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Geoelectrical Model Calculations on Investigation of Subsurface Nuclear Explosion

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SUMMARY

The Comprehensive Nuclear-Test-Ban Treaty (CTBT) is an international treaty outlawing nuclear explosions in aH environments.If CTBTO data indicates that a nuclear explosion might have taken place, an on-site inspection can be dispatched to the suspected area. The group of inspectors will search the ground for more concrete evidence of a recent nuclear test. At this stage application of geophysical survey methods are focused.

Subsurface nuclear activities cause such irreversible changes in the geological structure and rock properties that make the surface geoelectric methods suitable for inspection. Geoelectric models of the undisturbed and after explosion earth have been created for the purpose of investigating the possibilities of applying resistivity methods. Forward and inverse model calculations were carried out to find the most appropriate array parameters of the geoelectric survey.

Introduction

The Comprehensive Nuclear-Test-Ban Treaty (CTBT) is an international treaty outlawing nuclear explosions in aH environments. In providing for a total ban on nuclear testing, the Treaty seeks to constrain the development and qualitative improvement of nuclear weapons and end the development of new types of nuclear weapon. In doing so, it constitutes an effective measure of nuclear disarmament and non-proliferation in aH its aspects.

The CTBT bans all nuclear weapon tests. Its unique verification regime is designed to detect nuclear explosions anywhere on the planet. An International Monitoring System is currently operating in test mode: if CTBTO data indicates that a nuclear explosion might have taken place, an on-site inspection can be dispatched to the suspected area. The group of inspectors will search the ground for more concrete evidence of a recent nuclear test. At this stage application of geophysical survey methods are focused.

Adushkin and Spivak (2004) gave a detailed description on the geological environment of subsurface nuclear activity. They describe the irreversible changes in geological structure and rock properties (e.g.: porosity, permeability) caused by an underground nuclear explosion.

Geoelectric method is an effective tool for detection of subsurface objects. The geoelectrical response of 2D cavities was described analytically by Lösch et al (1979) and numerically by Dey and Morrison (1979). Nyari (2000) defined the limits of cavity detection from the point of depth/size ratio on 2D analytic models. According to the geological models of Adushkin and Spivak (2004) geoelectric survey method seems to be an effective tool for the on-site inspection team of CTBTO.

This paper presents the starting steps of application geoelectric method for the problem detailed above. A 2D geoelectrical model was created based on the geological model of Adushkin and Spivak (2004). Then sensitivity calculations were carried out in order to define the suitable electrode configurations. The model calculations were done by the free ware software Res2Dmod using the modeling method of M. H. Loke. The model pseudo sections were inverted by the software Res2Dinv using the algorithm of Loke and Barker (1996).

Geoelectric models

Model 1: undisturbed structure

A typical geological environment for subsurface nuclear facilities is described by Adushkin and Spivak (2004). The upper 150 m consist of sediments with different porosity and fluid content causing contrasts in electrical resistivity. It is followed by massive, high resistive bedrock. The geoelecrical model of the undisturbed environment is presented in Figure 1.

Model 2.

Adushkin and Spivak (2004) demonstrate the irreversible changes of the geological structure after an underground nuclear explosion. A camouflet cavity appears near the epicentre of the explosion. Its normalized radius is defined in the function of the explosion power. Zones of different degrees of failure with a vertical failure column with the height of 40-110 m appear at greater distances from the epicentre. The geoelecrical model of the environment is presented in Figure 2.

