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Geophysical prospecting in the Akropotamos dam (N. Greece) by GPR and VLF methods

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Abstract: *The present work demonstrates the application of two geophysical methods in the studies for the foundation of a dam in Northern Greece. The VLF and the Ground Penetrating Radar (GPR) were employed to investigate specific problems concerning the near surface tectonic setting. The local geological setting is relatively simple and it consists of granodiorite marbles and colluvial deposits.*

The VLF method was mainly used for the detection of the fault zones in the area that intersects the axis of the dam. The GPR method was used for a detailed study of the fractures in the area. The high-resolution capability of the method resulted in recording the cracks of the main geological formation of the area. The combined use of the two mentioned geophysical methods helped to reveal the large and small-scale fracture zones found in the area of the dam.

Key Words: *GPR, VLF, Dam foundation.*

INTRODUCTION

The high increase of the agricultural activity makes necessary finding solutions to the problem of water supplying. A common solution is the construction of an irrigation dam in areas, which are close to the upper and middle part of a river. An example is the area of Akropotamos (N. Greece) which is presented in Figure 1 (Wessel and Smith, 1995).

The use of the geophysical prospecting methods at the site of the foundation of the dam is very common especially at the initial stage of the whole study. Geophysical methods are used for the detection of inhomogeneities at shallow depth. Especially, they are used to reveal concealed fracture zones.

For these reasons, the VLF and the GPR methods were applied for the particular study (Fig. 2). The first geophysical method is commonly used for the accurate detection of fracture zones. However, the GPR method is not conventionally used in such problems. But, it was employed for this particular case in order to detect cracks in the bedrock.

The geological setting of the dam foundation mainly consists of granodiorite of Tertiary age. Also marbles and colluvial deposits outcrop in a wider area. The plutonic rock of diorite and tonalite also cover a broad part of the study area. Depending on the degree of metamorphism, the coarse-grained granodiorite can be differentiated from the medium to coarse-grained gneissed granodiorite. The granodiorite is ruptured and the fracture zones are filled with mylonit. There are two types of faults mapped in the area. The first type are of low dip angles from 10° to 35° and the second type are of high dip angles from 70° to 90°. The direction of the faults varies in all directions. The geophysical methods were used in order to detect the fracture zones and the cracks of the granodiorite.

VLF DATA

The WADI of ABEM was used for the acquisition of the VLF data. The measurements were carried out on eight profiles of varying length. The exact locations of profiles are shown in Figure (2). Readings

