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ON THE APPLICATION OF GEOPHYSICS IN THE EXPLORATION FOR COPPER AND CHROME ORES IN ALBANIA

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In this paper some generalized results of geophysical exploration for copper sulphide and chromite ores in Albania are presented. The most important geophysical methods used are electrical prospecting , gravity, magnetics and electromagnetics. Physical properties of the ores, genesis and geological problems to be solved have determined the proper choice of any of these methods in the complex exploration.

INTRODUCTION

The copper and chrome ores in Albania, as well as other solid minerals, oil and gas included are explored through a wide complex of geophysical and geochemical methods.

The contribution of geophysical methods in mineral exploration has been in the search for ore bodies or mineralized zones and in geological mapping.

Electrical prospecting and sometimes magnetics, EM or gravity have been the main methods in the search for copper sulphide deposits. Depth exploration up to 600-700m have been proved with Induced Polarization (IP) method.

Chromite ores have been explored through the gravity, magnetics and Induced Polarization method. Many good results have been obtained but in comparison with copper exploration, the chromite is more complicated and more problematic.

1. PHYSICAL AND GEOLOGICAL BASES FOR GEOPHYSICAL EXPLORATION OF COPPER AND CHROME DEPOSITS

The copper ore deposits in Albania are mainly connected with ophiolitic belt of Mirdita zone. Mineralization is presented by sulphides as pyrite and chalcopyrite located in volcanogenic rocks (diabase-spilite-keratophyre), in effusive rocks of volcano-sedimentary formations and by quartz-sulphides in gabbro rocks. The mineralization in volcanogenic media forms concentrated ore bodies or simply disseminated sulphide zones or both. The mineralized zones range from some meters to some hundred of meters wide and from some tenths of meters to kilometres in strike. Massive or veinlet ore bodies are often present inside these mineralized zones. In volcano-sedimentary formations mainly massive ore bodies are found.

In table 1 are given the results of a petrophysical study of copper sulphide ores and surrounding rocks (Avxhiu, 1979, Frasheri et al 1986, Alikaj 1989). Several hundreds of examples have been tested for every physical parameter included in the study.

The most typical and distinctive physical properties are chargeability and resistivity which are conditioned by mineral content, structure and degree of rock alternation. The surrounding rocks are characterized by low value of chargeability and higher resistivity than sulphide ores.

The sulphied ores have greater density than the surrounding rocks and when they contain pyrrhotite and/or magnetite they present magnetic properties.

These four properties serve as bases for the application of IP, resistivity, EM, self-potential and mise-a-la-masse in exploration of copper deposits. Occasionally, magnetic and gravity have been used, too.

As regards to the chrome ore deposits, they mainly are linked to the upper part of hartzbourgite-dunite tectonite sequence, as well as with lower part of dunite cumulate sequence of ultramaffic massifs. The most of chromebearing is of podimorf type and less stratiform.

Dunites and hartzbourgites are often serpentinized and contain secondary magnetite in fine grained disseminated form or thin veinlet.

These ore bodies are presented by rare up to dense disseminated, nodular, belted or massive chromites. The type of ore is chromespinelid, mainly magnezial and sometimes ferrous. Its chemical composition is simple and the content of olivine and serpentine is different. In some cases the chromite grains are enclosed by secondary magnetitie membrans, which are crystallized as a result of intensive dynamic processes. Secondary magnetite is present in chromite ore serpentine as well.

In table 2 are presented the physical properties of different kinds of chrome ores and ultramaffic rocks (Frasheri 1974; Lubonja and Frasheri 1966).

The chrome ore density is determined by the content of Cr2O3 and in general, for a simple case the following dependence is observed:

ϱ = 40ùX+2000 in Kg/m3

where ϱ - ore density

X - percentage of Cr2O3 in ore

This dependency is not unique, because the ore density is dependent on the degree of serpentinization of its olivine and on microfissures as well.

Intense chargeability values are characteristic of chromites which contain secondary magnetite in veinlet or network type. Because of chemical and thermal remnant magnetization, some chromite ores are magnetic.

The petrophysical properties of ultramaffic rocks are mainly subject to their serpentinization degree and their physical and mechanical conditions. According to table 2 the following conclusions can be drawn:

1. Density is the most stable and typical property to discriminate between chromite ores and ultramaffic rocks, so the gravity is the basic method to be used in our chrome exploration.
2. The values of geophysical anomalies over ore bodies are depended on physical contrast between chromites and surrounding rocks.
3. Sometimes physical property contrast between chromite and ultramaffic rocks is very low, so no geophysical anomaly of this parameter could be observed.
4. Over some parts of ultramaffic rocks, some geophysical anomalies can be fixed, due to physical property contrast with surrounding rocks.

