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FINITE ELEMENT MODELING OF IP ANOMALOUS EFFECT FROM BODIES OF ANY GEOMETRICAL SHAPE LOCATED IN RUGED RELIEF AREA

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Abstract

Modeling of geoelectrical sections is carried out by using finite elements in two cases:

1. Ore bodies with massive texture having contrast of resistivity with surrounding rocks, where modeling is done in 2.5D;
2. Ore bodies with disseminated texture having no contrast of resistivity with surrounding rocks, and modeling is done in 3D.

There ate taken into account two parameters, the apparent resisitivity and induced polarization. The effect of the relief as well as of the global geological structure is taken into account as well. Case stories are presented to demonstrate different effects and the usability of modeling by finite elements.

The results of modeling are presented according to new method of ***real geoelectrical section***, proposed by Ass. Prof. Dr. Perparim Alikaj, and developed recently in QUANTEQ IP Inc, CANADA**.**

The results are a synthesis of many years of working and are further developed least years in collaboration of the authors with QUANTEC IP Inc. CANADA, in a number of projects.

Introduction

Resolving of geophysical problems means a finite iteration of the couple interpretation↔modeling. Theoretical models exist for a number of ideal cases, rarely found in the nature. The problem becomes more complicated when the depth of investigation increases, together with the increase of secondary effects as of the relief and of the geology of sections. In this paper is treated the problem of modeling of geoelectrical real sections by using finite elements to solve elliptic equations in heterogeneous medium related with complex geological situations and rugged relief. This processus is used both for Resistivity and IP modeling.

Principles of application of finite elements in modeling of geoelectrical sections.

The key for modeling of geoelectrical sections is the scattering of electrical field in a heterogeneous geological medium under a rugged relief. For this purpose we have used [Frasheri A. et al., 1984; 1990-94] the elliptic equation in its generalized form, which related weak problem is [Zienkiewicz O., 1977]:

$$\min \int_{V} [(\nabla W)^T D \nabla U - WQ] \, dv = \int_{S_n} w \, [\underline{n}^T D \nabla U - U_n] \, ds \qquad (1)$$

Where: U is the potential of electrical field; W,w are weight functions; D is the matrix of resistivity; $\underline{n}$ is the unitary normal vector to the boundary S_n; U_n is the Newman boundary condition value.

We solved this problem by using parametric finite elements with four nodes. Normally the geoelectrical section may be considered as a rectangle, the upper part of it deformed corresponding to the relief [fig.1]

The boundary conditions are of type Newman which present power electrodes positioned in two nodes of the upper edge of the rectangle. In the other part of the boundary we normally use Newman conditions zero.

The solution of the problem (1) gives the scattering of the electrical potential in a discrete form. There data need to be interpreted in the right way to give information compatible with that collected during field surveys. We had considered two parameters, the Apparent Resistivity and the Induced Polarization.

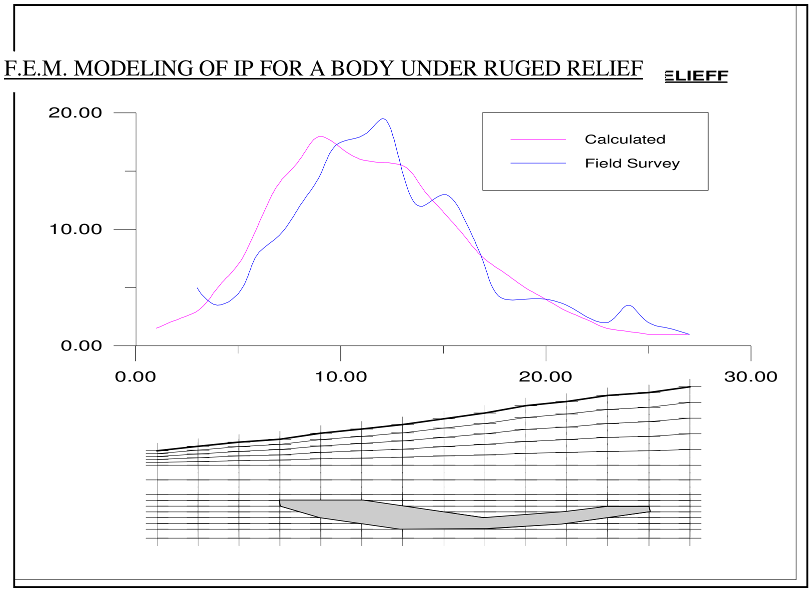

Fig.1. A finite element section of a geoelectrical section in rugged relief.

