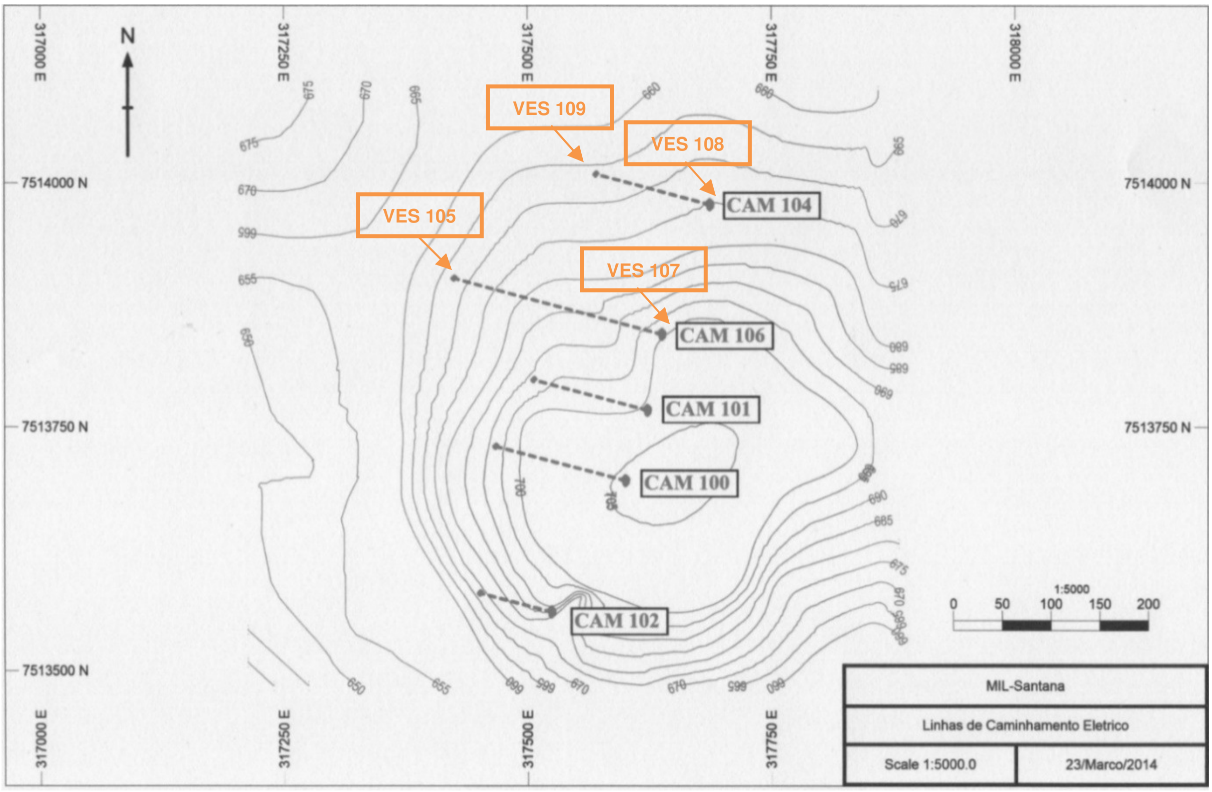

Figure 6: Points of VES and lines of electrical profiling at Fazenda Santana.

These surveys showed a layer with low resistivity (less than 200 ohm.m) and high chargeability (greater than 21 mV/V) that differs from the others and is interpreted as occurrence of manganese.

The results of VES indicate, as in Table 1, that the mineralized layer can exceed 10 meters thick, and parts of the deposit can be found over 40 meters deep.

Table 1: Depth and thickness of surface layers obtained through VES surveys.