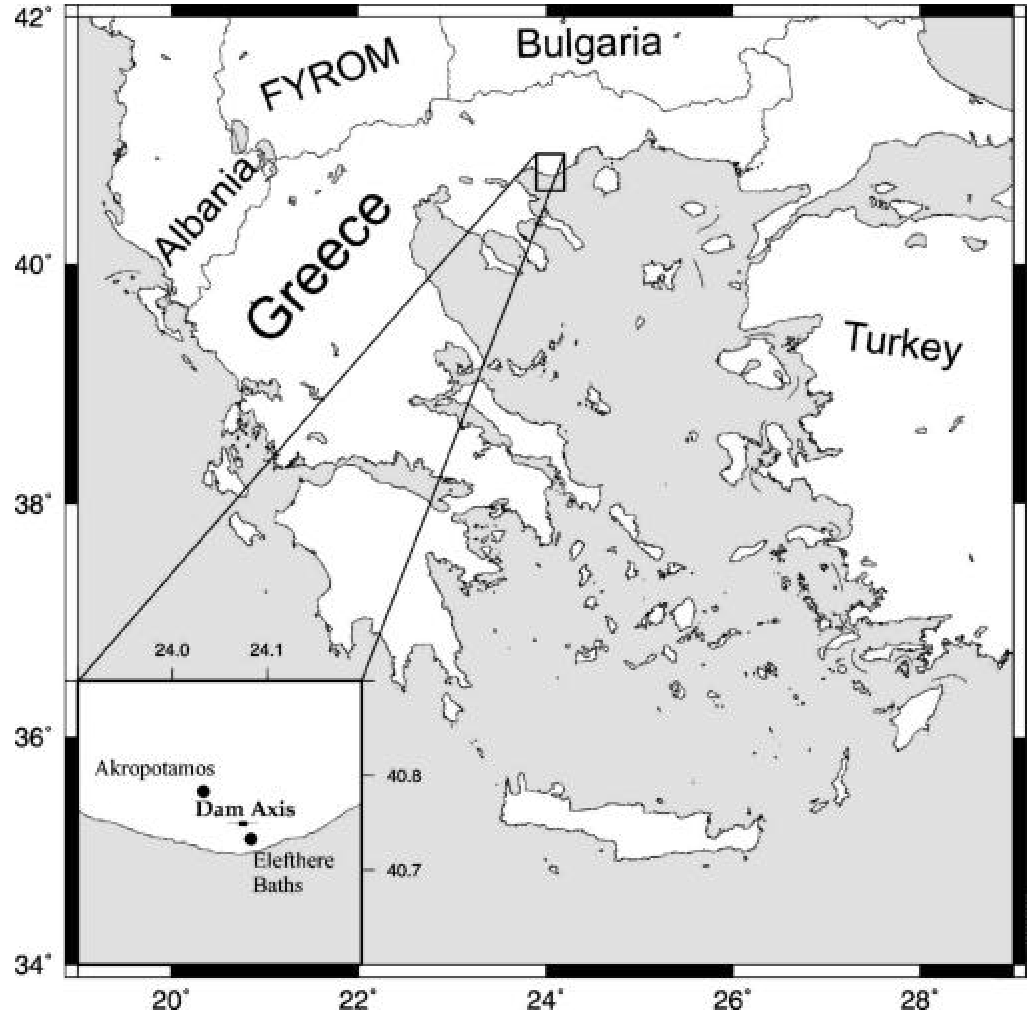

FIG. 1. Map of Greece showing the area of the foundation of Akropotamos dam in the inlet. The axis of the dam has been also drawn. It is striking in the East-West direction approximately.

were taken along the profiles stepwise at 5 m intervals. The profiles had an almost north-south orientation with the exception of profile 3 that was oriented along the river channel, i.e. at the northeast-southwest direction.

Profile 1 lies along the diversion tunnel that is almost perpendicular to the axes of the dam. The original data is presented in Figure 3(a). The Karous-Hjelt filter was applied to the data (Karous and Hjelt, 1983) and the filtered data are given in Figure 3(b). In Figure 3(c), the 2-D current density pseudo-section is presented. A fracture zone is located between 33 and 105 m with a dip towards the South.

The profile 10 is presented in Figure 4. The original data are given in Figure 4a, the filtered data along the Karous-Hjelt scheme are shown in Figure 4b, while in Figure 4c shows the 2-D current density pseudo-section. A fracture zone is detected between 117 and 137 m, which causes the high positive values of the real part (Fig. 4b). An attempt to find a model that describes the data was constructed (Fig. 4d). The software VLFMOD (Edsen and Nissen, 1997) was used for the modelling of the data. This software is based on the routine of Nissen (1986) that performs the modelling of 2-D structures. The Fraser filter (Fraser, 1969) was first applied to the data. This filter is designed for the noise suppression of the data. Specifically the modified 5-point Fraser filter was used to plot the output of the filter at the same locations as the tilt angle measurements. The concluded model consists of an ensemble of vertical sided prisms of low resistivity (70 Ohm-m) which is hosted in a half-space of high resistivity (1000 Ohm-m). In the upper part of Figure 4d, the filtered data are represented with the blue line while the green one represents the filtered model response. The model (lower part of Fig. 4d) represents a vertical fracture zone, which extends till the depth of 70 m. Its width

