Journal of Remote Sensing & GIS

Martins et al., J Remote Sensing & GIS 2016, 5:4
DOI: 10.4172/2469-4134.1000172

Research Article | Open Access

Impact of Geophysics in Small-Scale Mining

Antonio Carlos Martins*, Elisangela Romanelli Terenci, Giorgio De Tomi and Ricardo Marcelo Tichauer

Department of Mining and Petroleum Engineering, University of Sao Paulo, Sao Paulo, Brazil

Abstract

Geological exploration for new mining ventures involves drilling campaigns, an expensive activity that may take significant time, with no guarantee of financial success. The literature review indicated that the average cost of drilling may reach over US $100 per meter drilled, and that the use of Geophysics can reduce by 30% to 50% the number of negative drill holes (holes that does not intercept the mineral orebody), thus reducing time and cost of mineral exploration. This paper shows how the application of Geophysics in two small-scale mining operations, a limestone and manganese mine, resulted in reduced exploration time with satisfactory results for the companies. In the limestone mine, Geophysics allowed the updating of the geological model. In the manganese mine, it contributed to the generation of a preliminary geological model for the deposit. In both cases, there was a significant reduction of the time spent on exploration.

Keywords: Geophsysics; Small-scale mining; Mineral exploration; Mining; Saprolitic gneiss; Limestone

Introduction

The perception that society has of mining is associated with large companies that often operate with high capital investment. However, in Brazil only, there are thousands of small-scale mining companies that exploit different minerals, operating with little resources and low capital investment. One of the most challenging aspects about mining is how to identify the deposits to implement the mineral production projects. Mine implementation requires understanding of the risks associated with the business and the importance of quality in geological investigation.

Geological investigation involves drilling activities, which demand long periods of work and require costly investments, with no guarantee of return and financial success. According to geophysicist and business analyst Ribeiro [1], the average cost of drilling operations (a direct exploration method) is US$ 100/m drilled, and the use of Geophysics for indication of mineralized zones can reduce in 30% to 50% the amount of negative drill holes (holes that does not intercept the mineral orebody), resulting in reduced time and cost associated with drilling activities.

This paper includes a brief comment on the application of Geophysics in a limestone mine located near Taubaté, state of São Paulo, Brazil, and in a manganese mine near Campinas, also in the state of São Paulo. Both mines can be classified as small-scale mining operations. In both situations, the application of Geophysics reduced prospection work time and attended the demand required by the companies. On the limestone mine, Geophysics allowed for updating the geological model. In the manganese mine, it contributed to the generation of a preliminary geological model of the deposit. In both cases, there was a significant reduction in time spent on exploration.

Materials and Methods

The method used for obtaining geophysical data in both surveys was electro-resistivity. The technique of Vertical Electrical Sounding (VES) was used in the survey at the limestone mine. The techniques of Electrical Resistivity Imaging (ERI) and Vertical Electrical Sounding (VES) were adopted for survey at the manganese mine. Electro-resistivity may be defined as a measure of the difficulty with which the electrical current propagates itself through a given material [2].

Vertical Electrical Sounding (VES)

The VES technique consists of a succession of measures of a physical parameter, resistivity, with increasing separation between the electrodes of emission and reception, keeping fixed the center of the array (the attributed point of the survey) and its orientation. Increasing the distance between the A and B current electrodes, the total volume of the area included in the measure also increases, allowing for reaching deeper layers. The successive results will be strictly connected with variations of resistivity and with depth. Figure 1 presents the Vertical Electrical Sounding (VES) technique.

Electrical Resistivity Imaging (ERI)

Electrical Resistivity Imaging (ERI) investigations are performed along profiles and the obtained results relate to each other through map analysis at one or more depths or sections with several depths of

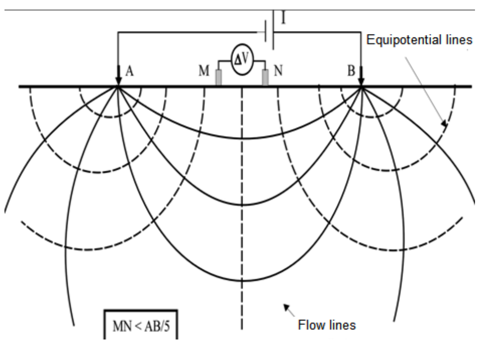


Figure 1: Vertical Electrical Sounding (VES) [3].