SURVEY		FROM	TO	ROCK
VES 105	S-01	0	0,6	Soil
	S-01	0,6	1,1	Soil
	S-01	1,1	10,0	Unconsolidated rock
	S-01	10,0	35,0	Unconsolidated rock
	S-01	35,0		Manganese
VES 107	S-02	0	0,7	Soil
	S-02	0,7	9,8	Soil
	S-02	9,8	28,0	Unconsolidated rock
	S-02	28,0		Manganese
VES 108	S-03	0	0,6	Soil
	S-03	0,6	13,5	Soil
	S-03	13,5	18,6	Unconsolidated rock
	S-03	18,6	29,0	Manganese
VES 109	S-04	0	0,5	Soil
	S-04	0,5	6,6	Soil
	S-04	6,6	42,9	Unconsolidated rock
	S-04	42,9	55,0	Manganese
	S-04	55,0		Bedrock

End of mineralized

10,4m thick mineralized layer

Part of the body can be 42,9m deep

12,1m thick mineralized layer

The five electrical profiling surveys were carried out in the NW-SE direction, transverse to the deposit axis. The resistivity sections generated are shown below in Figures 7 to 11. The mineralized layer, represented by resistivity of less than 200ohm.m, is illustrated with shades of green and blue. Chargeability data confirmed resistivity information.

Resistivity sections indicate that significant part of the deposit should be found in depths not exceeding 15 meters, and that the layer can exceed 10 meters thick. The section 106 shows an anomaly, which electrical characteristics suggest occurrence of a shallow mineralized zone.

The data obtained through VES and profiling strengthened the evidence of occurrence of an economically viable manganese deposit, enabled preliminary modeling of the deposit, and resulted in a lean, cost-effective drilling plan for Fazenda Santana.