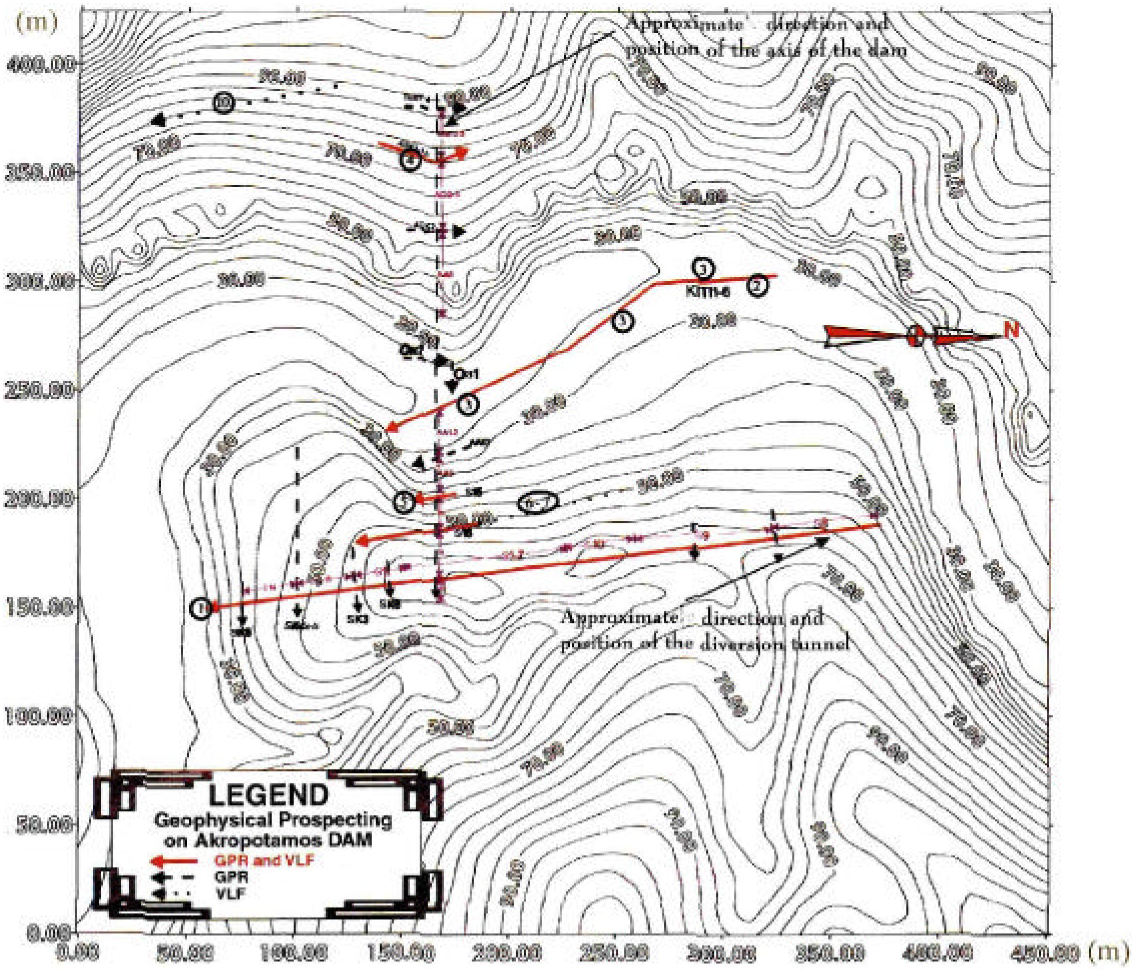

FIG. 2. Topographic map of the site where the Akropotamos dam is to be built. The profiles measured with both GPR and VLF method are given with red lines. The profiles along which only GPR readings were taken are represented with dashed black line. The dotted black lines show the profiles along which only VLF data were taken.

varies with depth and it is 10 m till the 40 m depth, 7 m from 40 to 61 m and 5 m from 61 to 70 m. The fracture zone is centred at the x position of 125 m.

GPR DATA

The instrument used for the GPR survey was a Pulse Ekko 1000 from Sensors&Software having antennas with central frequencies at 225 and 450 MHz. A radar trace was acquired every 0.2 m along the profiles.

The GPR data were processed using the Sensors & Software provided software (Annan, 1993; 1994). The traces were edited wherever it was necessary. Editing is essentially removing bad traces or a bad section of the profile. Then, a signal saturation correction (DEWOW) was applied. This is a slowly decaying low frequency component on the trace, which is superimposed on the high frequency reflections. Its magnitude and decaying rate depend on the proximity of the transmitter and the receiver as well as on the electrical properties of the ground. In order to remove this low frequency noise from the data, a running average filter is applied on each trace. The power spectrum was calculated and low pass filtering was applied to each radargram depending on the frequency with the highest amplitude. That was done in order to enhance the desired signal and remove the high frequency noise. Finally, a spatial high pass recursive filter was applied to the data.