***Corresponding author:** Antonio Carlos Martins, Researcher at NAP Mining/USP, Department of Mining and Petroleum Engineering, University of Sao Paulo, Sao Paulo, Brazil, Tel: 551130916038; E-mail: acmartins@usp.br

Received September 26, 2016; **Accepted** October 07, 2016; **Published** October 12, 2016

Citation: Martins AC, Terenci ER, Tomi GD, Tichauer RM (2016) Impact of Geophysics in Small-Scale Mining. J Remote Sensing & GIS 5: 172. doi: 10.4172/2469-4134.1000172

investigation. Figure 2 presents the electric resistivity method through the technique of electrical imaging.

The main focus of the research is to test the use of Geophysics in practical applications in different types of mineralization, using different geophysical methods in the context of small-scale mining. This research is based on surveys in two localities with mining potential: A limestone mining property in full activity in the region of Taubaté, Brazil, and an area in which there is occurrence of manganese mineralization in the region of Campinas, Brazil.

Limestone mine

The goal of the study carried out at the limestone mine was to update the geological model. The mine is located near the city of Taubaté, state of São Paulo, Brazil. The mine operates in a 50 ha area, and has an opportunity to expand this operations area to a total of 246 ha. The work to cover the expanded area and update the geological model was conditioned to tight deadlines. A drilling campaign through conventional approach, with 3 or 4 drilling equipment, would take approximately 60 days. In order to reduce the time for data collection, geophysical methods were introduced.

The work began with a test for accuracy verification of the electric-resistivity geophysical methods (ER) with the technique of VES to identify the geological structures of interest in the same position of an existing drilling survey and validate the adherence of the results to the information acquired from drilling sampling. With satisfactory results, 31 VES surveys were planned and carried out in the Southern portion of the property. Figure 3 shows the flowchart of the stages of operation.

Results

The results show that it was possible to identify the layers of interest set out in the premises of the survey. Most SEVs presented models of four layers. The layers 1, 2 and 3 were interpreted respectively as topsoil (low to medium resistivity, low to medium chargeability), weathered and unsaturated soil (high resistivity due to low moisture content and medium chargeability) and weathered soil or saprolite (low to medium resistivity and low chargeability).

The fourth layer usually presented high resistivity values (greater than 2000 ohm m) and higher chargeability (usually above 10 mV/V), interpreted as gneiss. High values of resistivity are expected for gneiss

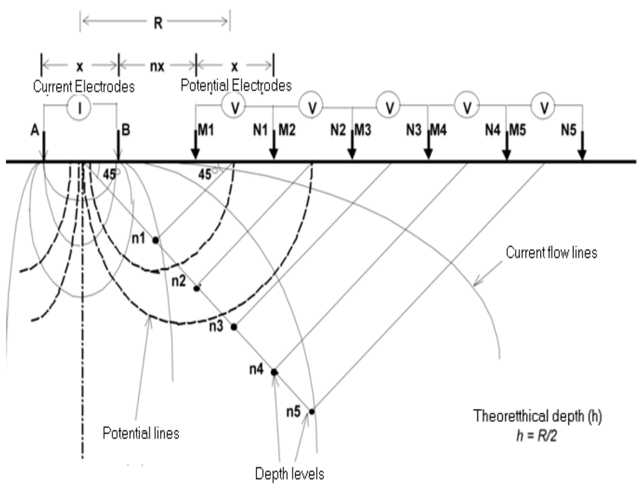


Figure 2: Electrical Resistivity Imaging (ERI) [3].

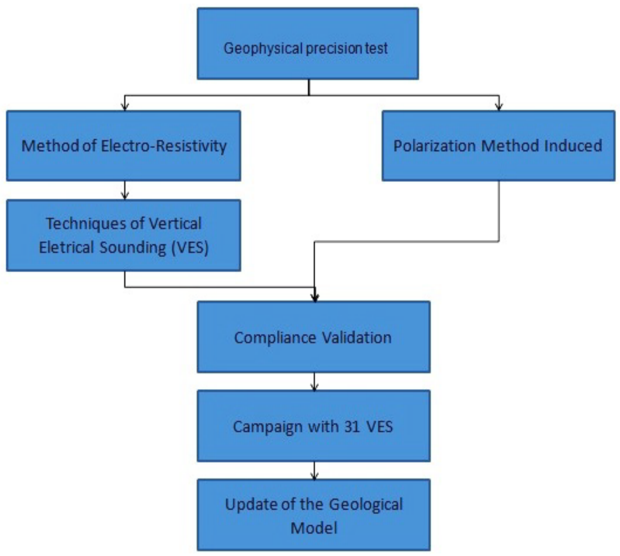


Figure 3: Flowchart of operation stages.

as a result of low degree of alteration and low porosity. Larger values of chargeability may be related to metallic accessory minerals within the gneiss, which have not yet been transformed by weathering. In the locations were SEVs 5, 6, 24, 27 and 28 were conducted, the resistivity values were below 1000 ohm m for the last layer, interpreted as altered or saprolitic gneiss. These relatively low values suggest a rock with some degree of weathering and/or fracturing. Figures 4 and 5 represent respectively VES 10 and 5 of the geoelectric model, in which the rock is characterized as altered or saprolitic gneiss.

