Testing the use of FDEM EM34 for disseminated chromite prospecting in Trás-os-Montes, Portugal

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Abstract. The use of geophysics electromagnetics Geonics EM34 applied to disseminated chromite prospecting is not common. Other methods, such as magnetics, induced polarisation or gravimetry are used instead. This work refers to some tests made in Trás-os-Montes, Northern Portugal, regarding the use of frequency domain electromagnetics using the device Geonics EM43 for chromite prospecting, in areas where soil geochemistry data were also available. Several electromagnetic profiles were made and data were inverted so that potential conductivity contrasts between mineralised metadunite formations and metaperidotites, shape of the mineralised bodies, dimensions and depth could be visualised. Inverted resistivity data were correlated with surface geology, borehole logs information and soil geochemistry. In this paper, results for the selected area of Sardoal are presented.

Keywords. Geophysics, electromagnetic methods, chromite.

1 Introduction

The application of geophysical methods to disseminated chromites prospecting is usually based on magnetic, induced polarisation and especially gravimetric methods (Frashieri et al. 1995; Frashieri 2006). Although the use of frequency domain electromagnetic (FDEM) methods, namely the Geonics EM34, in chromite prospecting is not common, tests were conducted in some selected areas, in Trás-os-Montes, NE Portugal. Results were correlated with soil geochemistry conducted in the same places by Pires (1998). This test was justified not only by the easy-to-use characteristics of the equipment to conduct preliminary surveys, but also by the fact that modelling may give interesting information about the way chromite mineralisation develops at depth, since the method reaches small investigation depths. In this paper, results for the selected study area of Sardoal are presented.

2 Local geology

The most promising spots in the Sardoal area are located in a metadunite unit or other metaperidotites with chromite mineralisation, with intense serpentinisation (Fig. 1). The metadunites and metaperidotites are characterised as fine to very fine-grained and by being dark in handspecimens with the presence of abundant, rounded to subrounded disseminated chromite grains with sizes ranging from 0.1 to 2 mm (Fig. 2), which make observation of chromite very difficult.

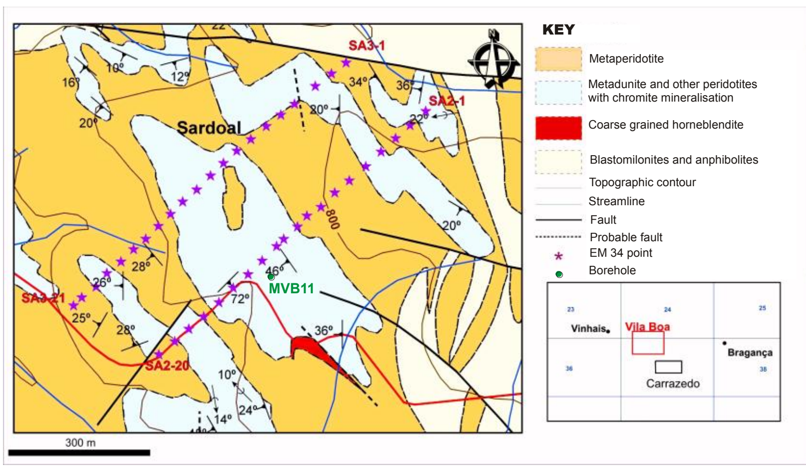

Figure 1. (left) Location of the points in Lines SA2 and SA3 over the geological base map by de Oliveira and Santana (2007). General look of the Sardoal zone (above).

This mineralised unit occurs inside a metaperidotite unit, whose appearance varies considerably, generally with fine to medium size, where all the ultrabasic lithologies not containing mineralisation were included in the same unit, namely the metaperidotites, metadunites and amphibolites (from 1cm to several centimetres of thickness).

3 Geophysical data acquisition and processing

The chromite grains produced as a result of serpentinisation processes are frequently altered to ferrichromite and magnetite, and, in some cases, are covered by magnetite membranes crystallised as finely disseminated grains due to the intense dynamic processes or due to the presence of secondary magnetite, in the serpentinised dunites (Frashieri et al. 1995). It is also the magnetite, acting as a good conductor when it appears as single crystals (Reynolds 1997), that gives higher conductivities to the serpentinised metadunites (Telford et al. 1990). Its contrast with conductivities of the adjacent metaperidotite formations may be detected with appropriate methods, such as magnetics, induced polarisation or gravimetry.

Since the metadunite serpentinisation gives them low resistivity that Frashieri et al. (1995) refer as varying between 100 and 650 ohm.m), they contrast electrically with non-serpentinised dunites (whose electrical resistivity, according to the same authors varies between 2200 and 7000 ohm.m), and therefore may eventually respond positively to this method.