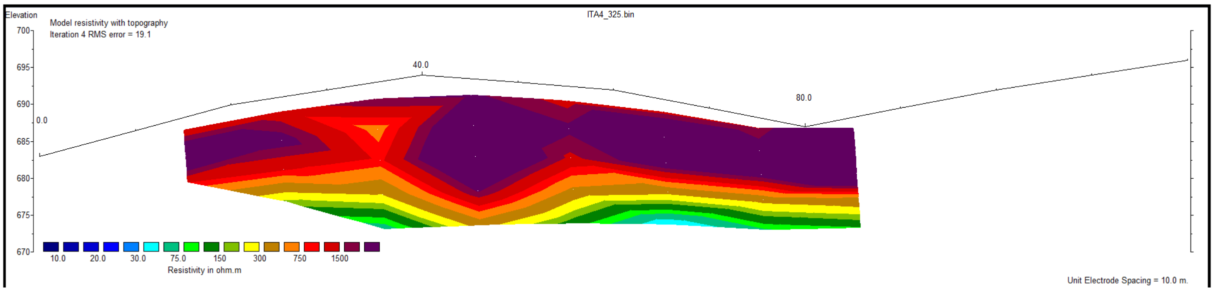

Figure 7: Section 104

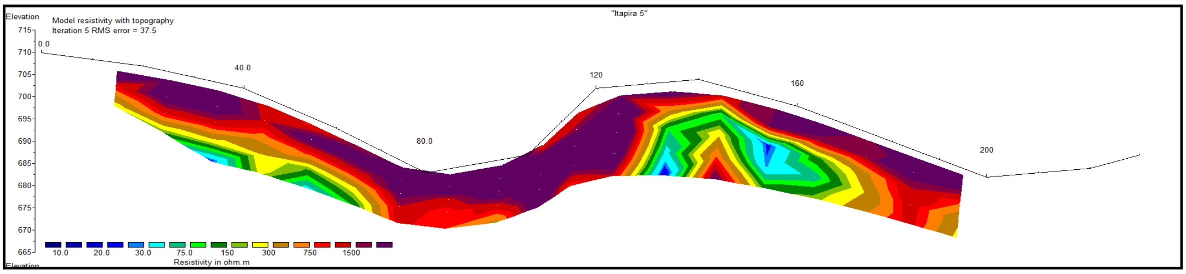

Figure 8: Section 106

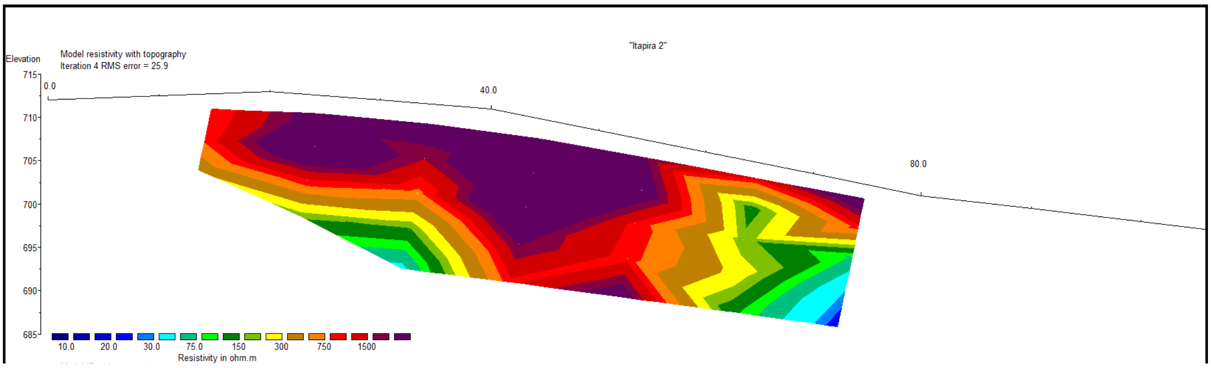

Figure 9: section 101

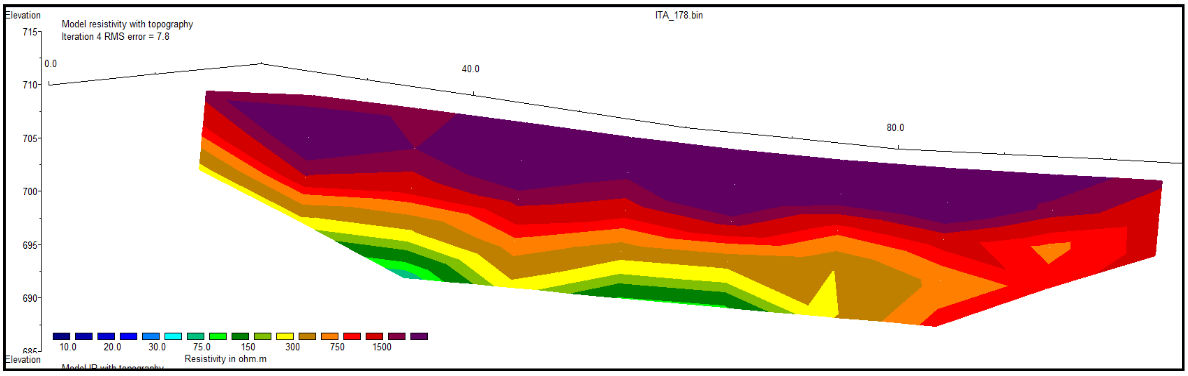

Figure 10: section 100

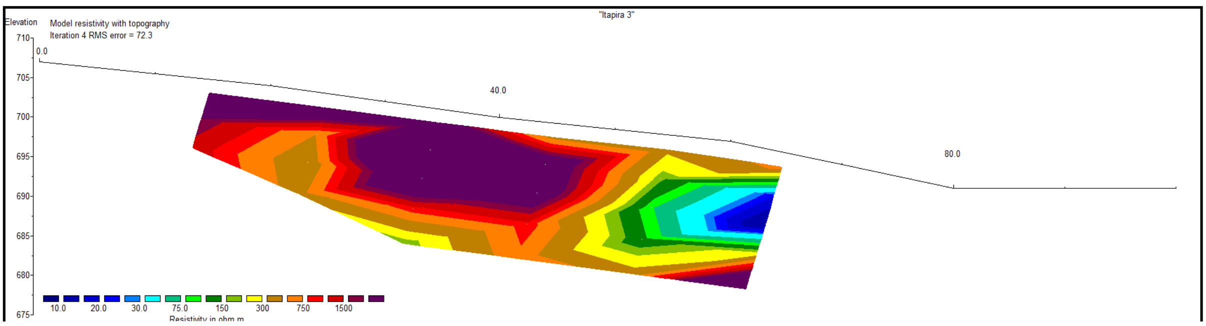

Figure 11: section 102

Preliminary Geological Model

The combination of geophysics data with the conceptual deposit model resulted in the preliminary model of the manganese deposit at Fazenda Santana, seen in Figures 12 and 13.