In practical terms, the introduction of the proposed Geophysics methods and techniques allowed for obtaining the information required for updating the geological model, which normally would have been executed in about 60 days (using between 3 and 4 drilling equipment), in only 15 days, which represents 75% reduction in survey time.

The application of Geophysics allowed for expansion of the deposit geological model within the investigation area with adequate precision of the lithological units of interest (layer of soil and rock contact), within the time limits set by the company. Figure 6 and Table 1 show the VES positions, Figure 7, the geological model (current area) and the expanded geological model (expanded area).

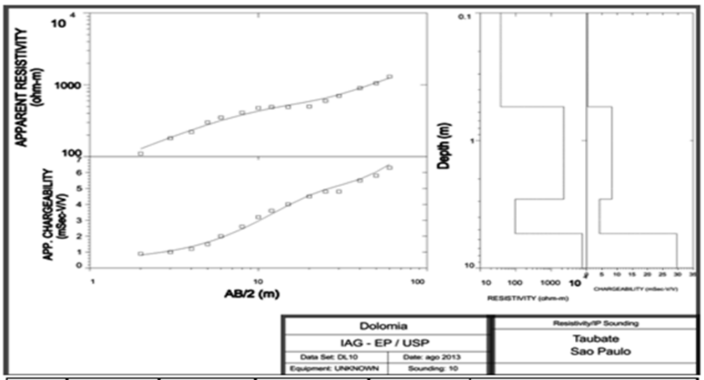
Manganese mine

The survey began with topographic and geo-structural mapping of the area of interest, which helped to define the locations of points and profiles of the geophysical investigations. The work was performed along five (5) ERI profiles and on four (4) VES positions. Figure 8 shows the flowchart of activities.

Results

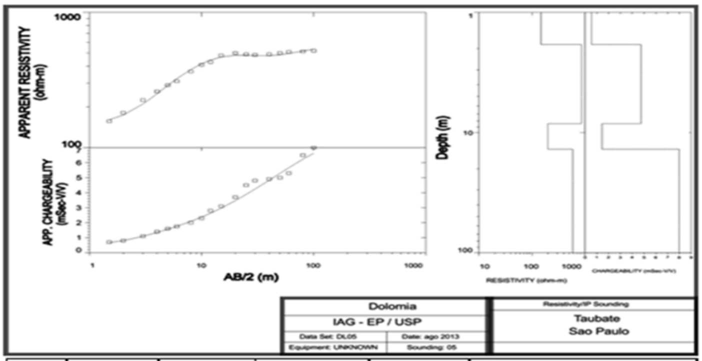
The results of the geophysical surveys indicated that a significant part of the manganese layer of should be found between 0 meters (outcrops) and 15 m deep, and that the layer thickness can reach or exceed 10 meters. Geo-structural analysis indicated that the manganese deposits in the region can be extremely deformed and boudin-shaped, with alignment to the NE-SW axis. It also indicated that the section of the manganese deposits in the region must be sigmoid-shaped.

Citation: Martins AC, Terenci ER, Tomi GD, Tichauer RM (2016) Impact of Geophysics in Small-Scale Mining. J Remote Sensing & GIS 5: 172. doi: 10.4172/2469-4134.1000172



Layer	r (ohm.m)	M (mV/V)	Thickness (m)	Top Depth	Interpretation
1	37.4	0.3	0.5	0.0	Top soil
2	2270.9	8.3	2.3	0.5	Unsaturated soil
3	96.5	4.2	2.5	2.9	Low saturated soil/saprolite
4	7633.5	29.6		5.4	Gneiss

Figure 4: VES10 of the geoelectric model.



Layer	r (ohm.m)	M (mV/V)	Thickness (m)	Top Depth	Interpretation
1	148.8	0.5	1.9	0	Top soil
2	851.6	4.7	6.6	1.9	Unsaturated soil
3	198.8	1.4	5.3	8.4	Low saturated saprolite/soil
4	585.9	8		13.8	Saprolite/weathered gneiss

Figure 5: VES05 of the geoelectric model.