Modeling of Apparent Resistivity Anomalous Effects.

The meaning of “apparent resistivity” is related with the formulae:

$$\rho_a = \Delta U/\Delta U_o \qquad (2)$$

Where: U is the electrical potential of heterogeneous geoelectrical section; U_o is the electrical potential of homogeneous half-space with resistivity 1 Ohm.m.

During the field measurements the U_o is evaluated by theoretical formulae of the electrical dipole:

$$U_o = c\ (1/R_A - 1/R_B) \qquad (3)$$

Where: U_o is the potential of the electrical field for the homogeneous half-space; R_A,R_B are distances from the calculation point to the current electrodes A and B.

To carry out mathematical modeling we used two solutions.

First solution was to solve the weak problem two times, one for the heterogeneous case and the other for the homogeneous half-space, having so both discrete approximations of U and U_o for the formulae [2]. The second solution was based on special treatment on the boundary conditions. The real geo-electrical section has to be considered similar to the lower half infinite space, but the ordinary finite element model implies a finite domain as shown in the Fig.1. As consequence the application of theoretical solution for the Uo gives deformed results having a non-negligible error. To avoid this error it is necessary to imply “the infinite” on the finite boundary.

A “classical” solution to imply the infinite is to use “infinite elements”. A case of infinite elements we used for geo-electrical models is treated in [Frasheri N., 1983]. Another solution based on hybrid elements and Furrier transform is given in [Tong, Rossettos, 1978]. A simple solution we used for geo-sections having no important heterogeneous horizontal layered structure. In this case it is possible to evaluate theoretically the normal gradient of the field in the boundary using the formulae:

$$dU/dn = c\ (R_A/R_A^3 - R_B/R_B^3) \qquad (4)$$

Where; dU/dn is the gradient of potential of the electrical field; R_A,R_B are distance vectors of the receiving point to the current electrodes A and B.

In this case we simply calculate the flux of electricity on the boundary nodes and add respective values in the right side of the simultaneous linear equations resulting from the problem [1]:

$$[K].[U]=[F] \qquad (5)$$

Where: [K] is the master matrix of the system; [U] is the vector of discrete values of the potential U in nodes; [F] is the vector of flux concentrated in boundary nodes.

A comparison of apparent resistivity values over a geo-section with a vertical contact for the theoretical, finite elements and "infinite" elements is given in Fig.2.

Modeling of Induced Polarization Anomalous Effect.

We used the finite element modeling of IP in two ways, related with physical characteristics of geo-sections. The IP phenomena is modeled mathematically as the potential of a double layered surface which represents the boundary between the mineralized homogeneous ore body and the surrounding rocks. In reality mineralized ore bodies have a certain texture, being not really homogeneous. The bodies with disseminated texture have the IP scattered in the volume, and bodies with massive texture have the IP concentrated on its boundary surface. The calculation of IP effect is based on the formulae of Bleil [Bleil D., 1953; Seigel H.O., 1959], as well as evaluation of Komarov [Komarov V.A., 1972] assuming that $C(Uo+Uip) \approx CUo$.