The use of this filter is to enhance localised features at the expense of strong long wavelength features such as stratigraphy or flat lying horizons. The cut-off frequency was 10% of the Nyquist frequency, i.e. 0.5 cyc/m. Figure 5a shows a part of the radargram of profile S1. Its length is 23 meters and its direction is from south to north. The antenna with central frequency of 450 Mhz was used. In the first 20 ns a lot of reflectors of low apparent dip are presented (a, b, c). They are clearly seen in the area between 11 to 23 meters from the north edge of the

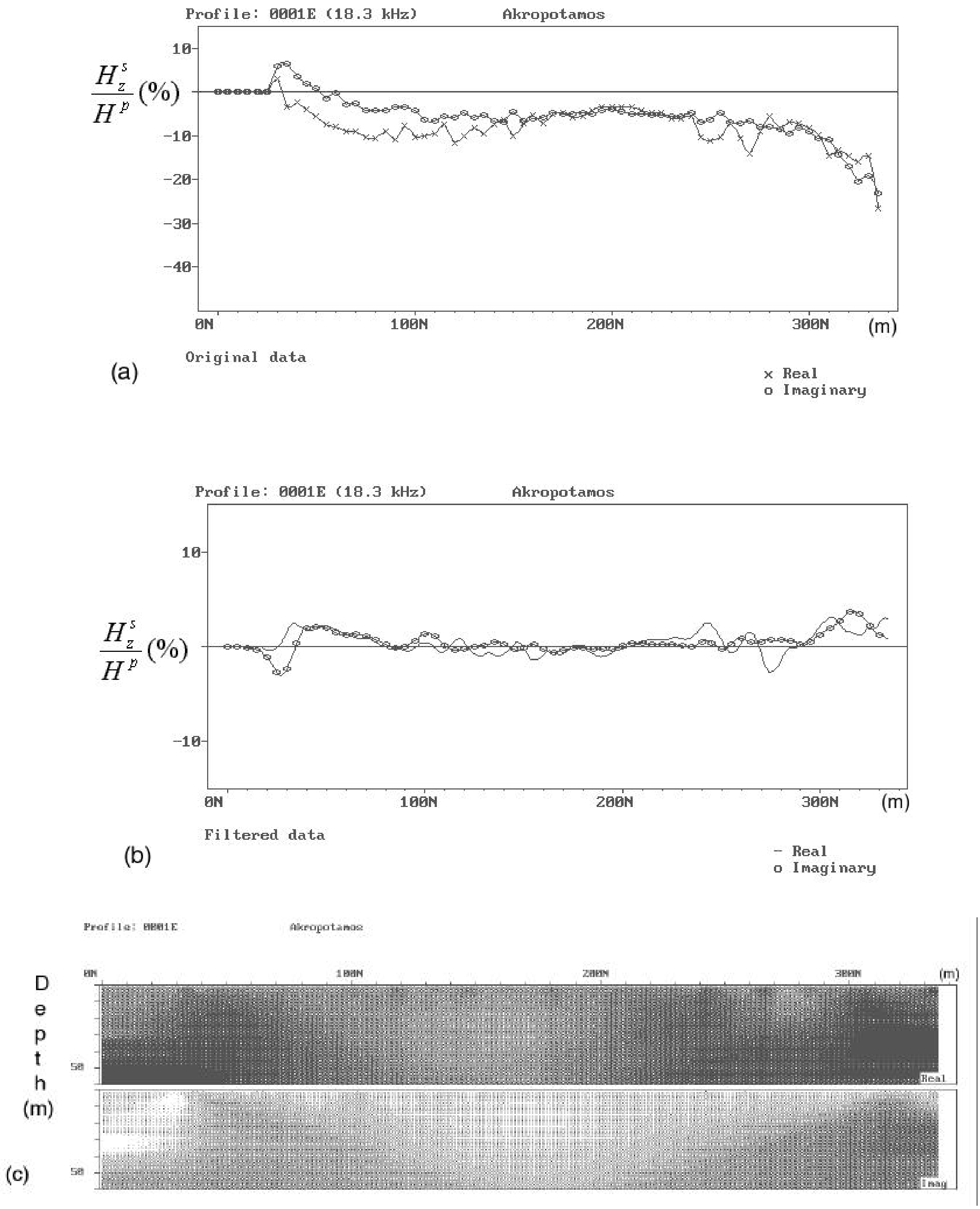

FIG. 3. VLF profile 1 along the diversion tunnel of the dam (Fig. 2). Source frequency is equal to 18.3 kHz. (a) Original data. In the x-coordinate the distance from the beginning of the profile is given. In the y-coordinate the percentage of H_z^s/H^p is given. (b) Filtered data. The Karous-Hjelt filter was applied to the data. (c) 2-D pseudosection.