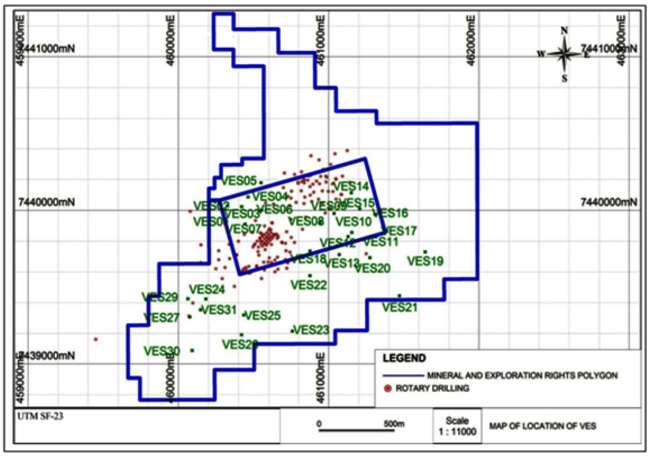


Figure 6: Implementation area for the 31 VESs.

Point	Coord UTME-W	Coord UTMN-S	Point	Coord UTME-W	Coord UTMN-S
VES 01	460272	7439974	VES 16	461262	7439890
VES 02	460292	7440072	VES 17	461323	7439776
VES 03	460390	7440046	VES 18	460810	7439708
VES 04	460440	7440103	VES 19	461562	7439608
VES 05	460530	7440217	VES 20	461193	7439613
VES 06	460465	7440008	VES 21	461365	7439346
VES 07	460394	7439931	VES 22	460776	7439552
VES 08	460889	7439888	VES 23	460622	7439201
VES 09	460991	7439935	VES 24	460080	7439474
VES 10	461093	7439772	VES 25	460318	7439337
VES 11	461153	7439735	VES 26	460283	7439194
VES 12	461063	7439772	VES 27	459959	7439368
VES 13	460999	7439659	VES 28	459962	7439499
VES 14	461111	7440079	VES 29	459948	7439144
VES 15	461163	7439947	VES 30	460036	7439407

Table 1: Coordinates of the VESs implemented in the area.

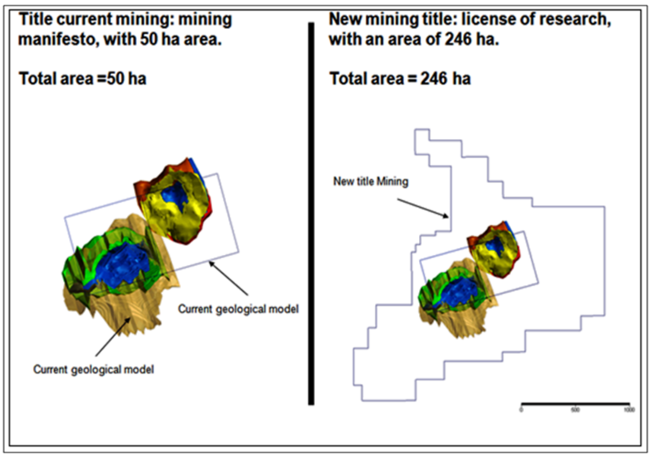


Figure 7: The geological model (current area) and the expanded geological model (expanded area).

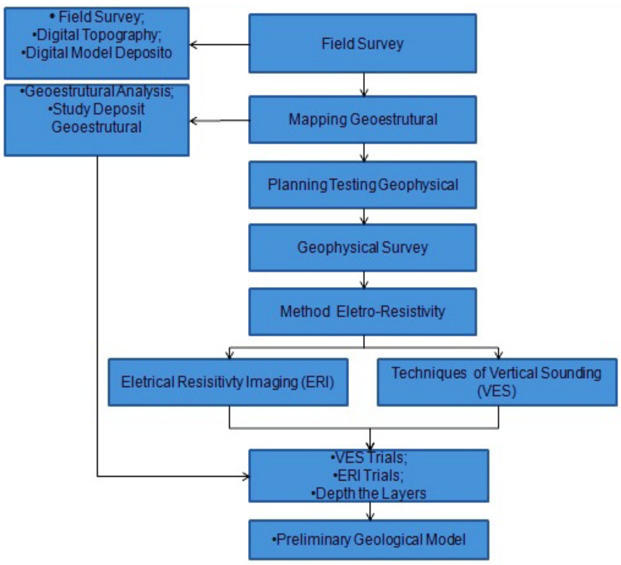


Figure 8: Flowchart of activities.