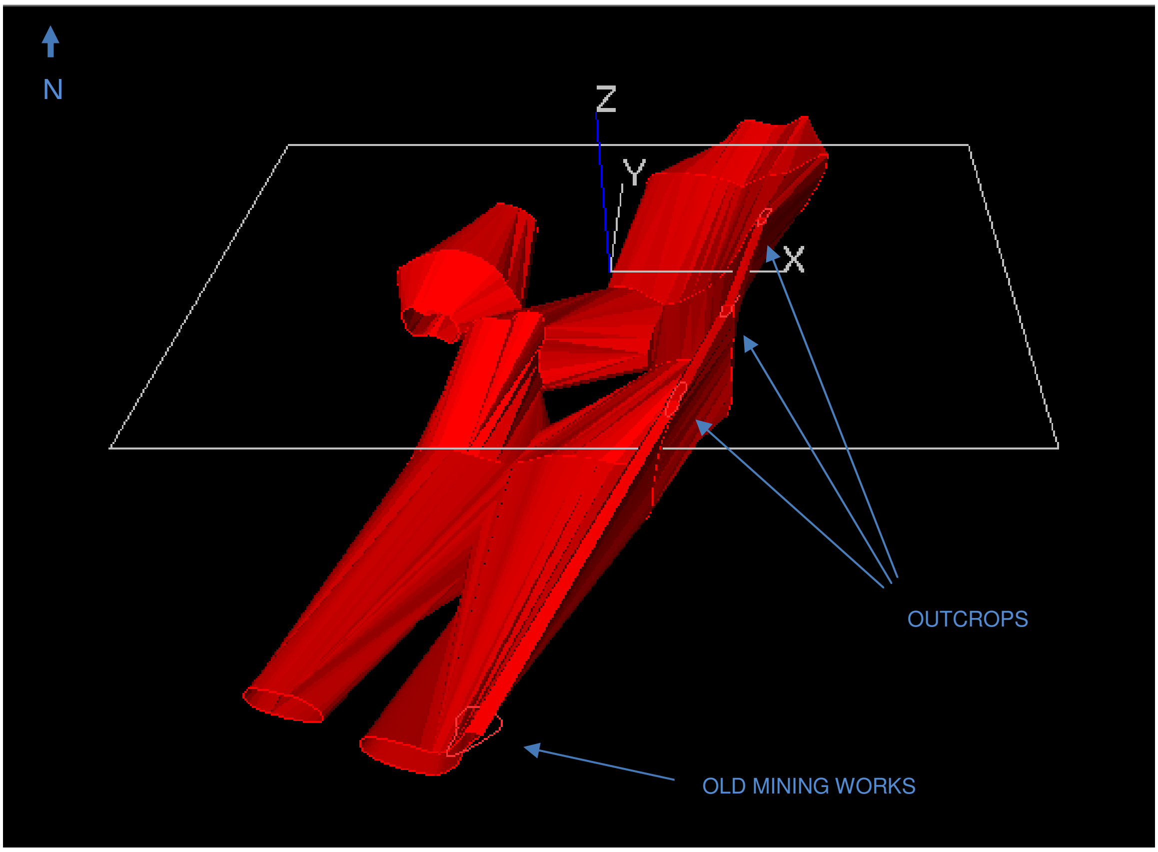

Figure 12: Preliminary model of the manganese deposit at Fazenda Santana.