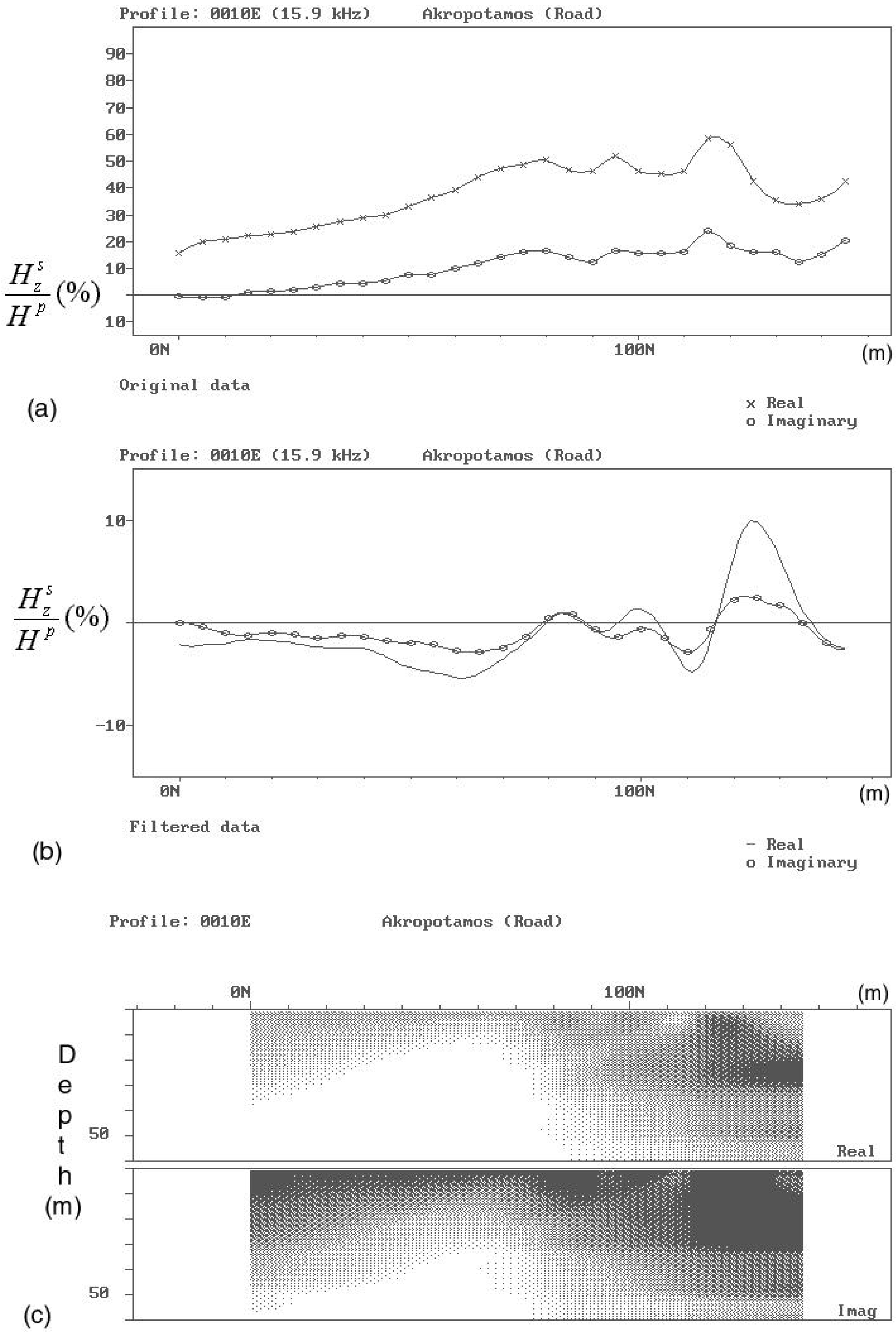

FIG. 4. VLF profile 10 along a road in the west part of the area of study. Source frequency is equal to 15.9 kHz. (a) Original data. In the x-coordinate the distance from the beginning of the profile is given. In the y-coordinate the percentage of H_z^s/H^p is given. (b) Filtered data. The