The cavity has normally an ellipsoid shape and is partly of fully filled with by rock fragments. The porosity is 20-25% and the filtration coefficient is 25-30 m/day. Those changes in the mechanical properties make the camouflet cavity conductive. The cavity is surrounded by a rock contortion zone. The total porosity increases 2-6 times greater than the initial values, rocks are transformed to loose, dusty material. In case of water saturation this zone turns into conductive clay mass. The contrasts of

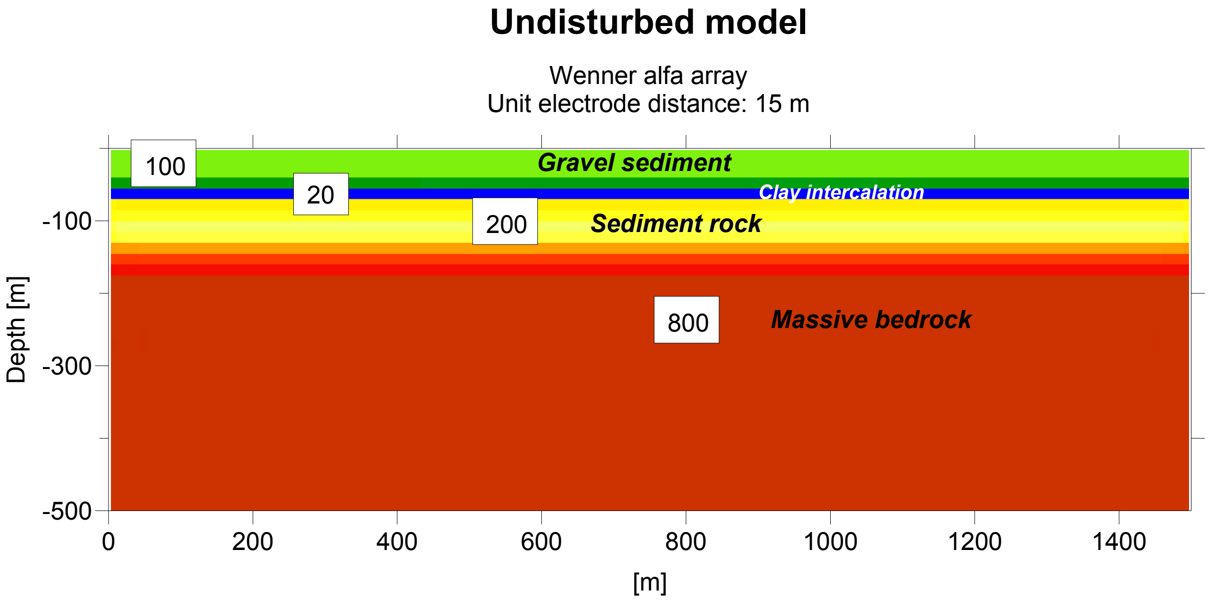

Figure 1 *Geoelectrical model of typical geological structure for subsurface nuclear facilities. The resistivity values of the strata are given in Ohmm.*

electrical resistivity of these two zones are not significant, that's why they are united in the geoelectrical model.

In greater distances fracturing and fragmentation zones appear in the bedrock. That's why the resistivity value of the bedrock slightly decreases. The resistivity contrast of the explosion zone and the fracture zone is taken to 10.

The upper geological structure is deformed by the inelastic changes of the bedrock.