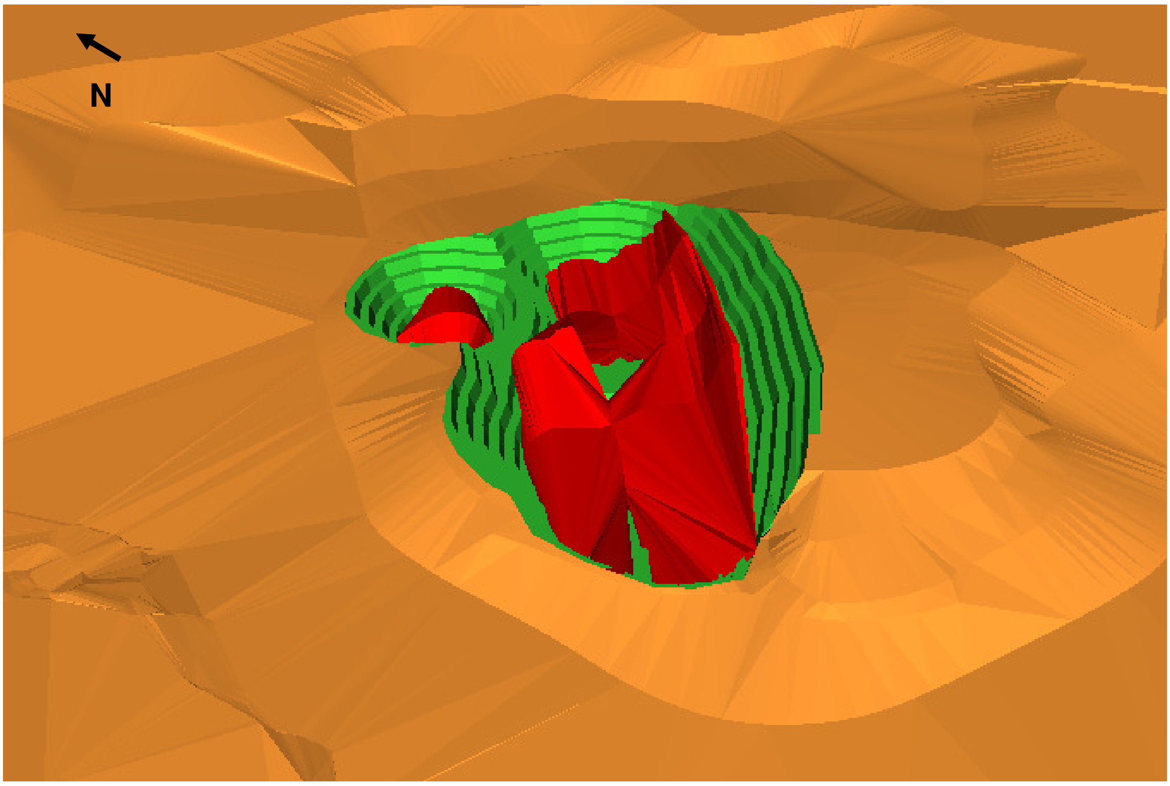

Figure 13: View of the geological model exposed on the surface with conceptual benches.

Drilling Campaign Plan

With the data obtained, a plan of exploratory drilling at Fazenda Santana was drawn up, as represented in Figure 14. The proposed drilling campaign includes two phases of works and 1,660 meters of drilling, according to the following parameters:

Phase 1: net of approximately 150m x 50m, on parallel lines coincident with the lines of the horizontal profiling, with 10 holes and estimated total length of 780 meters of drilling.

Phase 2: “in-fill” net of approximately 75m x 50m, with parallel lines and interspersed with the lines of phase 1, with 12 holes and estimated total length of 880 meters of drilling.

All drilling must be executed at vertical dip. Depth for each individual hole must range between 60 to 100 meters, according to the conceptual morphology of the preliminary geological model.