Karous-Hjelt filter was applied to the data. (c) 2-D pseudosection (d) Suggested model for the anomaly presented in (b). Resistivity is in ohm-m and the size of squares is in meters. The blue line represents the filtered data while the green one is the filtered model response.

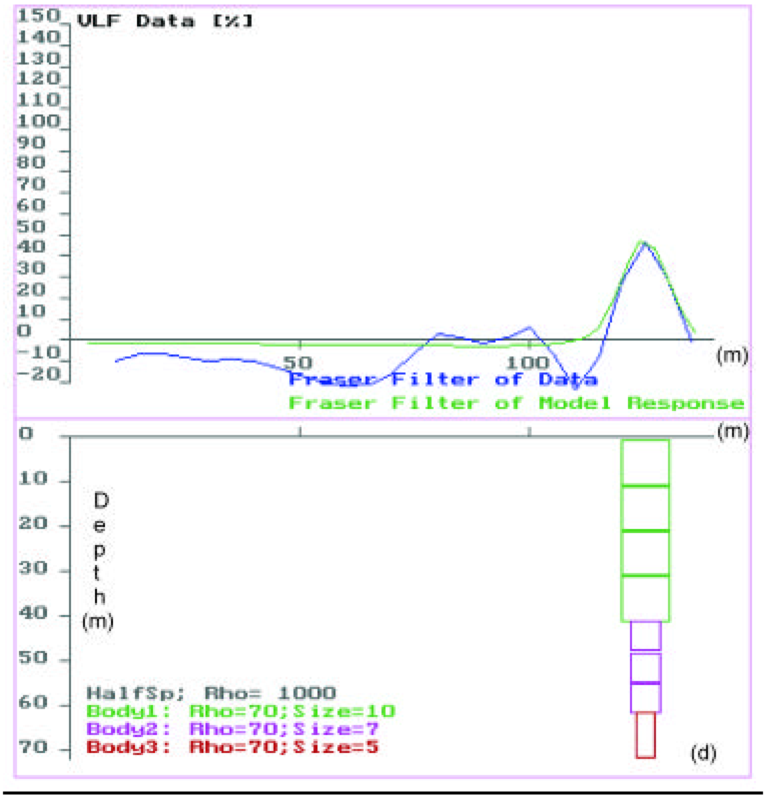

FIG. 4. (Continued).