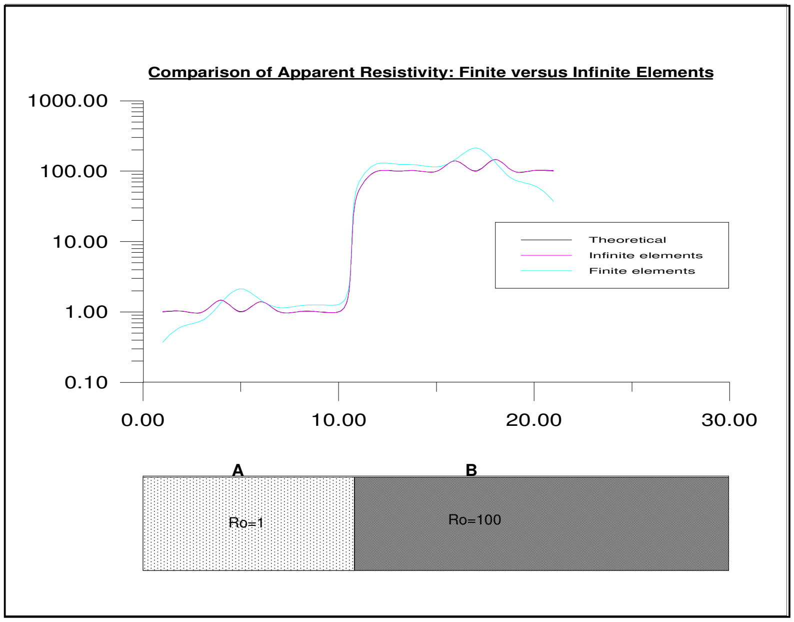

Fig.2. Comparison of theoretical (1), finite elements (2) and "infinite" elements (3) solution for the apparent resistivity anomaly over a vertical contact.

Taking into account the fact that in some cases the heterogeneity of the medium may influence considerably in the IP responses measured at the earth surface, we used 2.5D finite element modeling of IP for heterogeneous medium [Fig.1]. After calculating the potential U of the electrical field, we used the Bleil formulae for the calculation of the IP effect :

$$U_{ip} = c \int_V \nabla U \, (1/R) \, dv \qquad (6)$$

Where: U_{ip} is the potential of induced polarization;

R is the distance vector from the integration point to the receiving point; ∇U is the potential gradient of the primary electrical field, calculated by solving the finite element model.

For 3D modeling of bodies with massive texture in homogeneous medium we used the Bleil formulae, transformed using Green's formulae:

$$U_{ip} = c \int_{S} (1/R)\,(dU/dn)\,ds \qquad (7)$$

Where: R is the distance vector from the integration point to the measurement point; dU/dn is the gradient of the primary electrical potential on the boundary S of the body, calculated as in the formulae [4].

The integral is numerically calculated using the concept of finite elements for the boundary of the body, and using the standard numerical integration methods for the finite elements, defining automatically the number of integration points on the basis of relative size of elements [Fig. 3].

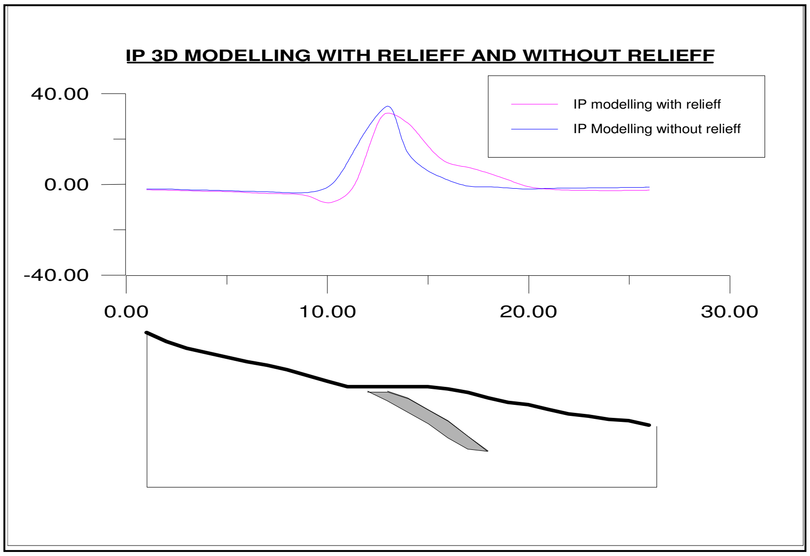

Fig.3. The 3D modeling of IP anomalous effect.