Based on uppermentioned conclusions we can state that geophysical anomalies present some targets which on a certain probability, show for the presence of chrome ore bodies. Their lack shows only that up to the depth of investigation do not exist ore bodies with property contrast with ultramaffic rocks. In this way, the geophysical exploration of chrome ore is rather complicated so, a wide integration of geological, geophysical and geochemical methods should be used.

2. GEOPHYSICAL EXPLORATION FOR COPPER ORE DEPOSITS

During the sixties, the main Electrical Prospecting method in copper exploration in Albania has been Self-Potential (SP). Resistivity and Magnetic surveys have been carried out, too. Occasionally, the Gravity method has been used. Good results have been provided through this geophysical integration for shallow depth, some tenths of meters (Fig. 1) (Frasheri 1963).

After rapid development of IP methods in early seventies, it turned out to be the major surveying method for copper sulphide exploration, while the others served as complementary or follow-up methods. In this period the depth of investigation has increased up to 200 m (Fig. 2) (Avxhiu 1979).

In the last decade our copper exploration was extended to greater depths, up to 400-700 m. For this purpose we have worked in different ways:

1. New IP instrumentation with high power transmitter and high sensitivity receiver was used (IPC-7/15KW, IPR-10A, IPR-11, SCINTREX).
2. It were studied theorically and experimentally the surface-to-hole IP responses to investigate the ore bodies around the boreholes, especially at great depths (Lubonja et al 1985; Frasheri, Avxhiu and Alikaj 1990).
3. The possibily of separation of low amplitude and frequency IP anomalies was sudied (Lubonja et al 1984).
4. A good coordination between direct mineral exploration and geological mapping with geophysical methods has been applied (Avxhiu, Bushati and Alikaj 1984).

In theorical studies were included the investigations of IP field distribution in heterogeneous geological media, with curved boundary, over mountain relief. Using the finite element method and other techniques were developed the proper algorithms and were compiled some programme packets for the computation of synthetic IP anomalies (Frasheri, Tole and Frasheri 1984; Frasheri 1987; Frasheri 1989; Likaj and Alikaj 1989; Frasheri, Avxhiu and Alikaj 1990).

Mathematical models were computed for polarizable bodies of any geometrical shape, with or without resistivity contrast, in 3-D, 2 1/2-D, 1/2-D and 2-D. The current electrode could be set on surface or underground.

As a result of theoretical and experimental studies in the different geological media the depth of investigation of IP method in copper sulphide exploration have increased markedly, up to 600-700 m. In Fig. 3 is presented such a case in volcano-sedimentary formation in the Northeastern part of Albania. Survey was carried out using deep IP soundings with a maximum separation of AB=4400 m.

Chargeability responses for every separation are plotted at points located at the approximate depth of investigation Hi. The geological data are plotted on the same section, also. This type of presentation is called a "real section" (Alikaj 1989; Langore, Alikaj and Gjevreku 1989). Chargeability contours shows an anomaly at a depth of 500-700 m, which after the performance of boreholes confirmed a thick sulphide zone at this depth. The shallow chargeability anomaly is connected with the contact zone between ultrabasic and amphibolite rocks, which contain magnetite and scattered sulphides.

Another important problem of IP method is to discriminate between high grade and low grade sulphide ores. Recently, Spectral IP parameters are being investigated (Alikaj 1989; Langore, Alikaj and Gjevreku 1989). We have used Cole-Cole (Pelton et al 1978) model in time domain to derive the synthetic Spectral IP parameters "m", "ç" and "C", according to Johnson (1984).

The study of Spectral IP parameters was carried out in samples, in test sites and in field conditions. The main conclusion of the study was the good discrimination between massive or veinlet sulphide ores and disseminated ones. In Fig. 4 is presented a field case history of Spectral IP survey in Derveni volcanogenic rocks. Within the chargeability "real section" of M4 window, an intensive apparent time constant (ç) anomaly was fixed. The first borehole drilled near this section intersected a thick mineralized zone with some intervals of concentrated sulphide belts. However the centre of the anomaly is not yet verified.