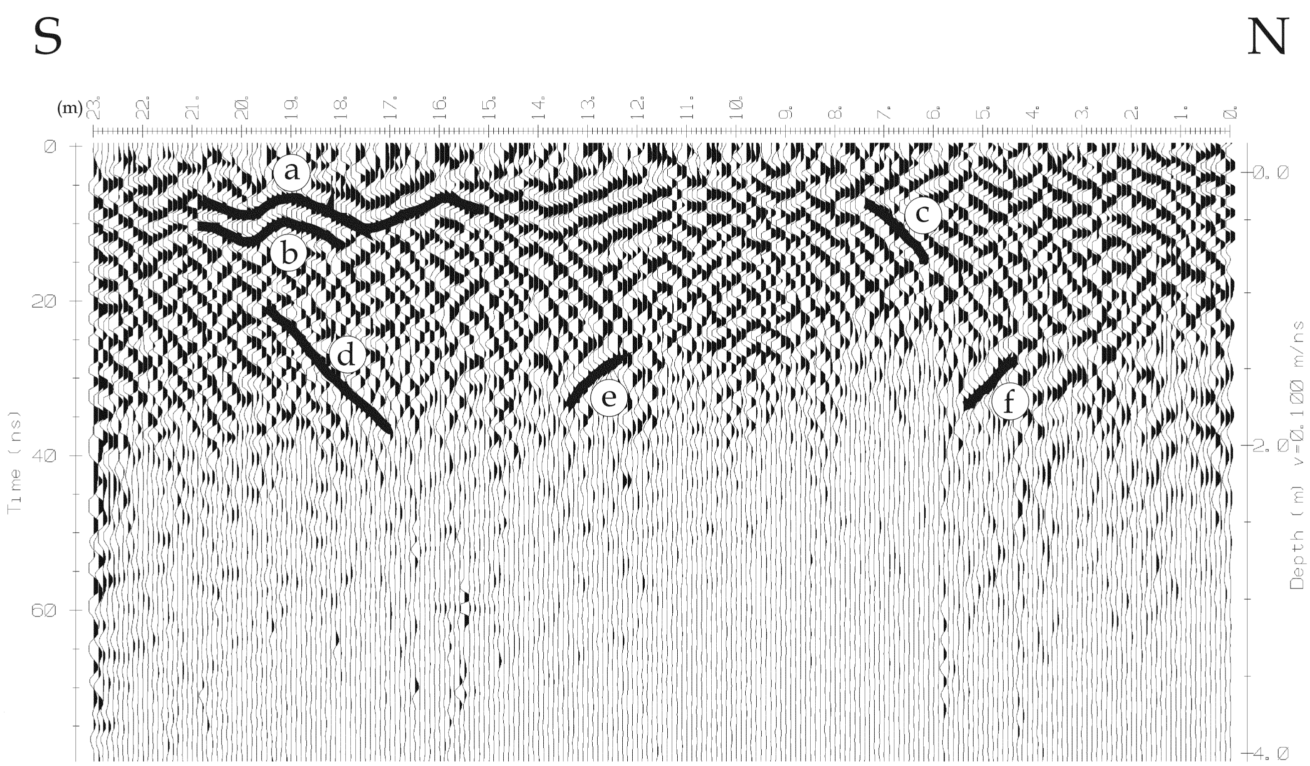

FIG. 5. A part of the radargram of the S1 traverse, which is a part of profile along the diversion tunnel of the dam. Reflectors at the upper part are easily recognised (a, b, c). In the deeper part, reflectors are very rare (d, e, f) and they show a greater apparent dip.

profile. In the deeper part, i.e. in the part between 20-40 ns, the reflectors are not very frequent and not very well defined. However at least three reflectors are detected (d, e, f). All these reflectors are due to cracks filled with low resistivity and/or high dielectric permeability material. These reflectors indicate small cracks at the geological formation.

Figure 6 illustrates the radargram of profile KIT4b. Its length is 11 meters and its direction is northeast to southwest. The antenna with central frequency of 450 MHz was used. Reflectors of low apparent dip are also present in this profile in the upper part (0-20 ns) of the section. At the part of the section between 20-60 ns, reflectors (a, b, c, d) of high apparent dip are