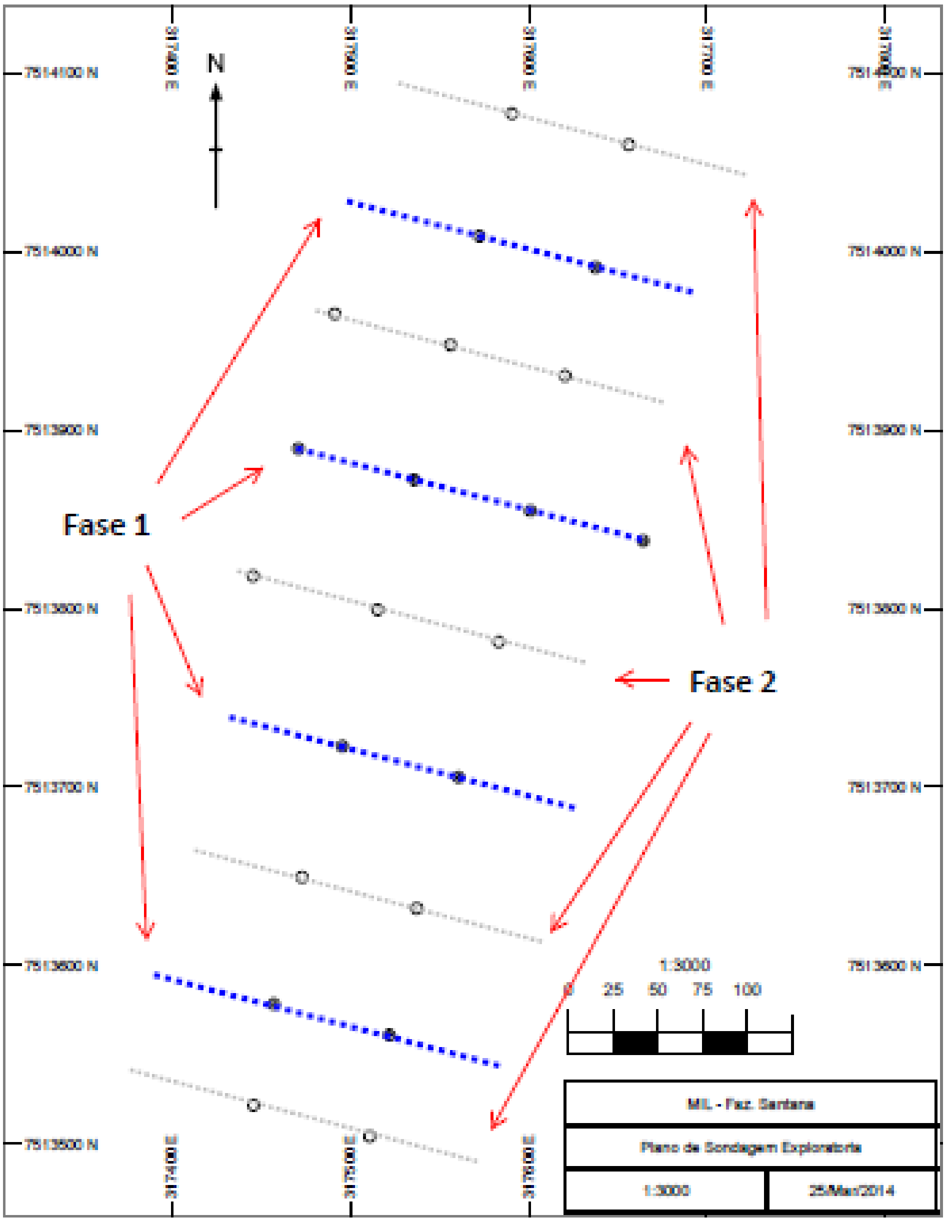

Figure 14: Drilling plan for Fazenda Santana.

CONCLUSION

Typically, small-scale mining is presented with the challenge of developing a mining venture without sufficient technical knowledge and financial resources to support the project. A new methodology is proposed to enable adequate mineral exploration in small-scale mining. This methodology relies on the application of geophysics methods and techniques to generate cost-efficient drilling campaign plans, thus reducing cost and improving accuracy of mineral exploration. The proposed methodology has been applied to a small manganese deposit in Brazil.

The interpretation of the data obtained through geophysical surveying resulted in:

- A preliminary geological model, which seems to confirm the evidence of a manganese deposit which exploitation may be economically viable;
- A target-oriented, lean, low-risk, cost-efficient drilling campaign plan at Fazenda Santana; and
- A reliable, yet economical, exploration assessment to support the mining and business plans.

The drilling campaign, as proposed, shall be executed to validate the preliminary geological model and the benefits of using geophysics to support mineral exploration in small mining ventures. Validating this methodology will allow for its replication, thus contributing to mineral exploration and business development in small-scale mining.

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