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Two case studies of the determination of parameters of urban waste dumps

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Abstract

This paper describes a survey carried out on two wastes dumps using VES and the seismic refraction technique. The dumps have different geometrical and technical characteristics and are located on different geological formations. Anomalously low P waves velocities in the dumps allow us to identify the limits and the thickness of the dumps. The VES method contributed to the general reconstruction of the area and indicated the presence of pollution in the surrounding area.

Keywords: waste dump; seismic refraction; VES; pollution

1. Introduction

Determining the characteristics of buried waste dumps is important in urban planning. The methods generally used for this are geological surveys, mechanical drilling, and in some cases geophysical surveys (Armando et al., 1994; Amodio and Serangeli, 1994). For the identifications on large waste dump zones, airborne infra-red surveys are often used. However, as a result of the heterogeneity that dumps exhibit, no single method exists for the solution of the problem. The aim of this study is to verify whether some of the geophysical methods more routinely applied in the near-surface investigations may be used to determine geometrical parameters that characterize waste dumps and to give an indication of the extent of the pollution produced in the surrounding area (Buselli et al., 1990; Ross et al., 1990; Dodds and Dragan, 1990). VES and seismic refraction methods were considered because these are the most used in shallow geophysical investigations.

In this paper results obtained during surveys carried out on two urban wastes sites, each with diverse characteristics and situated on different geological formations, are described.

2. Site 1

The first waste dump is situated on the outskirts of Caprarola, a small town near Viterbo, 100 km north of Rome. It is on the external edge of the Vico volcano. The dump is situated in an old quarry of volcanic formations (phonolitic tefritic tuffs). The

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tuff has good mechanical characteristics, it contains wastes amassed in a chaotic way. Its extension is approximately 2500 m^2 and it is square shaped. Fig. 1 shows the limits of the site (the hatched area) whose center is raised in the form of a frustum of a pyramid.

The permanent water table is quite deep (more than 50 m below topographic surface) but some small suspended ephemeral ground water bodies are present on variable permeability strata gently sloping parallel to the topography.

In this area 10 VES were carried out, utilizing the Schlumberger array, with an electrodic distance AB of maximum 100 m length. The soundings were distributed in part in the interior of the site and in part external to the site. A seismic refraction line was also carried out. It was 55 m long and composed of 12 geophones and 5 shots. It was effected partly on the waste and partly outside as shown on the plan of Fig. 1, by a continuous line. The interpretation effected by means of the delay-time method is shown in the bottom part of Fig. 2. A shallow layer presents particularly low velocity values (0.28 km/s) and a thickness of 5–12 m, in the zone between geophones 5 and 12, corresponding to the dump. Laterally (geophones 1–4) the shallow layer velocity assumes values of 0.4 km/s, which is normal for a weathered layer in tuff whereas the velocity values at a depth of 1–1.5 km/s are typical of a litoid tuff. Results of preceding investigations indicate that the thickness of the shallow layer was characterized by a velocity of 0.28 km/s corresponding to the urban waste, which was detected with an error less than 10%.

Fig. 3 shows field diagrams of some electrical soundings. The sounding S_6, which is similar to the soundings S_5, S_7 and S_{10}, carried out on the tuff, shows an almost constant resistivity value (160–200 Ω m). The sounding S_3 carried out on the dump presents very low resistivity values, while sounding S_8, as sounding S_9, indicates the presence of a stratum of intermediate resistivity (50–60 Ω m) lying between two layers of greater resistivity. The electric section A–A′ is shown in the upper part of Fig. 2. Sounding S_1 shows resistivity values which