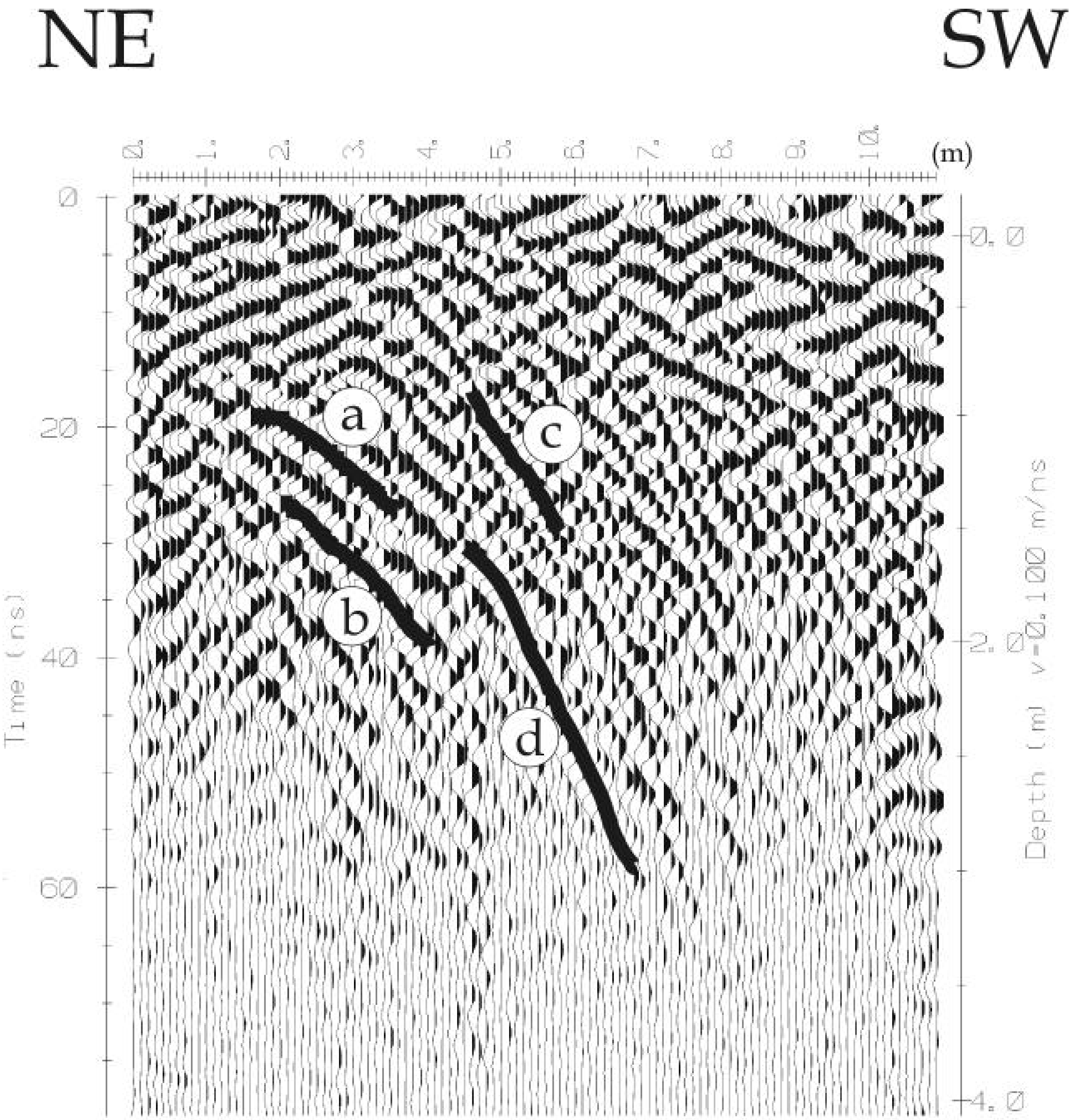

FIG. 6. Radargram of the KITI4b traverse, which is a part of profile KITI that is almost along the route of the river. Reflectors are easily recognised (a, b, c, d). Their apparent dip is greater than that of the reflectors revealed in traverse S1.

indicating cracks that are longer than those on profile S1 (Fig. 5).

CONCLUSIONS

The use of the various geophysical techniques illustrates their importance in the study for the foundation of dams. The current case history shows that the joint use of ground radar and VLF methods provide information to solve several issues concerning the ability for the construction of a dam in the area.

The VLF method revealed the large-scale fracture zones and helped on deciding the techniques that are going to be used on the construction of the diversion tunnel and the foundation of the dam. Also, it defined the width and depth extent of these fracture zones so these can be mapped along the axis of the dam.

The GPR data manage to give information on the small-scale problems as revealing the cracks in the bedrock. These are of low apparent dip in the upper part (near surface) and of higher apparent dip in the deeper part of the section.

The use of the geophysical methods at the initial study stage and also their decisive role at the construction stage of a dam is demonstrated. The low cost of the geophysical methods in comparison to the geotechnical boreholes, that are used for defining the extent of fracture zones and the inhomogeneities, show the necessity of the geophysical techniques because of their cost effectiveness.

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