Being already a classical theory, finite elements continue to give way to new aspects of development and application of geophysics. Finite element modeling of complicated geological situations is necessary not only as a proof of the correctness of the interpretation of field data, but also it is very important for the development of new concept and techniques, as it is the "real section" [Langore L., 1989] and special methodologies for field surveys. A typical IP real section modeling is presented in the [Fig.4].

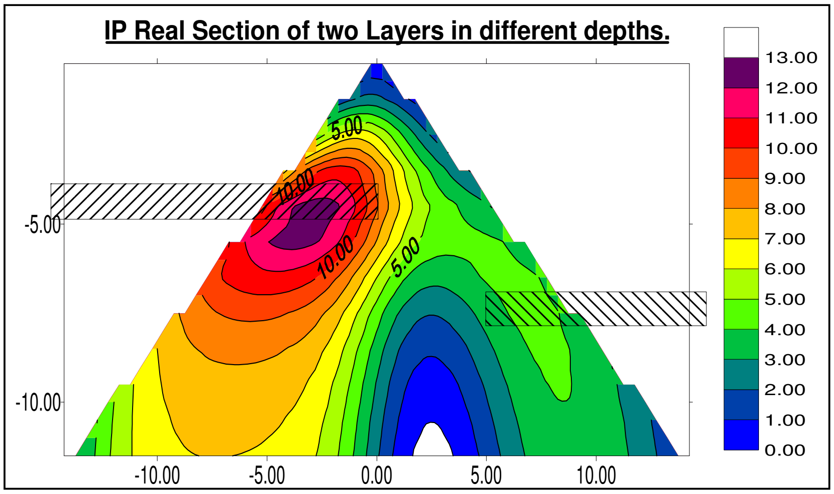

Fig.4. IP real section of two layers in different depths.

4. Conclusions.

Finite elements represent a good tool for the modelisation of complicated geo-electrical sections, characteristic of the Albanian geology. It permitted in a number of cases to evaluate correctly the influence of effects of rugged relief and of geology as layered mediums, contacts and faults to the anomalies of ore bodies or mineralized zones.

Real geoelectrical sections, created using the methodology presented also in the paper, offer a sure way for the interpretation of field data. Moreover, real sections have shown the existence of many problems related with the interpretation of field data, and the necessity of special studies to solve these problems.

5. Literature

Bleil D., 1953. “Induced Polarization: a method for geophysical prospecting”. Geophysics 18 (3), 636-662.

Frasheri A., Tole Dh., Frasheri N., 1984. “A Finite Element Algorithm for studding of the propagation of Electric Field in mediums divided by curved surfaces” (in Albanian). Bulletin of Natural Sciences 1, 23-31; University of Tirana.

Frasheri A., Tole Dh., Frasheri N., 1990-94. “Finite Element Modeling of Induced Polarization electric potential field propagation caused by ore bodies of any geometrical shape in mountainous relief”. Commun. Fac.Sci. Univ. Ankara Series C v8, 13-26.

Frasheri N., 1983. “Two Superparametric 4-node Elements to solve Elliptic Equations in Infinite Domains”. Bulletin of Natural Sciences 1, 17-23. University of Tirana.

Komarov V.A., 1972. Electrical Prospecting for Induced Polarization Method. (in Russian). Published by Njedra.

Langore L., Alikaj P., Gjovreku Dh., 1989. “Achievements in copper exploration in Albania with IP and EM methods”.
Geophysical Prospecting 37, 975-991.

Seigel H.O., 1959. “Mathematical formulation and type curves for Induced Polarization”. Geophysics 24, 547-565.

Tong, Rossettos, 1978. Finite Element Method - Basic techniques and Implementation. The MIT Press.

Zienkiewicz O., 1977. The Finite Element Method. McGraw Hill London.