3. SOME RESULTS AND PROBLEMS IN CHROME EXPLORATION WITH GEOPHYSICAL METHODS

The geohysical investigation, consisting of Gravity, Magnetic, Resistivity and Induced Polarizatoin methods has proved good results in supporting the geological mapping of ultramaffic rocks and their relationships with surrounding formations, in cognition of geology of the mineralized belts and primary textures of rock massifs (Frasheri 1974, Langore et al 1989). In this paper we present some results of chrome exploration.

Over the ore bodies weak gravity anomalies are fixed, which are more evident after the transformations of the gravity field. In Fig. 6 is presented such a case from north-east Albania (Frasheri 1974). It is to be noticed that such anomalies are also caused by fresh rock isolations settled among serpentinized rocks. Magnetic survey may help in some cases to solve this problem. Based on the orientation of magnetization axis of the ore body and the magnetic property contrast, the magnetic anomalies can be negative or positive (Figs. 5 and 6, Lubonja and Kosho 1974, Frasheri 1974). Positive magnetic anomalies have been also recordered over the magnetic serpentinites which contain secondary magnetite due to dynamometamorphism. But these cases differ from those of ore bodies because of the lack of gravity anomalies.

In many cases there are fixed IP anomalies over ore bodies, consisting of polarizable chromite (Fig. 7, Lubonja and Frasheri 1966). These anomalies are often wider than ore bodies because of a dunitic envelope which presents the same IP parameters as chromite ore. In some cases IP anomalies are caused by polarizable ultramaffic rocks, too. Some laboratory tests of chromite samples with Spectral IP have shown no correlation between Cole-Cole parameters and chromebearing.

In our practice of chrome exploration we have cases where the distribution of physical fields is very complicated, because the ultramaffic rocks are very heterogeneous. In these cases, the "ore" anomalies may be detected using a wide integration of geophysical and geological methods. However, the complicated physical fields render more difficult the data interpretation and decrease their reliability.

To increase the depth of exploration of chromite ores we have successfully used the borehole magnetic survey and hole-hole radiowave method (Fig. 8, Gjevreku 1986). The boreholes S-17 carried out in this section did not intersected any ore body. From vectorial magnetic survey in this hole, an anomal sector of total vector of magnetic field (T) at depth 190-330m was fixed. This anomaly was interpreted as linked to a magnetic chromite ore body between the boreholes S-17 and S-16. The shallow boreholes S-1, S-2, S-3 and S-4, carried out from the mine working G5 intersected the predicted ore body.

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LIST OF CAPTIONS

Fig. 1. Geophysical profiles and geological section of a copper sulphide ore deposit.
1. Ultrabasic rock. 2. Argillaceous schists. 3. Diabase. 4. Massive ore body. 5. Gossan. 6. Tectonic faults

Fig. 2. Geophysical and geochemical profiles over the cross-section of a copper sulphide ore deposit.
1. Overburden. 2. Keratophyre rocks. 3. Spilites. 4. Disseminated sulphides. 5. Massive sulphide ore body.

Fig. 3. "Real-section" of chargeability parameter (Ma) according to the VES-IP measurements in volcano-sedimentary formations.
1. Overburden. 2. Ultrabasic rocks. 3. Amphibolites. 4. Volcano-sedimentary rocks. 5. Limestones. 6. Disseminated and veinlet sulphides. 7. Chargeability contours in mV/V. 8. Center and the number of VES-IP.

Fig. 4. "Real-section" of chargeability (M4) and apparent time constant Spectral IP parameter (ç) over a mineralized sulphide zone.

Fig. 5. Gravity and Magnetic profiles over a chromite ore body.
1. Overburden. 2. Hartzbourgites. 3. Dunites. 4. Chromite ore.

Fig. 6. Geophysical profiles and geological section over a chromitic ore deposit.
1. IP profile. 2. Resistivity profile. 3. Vertical component of magnetic field profile. 4. Hartzbourgites. 5. Dunites. 6. Chromite ore. 7. Gradual geological boundary. 8. Overburden. 9. Mine working.

Fig. 7. IP and resistivity profiles over a cross-section of a chromitic ore deposit.
1. IP profile. 2. Resistivity profile. 3. Massive chromite. 4. Disseminated chromite. 5. Hartzbourgites. 6. Dunites. 7. Tectonic fault.

Fig. 8. Results of a borehole three component magnetic field survey in search for chromite ores. (Total magnetic field T).