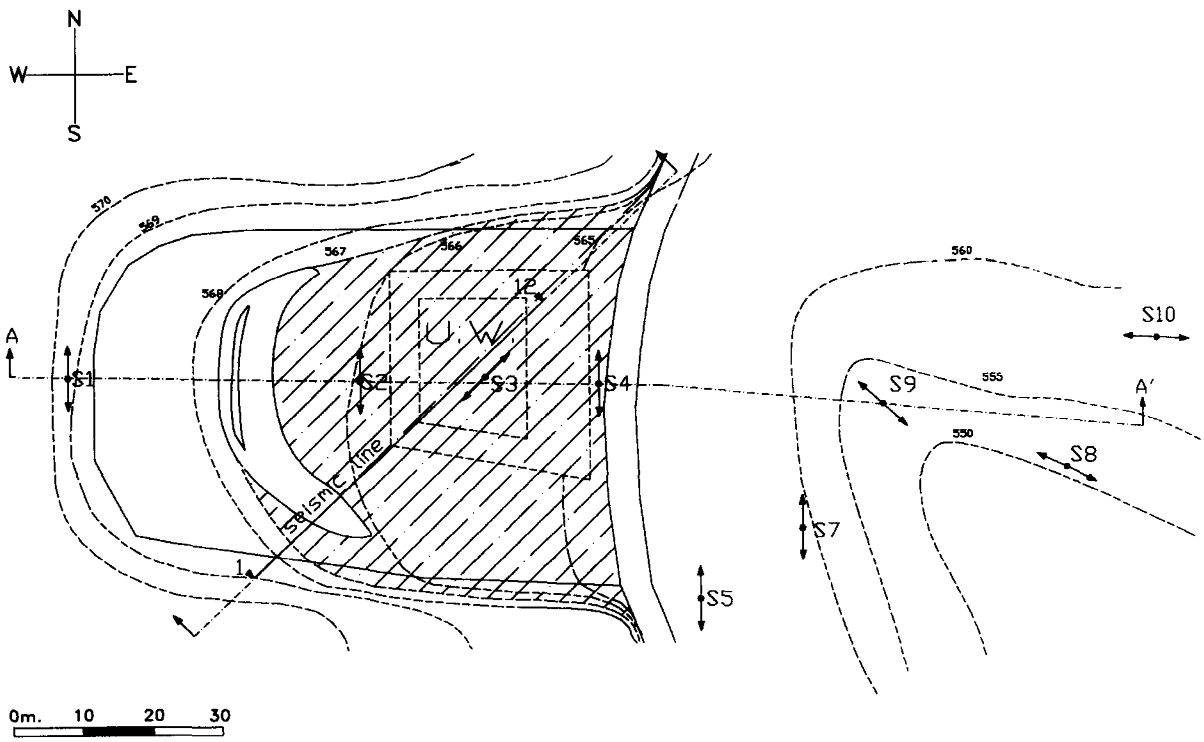

Fig. 1. Plan of the dump at Caprarola.