Together, topographic, geo-structural and geophysical investigations allowed for the generation of a preliminary geological model. Figure 9 shows the ERI profiles 102, 100, 101, Figure 10 shows the ERI profiles 106, 104 and Figure 11 shows the map with the location of the ERI surveys conducted.

The geophysical survey as a substitute to drilling allowed for reduction in time, as occurred in the limestone mine. The execution of an exploratory drilling plan would last for a month and, with Geophysics, was limited to a week, that is, a reduction of 77% in survey execution time. Figures 12A-12D show the geological interpretation, the preliminary geological model, and the conceptual pit generated with aid of a mining software.

Conclusion

The results achieved through the studies carried out at both small-

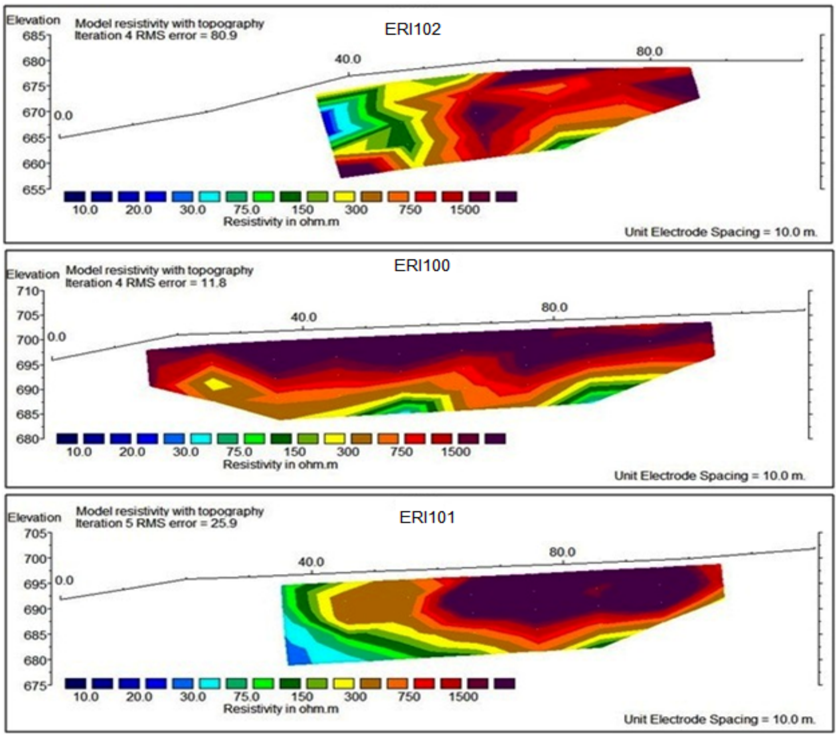


Figure 9: ERI102, ERI100, ERI101.

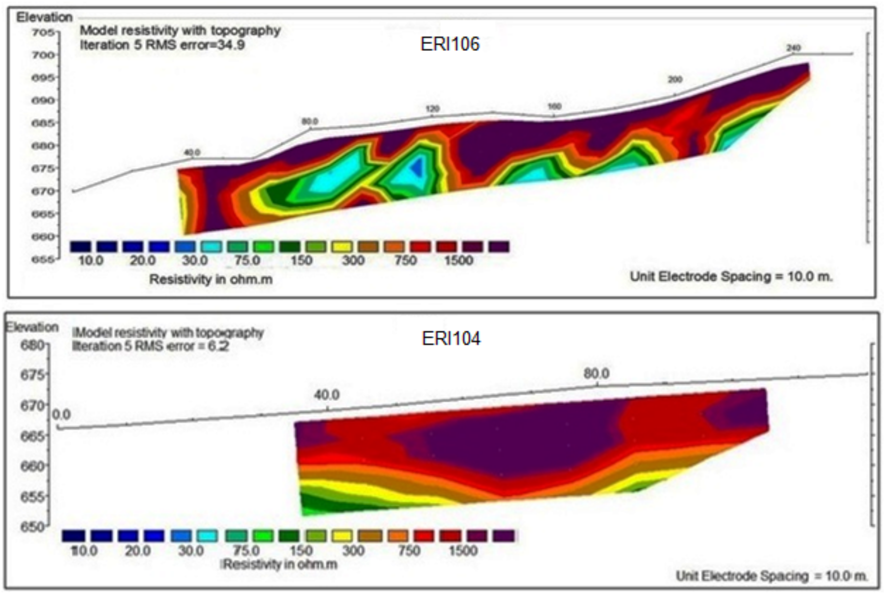


Figure 10: Shows the ERI profiles 106, 104.