This method was applied to several zones in the Trás-os-Montes area, Northern Portugal, where soil geochemistry analysis were conducted and also where a few boreholes were drilled.

In this paper the results for the Sardoal zone are presented. In this zone, two FDEM lines with the Geonics EM34 device headed perpendicularly to the main axis of the metadunitic structures (Fig. 1) were conducted. Data acquisition took place every 40 m with cables of 10 and 20 m (6.4 and 1.6 kHz, respectively). FDEM data processing was carried out with the software EM34-2D, developed by Monteiro Santos (2004), where the bi-dimensional model used in the inversion process consists of a number of blocks, where their distribution and size depend on the locations and spacings number between the coils used in data acquisition. The use of the cumulative response to calculate the model response in each point means that the interaction between the blocks that form the model is not being considered (Monteiro Santos 2004). The model has the objective of obtaining an inverse 2D model and to distinguish between layers with different conductivity producing layers (showing significant contrasts between serpentinised metadunites and metaperidotites) and highlighting their different alteration degrees. The obtained errors were 2.3 and 3.1 % to the Lines SA2 and SA3, respectively.

4 Borehole data

The analysis of the MVB11 borehole (Fig. 1, left), reaching 50 m depth in the Sardoal area (de Oliveira et al., 2008), near Line SA3 allowed interpreting and correlating electrical resistivity modelled values and observed lithology. The borehole was drilled in an area that simultaneously shows resistivity modelled values that may be attributed to serpentinised dunites and where soil Cr and Pt concentration values give good prospects in depth. The borehole lithology shows that the existence of disseminated chromite is constant along the borehole, with Pt concentrations varying from <2 to 10 ppb. However, serpentinisation processes only occur at 10 m and from 17 to 34 m (with intense serpentinisation between 17 to 30 m).

Figure 2. Metadunite with disseminated chromite and microfractures filled with serpentine (de Oliveira et al., 2008).

5 Discussion

The analysis of modelled electrical conductivities and resistivities from both Sardoal FDEM lines (Figs. 3 and 4), allowed inferring that the investigation depth of the method in seems to be higher in some areas than the depth of the formations where, according with Frashieri et al. (2006), can occur serpentinised dunites, which seems to be in average about 20 m deep.

Inverse modelling confirms the existence of resistivities ranging from 100 to 650 ohm.m in zones where old chromite exploitations are registered. This is the case of points SA2-4 and SA2-5 in Line SA2 that may indeed be related with the presence of disseminated chromite. However, from the observation of MVB11 borehole log and the geological mapping these doesn't seem to exist a systematic correlation between the metadunitic zones and the electrical resistivity models and resistivity ranges defined by Frashieri et al. (1995).