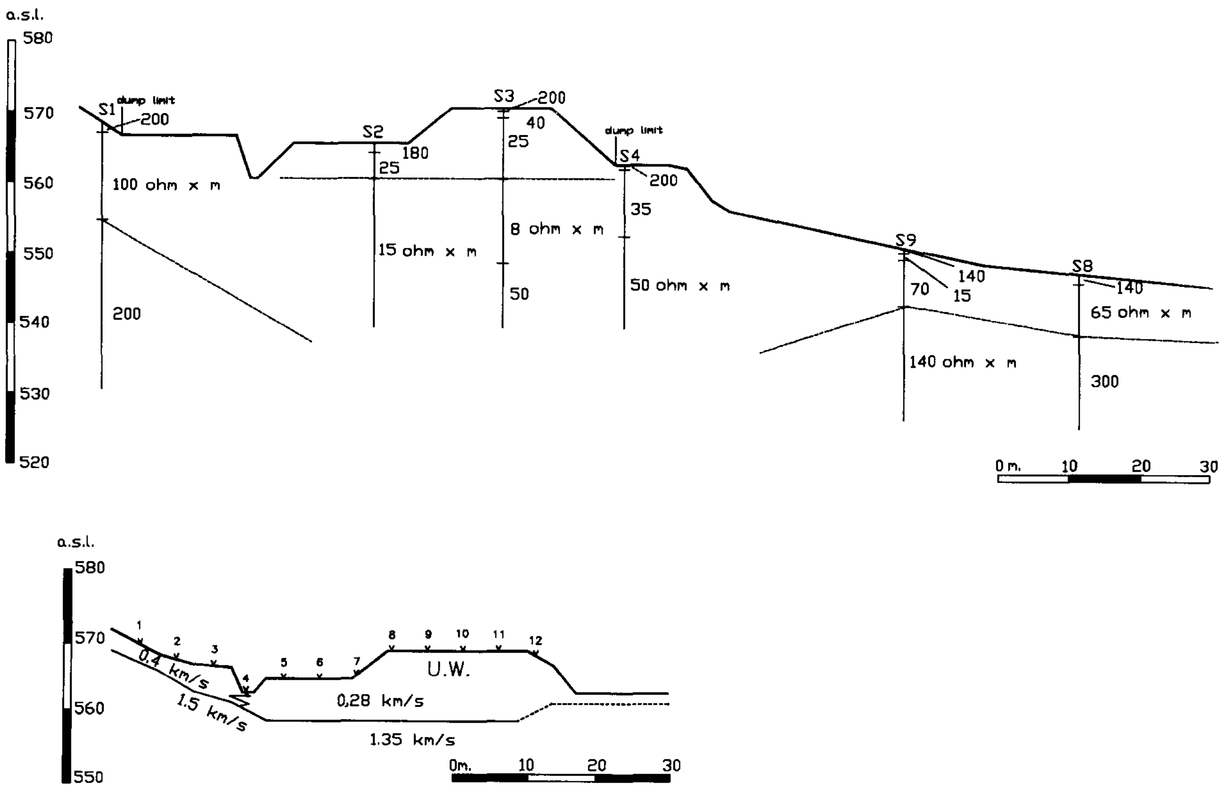

Fig. 2. Seismic refraction profile of Caprarola in the bottom. The section indicates the velocity values in km/s and the limits between the refuse and the surrounding terrain. Electrostratigraphic section A–A[I] of the site of Caprarola deduced from the soundings shown in Fig. 1. The resistivity values, in Ω m, of the investigated area and of the wastes are shown in the upper part of the figure.

are similar to those obtained in the soundings S_6 and S_{10}, and delimits the dump to the west. The wastes, identified in soundings S_2 and S_3, are characterized

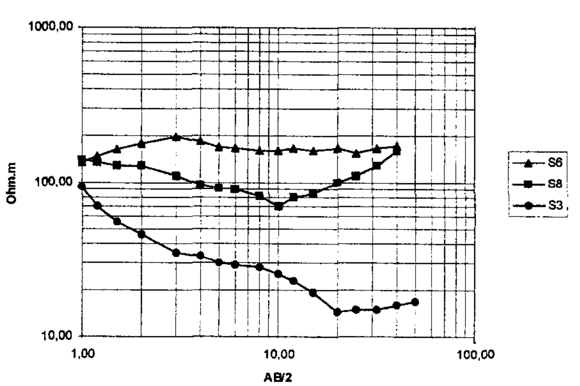

Fig. 3. VES carried out at Caprarola: S_6 (▲) carried out away from the dump; S_3 (●) carried out inside the dump; S_8 (■) carried out downstream from the dump.

by a resistivity of 25 Ω m. The thickness coincides with that of the layer identified by the seismic refraction line and characterized by a velocity of 0.28 km/s. Below this layer, the S_2 and S_3 VES indicate lower and heterogeneous resistivity values. They are very likely due to organic liquids which soaked the terrain in an inhomogeneous way, thus considerably reducing its resistivity. The interpretation of data was ambiguous because of the heterogeneity and lateral variations of resistivity and topography. In any case the resistivities below the dump are lower than 20 Ω m. The soundings S_9 and S_8, on the surface, also present lower resistivity values (40–70 Ω m) with respect to those measured in the zones far away from the dump. This was also ascribed to the presence of organic liquids which flow from the dump. In the depth the resistivity returns to the normal values of the tuff (see sounding S_8 in the diagram of Fig. 3).