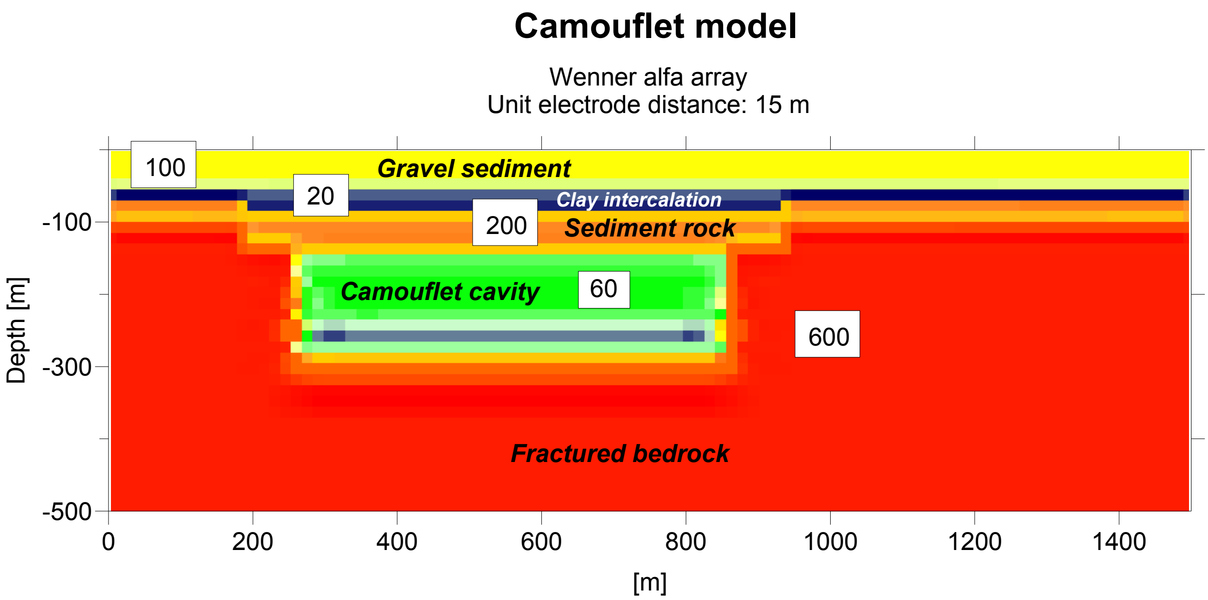

Figure 2 *Geoelectrical model of typical geological structure for subsurface nuclear facilities. The resistivity values of the strata are given in Ohmm.*

Electrode arrays

The applied electrode array is key parameter of a successful geoelectrical survey. In order to find the most appropriate configuration for the inspected problem the model calculations have been executed on four electrode arrays (Figure 3) and two different unit electrode spacing values.

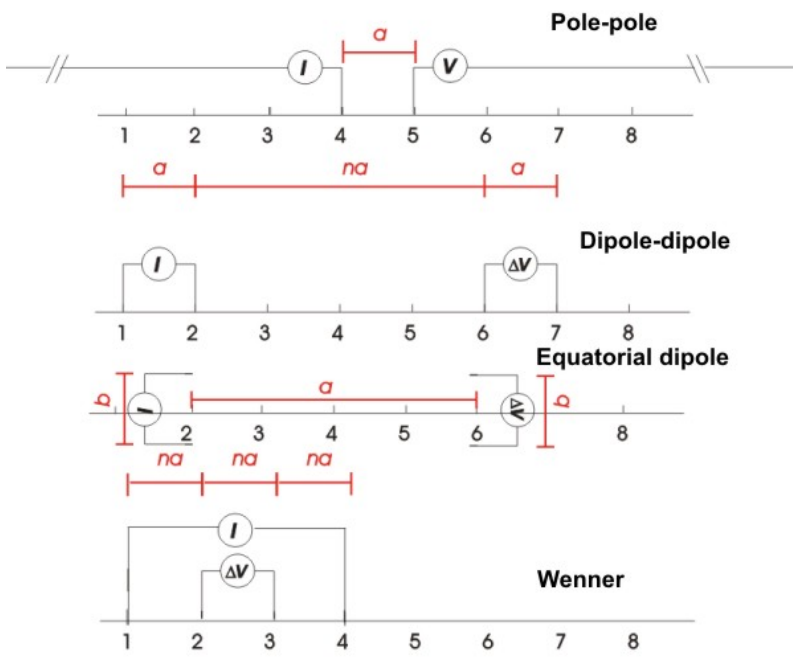

Figure 3 *Characteristics of electrode arrays participating in model calculations.*

The arrays participating in the model calculations were chosen on different specific characteristics like excellent horizontal resolution (dipole-dipole) or deep penetration (pole-pole). The detailed description of the applied arrays are explained in plenty of sources, e.g.: White et. al. (2003).