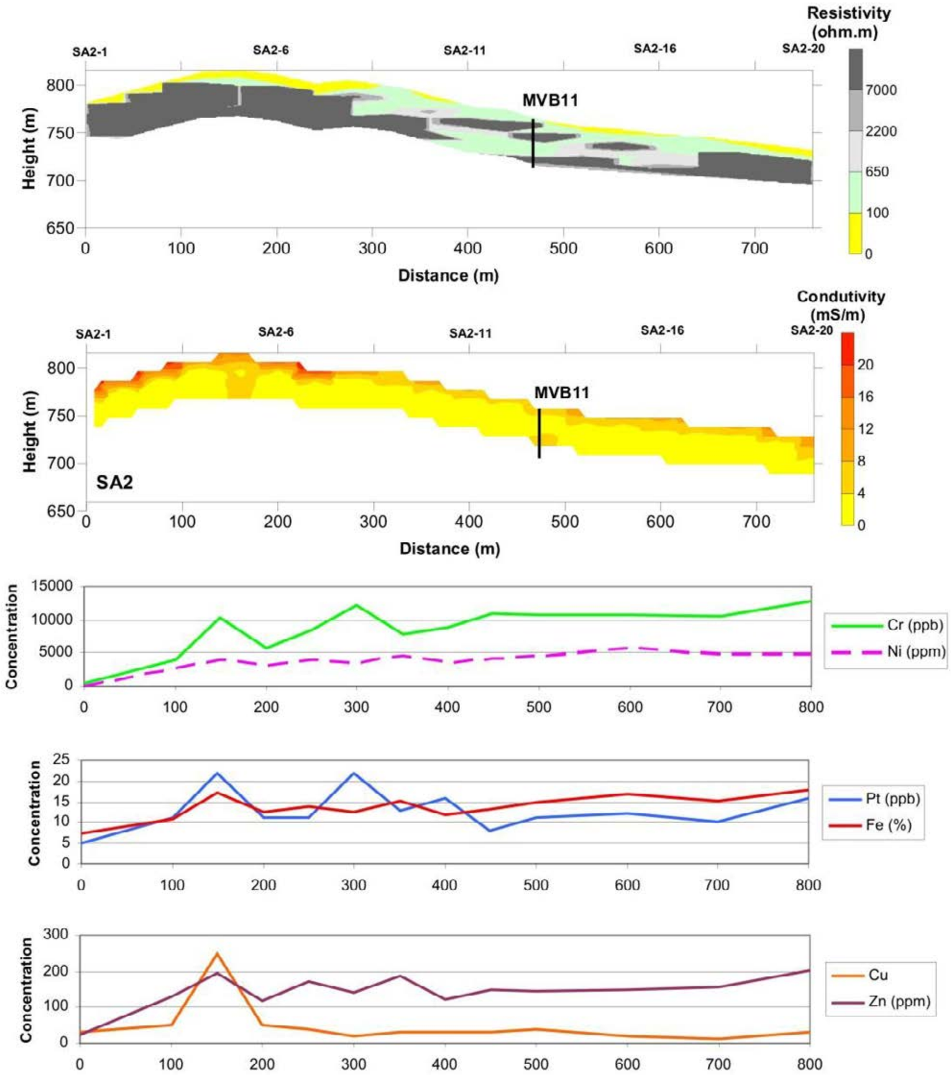

Figure 3. Correlation between the inverse electrical conductivity and resistivity models and the concentrations of some elements determined on Line 0 from the Pires (1998) report, corresponding to the Line SA2. The vertical borehole MVB11, whose location is presented in Fig. 1, is also shown.

On the other hand, the metadunitic spot located in the NE studied area shows lower resistivity values than those that were found in the inverted electromagnetic profiles, larger than the mapped metadunitic spot. These lower conductivity values seem to have continuity, since they were mapped in both profiles. For instance, the Line SA2, where the mapped dunitic spot between points SA2-10 to SA2-16 is slightly smaller than the outcropping electrical resistivity values ranging from 100 to 650 ohm.m. These values, however, vary in depth, creating a body where Cr and Pt concentrations have some peaks in those zones. Between points SA2-5 and SA2-8 the lower resistivity may not correspond to serpentinised metadunites, since they are located in metaperidotite outcrops.

In Line SA3, the correspondence between the metadunite outcrops and the lower resistivity values near the surface is much more correlated than in Line SA2. However, these lower electrical resistivities are not reflected in higher surface concentrations of Cr, Fe and Pt. It must be highlighted that in this profile, the lowest resistivities that correspond to the large metadunitic central spot are not continuous. The average depth of 20 m of the electrical resistivities affects zones topographically lower, whose resistivity is affected by the existence of crossing streamlines and with a shallower saturated zone, which may also affect the results obtained by the method.

Line SA2 was conducted in a zone where the Pt concentration registered by Pires (1998) ranged from 5 to 25 ppb and with Cr values varying from 6660 and 16300 ppm. Line SA3 was conducted in a zone where Pt concentration is between 2.5 and 11 ppb, lower than the average values of Line SA2 (Pires 1998). Regarding Cr, concentration values vary from 7730 to 17100 ppm. In general, for Line SA2, the best correlation between shallow low resistivity values and elements analysed by Pires (1998) seems to correspond to higher contents of Pt. However, for Line SA3, this correlation doesn't work in the same way.

6 Summary

Based on works conducted by Frashieri (1995) and Frashieri et al. (2006), and keeping in mind the results of the inverse resistivity models, the FDEM Geonics EM34 is a method that may be considered as an interesting and easy-to-use method to obtain some preliminary information about the development in depth of the disseminated chromite mineralised structures. In the tested Sardoal zone, there seems to be a relation among the electrical resistivity inverse model and soil geochemistry, borehole lithology and chemical analysis related with some elements, whose presence could explain the resistivity variation values. Although there is a strong correlation between the identification of serpentinisation processes and the modelled electrical resistivities attributed to these processes, the relation between shallow modelled resistivity values with mapped geology is not clear and in some areas they do not seem so correspond. Nevertheless, it is important to use other methods whose applicability has proved to obtain more consistent results with this objective, such as magnetic and gravimetric prospecting.