3. Site 2

The second site is to the south–west of Rome on an ancient alluvial plain of the Tiber river in a heterogeneous fluvial lacustrine type formation. The dump, covered with loamsoil, is situated in an old quarry (Galeotti et al., 1990) of aggregate material, and it is formed by waste in which organic material was eliminated. The fluvial lacustrine formation presents variations both laterally and vertically changing from sand and gravel to clay, consequently the resistivity values vary greatly as well. The area and the thickness of the dump are unknown even though the morphology of the ground suggests the limits of the area. The presumed area of the dump was hatched and is shown in Fig. 4.

In this area 20 VES were carried out. 13 of these were spaced on two sections (A–A′–B–B′) within the zone assumed to contain the waste. The others were carried out on the outcrop of the alluvial deposits. The diagrams of the apparent resistivities did not allow us to establish with certainty the boundaries of the dump even though the resistivity values at medium depth, on average greater in the presumed area of the quarry, indicated the presence of waste materials.

Furthermore, a seismic refraction profile was carried out. It consisted of 36 geophones placed at distances of 5 m which coincided with the geoelectric profile BB′ and was outlined in bold in Fig. 4. Another seismic profile, of 12 geophones and 55 m long, transverse (cross wise) to the previous one was also carried out with the aim of determining the lateral extension of the dump. In the bottom of Fig. 6 is shown the interpretation of the seismic line in coincidence with the geoelectric profile B–B′. The first part of the line (geophones 1–13) placed outside the presumed area of the dump shows velocities that increase rapidly from 300 m/s on the surface to 1600 m/s at a depth of 10 m. For the rest of the seismic line, the increase in velocity is much slower (from 0.3 to 0.5 km/s) to a depth of 13–14 m beyond which a substratum exists with a velocity of 1.8–1.9 km/s. The presence of a layer with a velocity of 0.3–0.6 km/s and a thickness of 13–14 m is incompatible with a fluvial lacustrine formation composed of clay with silt, sand and gravel with a clayey matrix. A more realistic hypothesis is that such a velocity is due to the presence of a waste dump. The limit of the dump is indicated by the lateral variation between the velocities of 0.5 and 0.9 km/s in the intermediate layer (geophones 13–14).

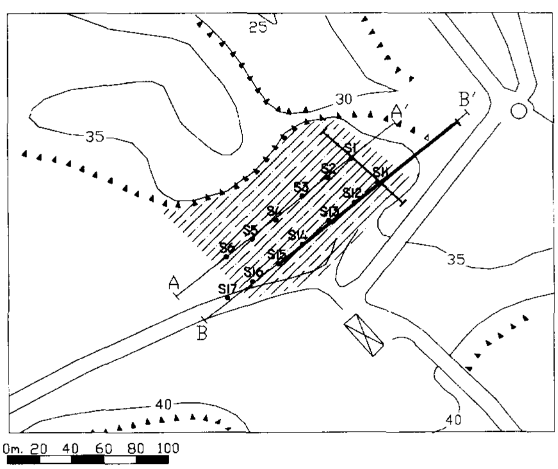

Fig. 4. Plan of the second site near Rome (Pisana zone).

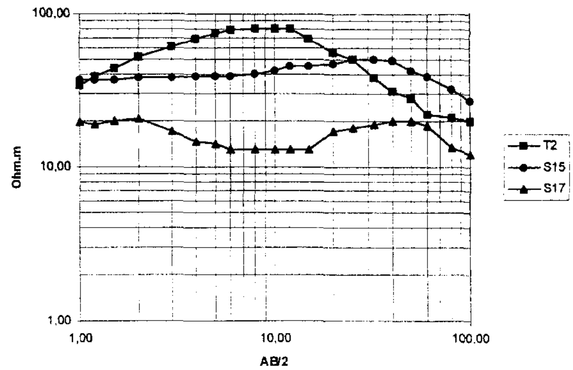

Fig. 5. VES carried out in the Pisana zone: S_{15} (●) carried out inside the dump; S_{17} (▲) carried out on the limit of the dump; T_2 (■) carried out on the outcrop of the fluvial formation.