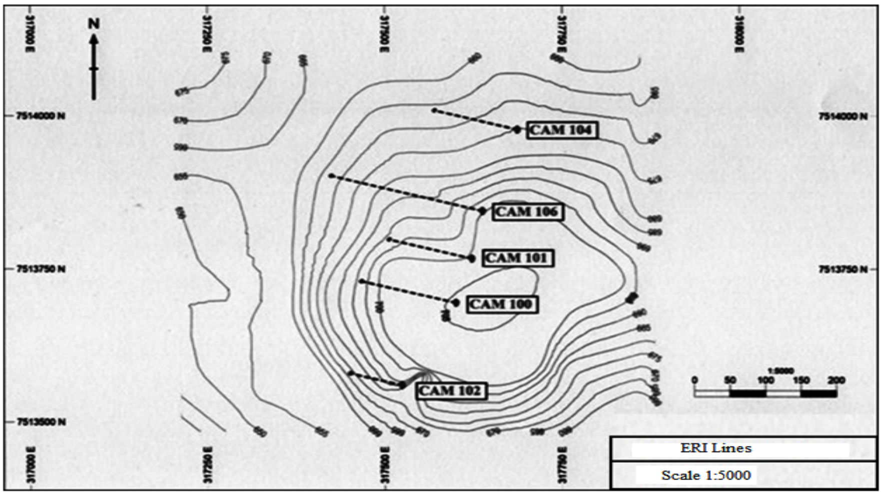


Figure 11: Map of ERI surveys conducted.

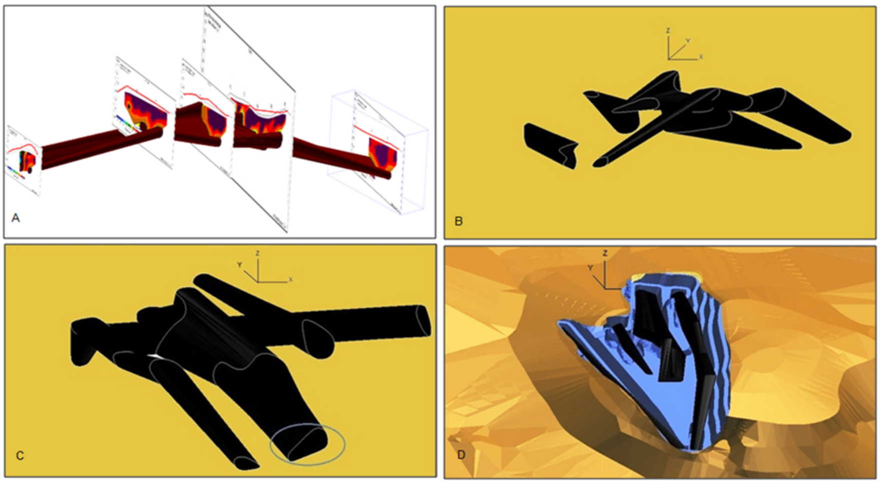


Figure 12: A) Position of ERI profiles; B, C) Geological model; and D) Conceptual pit design.

scale operations indicate time savings of more than 75% over the traditional drilling approach for the purpose of defining the orebody outline. Both cases show that the proposed Geophysics methods and techniques may improve the level of geological knowledge and that its implementation has potential to be extended and expanded. Geophysics may be successfully used in identification of the strata of interest, as a support tool to enhance and improve the level of information necessary to the generation of a geological model in short time.

References

1. Elis VR (1999) Evaluation of the applicability of electric geophysical prospecting methods in the study areas used for waste disposal. PhD Thesis, Institute of Geosciences and Exact Sciences, UNESP, Rio Claro, Brazil, p: 264.
2. Ribeiro A (2010) Geophysics in Industry Mining. Newsletter SBGf Number 4, p: 10.
3. Braga ACO (1997) Methods Applied in geoelectric characterization Geological and Geotechnical-formations Rio Claro and Corumbataí in the city of Rio Claro-SP 1997. PhD Thesis, Institute of Geosciences and Exact Sciences-UNESP, Rio Claro, SP, Brazil, p: 173.