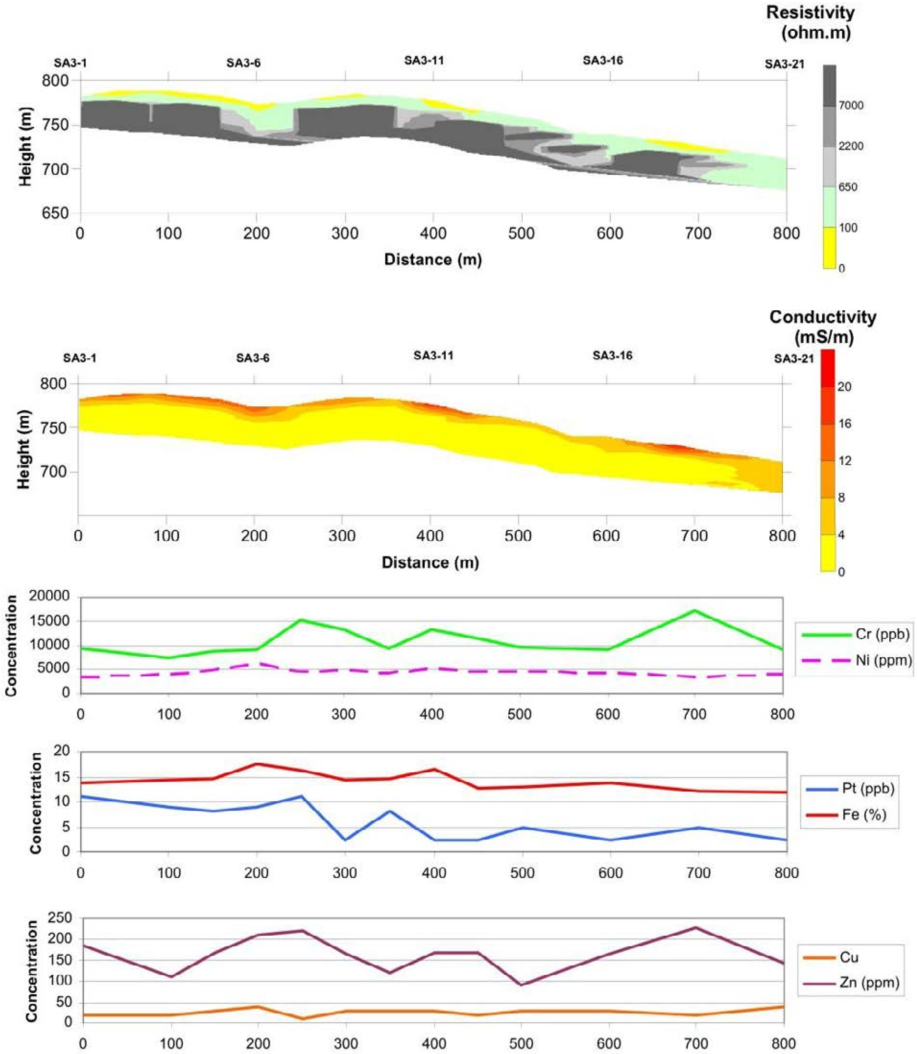

Figure 4. Correlation between the inverse electrical conductivity and resistivity models and the concentrations of some elements determined by Pires (1998) in his Line 200, corresponding to the Line SA3.

References

de Oliveira DP and Santana HM (2007). Geological mapping of 30 km^2 of the Bragança Massif in the Carrazedo-Alimonde-Conlelas. Vila Boa de Ousilhão area (NE Portugal): A guide to further chromite exploration and other possible associated PGE's. INETI internal report, 57p.

de Oliveira DP, Santana HM and Ramalho EC (2008). Campanha de Sondagens no Maciço de Bragança para prospecção de Platinídeos. INETI internal report, 46p.+annexes

Frasheri A (2006). Outlook on the application of geophysical methods in exploration for copper and chrome ores in Albania. Polytechnic University of Tirana.

Frasheri A, Lubonja L and Alikaj P (1995). On the application of geophysics for copper and chrome ores in Albania. Geophysical Prospecting, v.43, pp.743-757.

Pires M (1998). Relatório anual 1998. Relatório interno do Instituto Geológico e Mineiro, Refª #2829 and #2836.

Reynolds JM (1997). *An Introduction to Applied and Environmental Geophysics*, West Sussex, John Wiley & Sons.

Monteiro Santos FM (2004). 1-D laterally constrained inversion of EM34 profiling data. Journal of Applied Geophysics. v.56, pp.123-134.

Telford WM, Geldart LP and Sheriff RE (1990). *Applied Geophysics*, Cambridge University Press, 770p.