The unit electrode spacing determines the resolution and the penetration depth that can be reached by the applied array. The values of 15 m and 20 m were tested along a survey line with 101 electrodes.

Model calculations

Combining the geoelectric models with the electrode arrays of different unit electrode spacing values eight model pseudo sections were created. The accuracy of the investigated survey parameters were qualified on the bases of two aspects:

1. Aspect 1: Resistivity contrast
   Creating sensitivity images of resistivity values of the camouflet model normalized to the undisturbed structure.
2. Aspect 2: Imaging ability
   Creation of inverse pseudo sections of the models (Figure 4) in order to find the best survey parameters for imaging the subsurface structure in the case of the camouflet model.

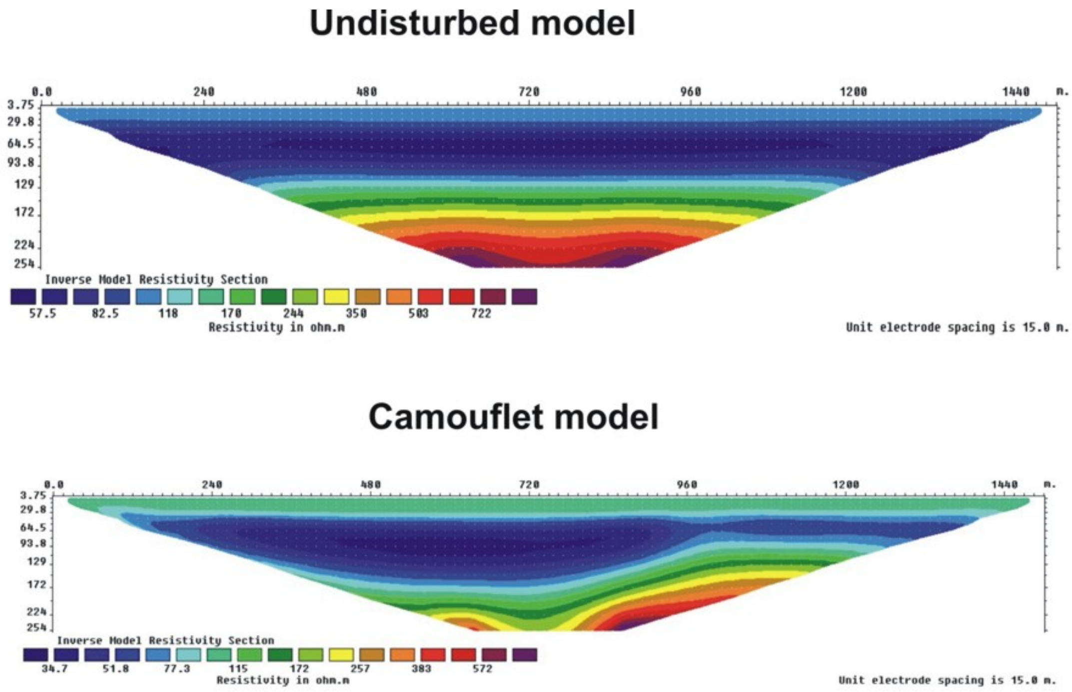

Figure 4 *Inverse resistivity pseudo sections of the two models. Array parameters: Wenner alfa array, unit electrode distance: 15 m.*

Conclusions

Subsurface nuclear activities cause such irreversible changes in the geological structure and rock properties that make the surface geoelectric methods suitable for inspection. Geoelectric models of the undisturbed and after explosion earth have been created for the purpose of investigating the possibilities of applying resistivity methods. Forward and inverse model calculations were carried out to find the most appropriate array parameters of the geoelectric survey.

The model calculations proved the applicability of geoelectric method in surface inspection of the traces subsurface nuclear explosions. Though the images of the inverse pseudo sections don't give as obvious result as e.g a seismic cross-hole or even a surface reflection section, this method is a fast, economic solution for a large scale pre-seismic investigation of the suspected zone.

References

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