The seismic profile crossing the first one presents similar values to those of the longitudinal line but no lateral variations exist which might indicate the boundary of the dump.

The electric soundings carried out away from the presumed site of the dump show below a superficial layer with variable resistivity a layer whose resistivity is about 40 Ω m (gravel, sandy clay, materials taken away from the old quarry) and finally a substratum with resistivity values of 10–20 Ω m (Monte Mario clay formation) (Fig. 5, sounding S_{17}). Sound-

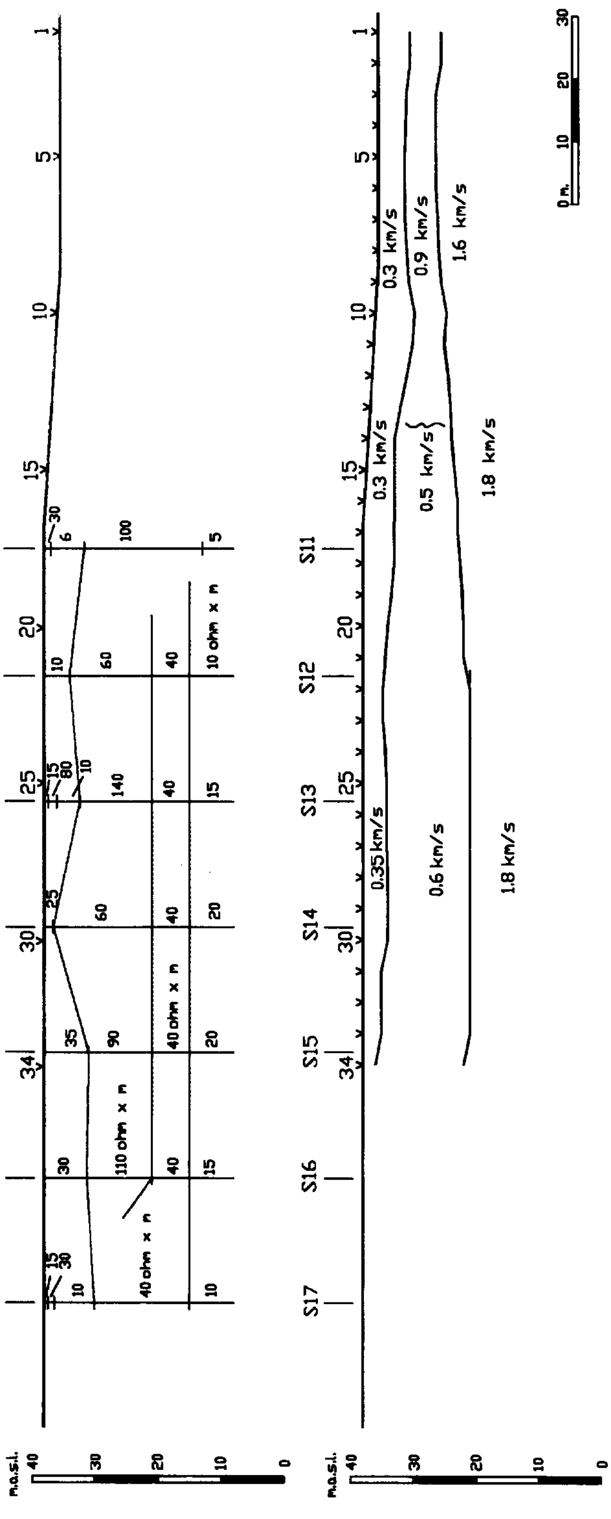

Fig. 6. Seismic section on the bottom and electrostratigraphic one on the top, corresponding to the second site near Rome. The velocities are expressed in km/s. The seismic profile terminates with the electric sounding S_{16}. The resistivity values of the strata are expressed in Ω m.

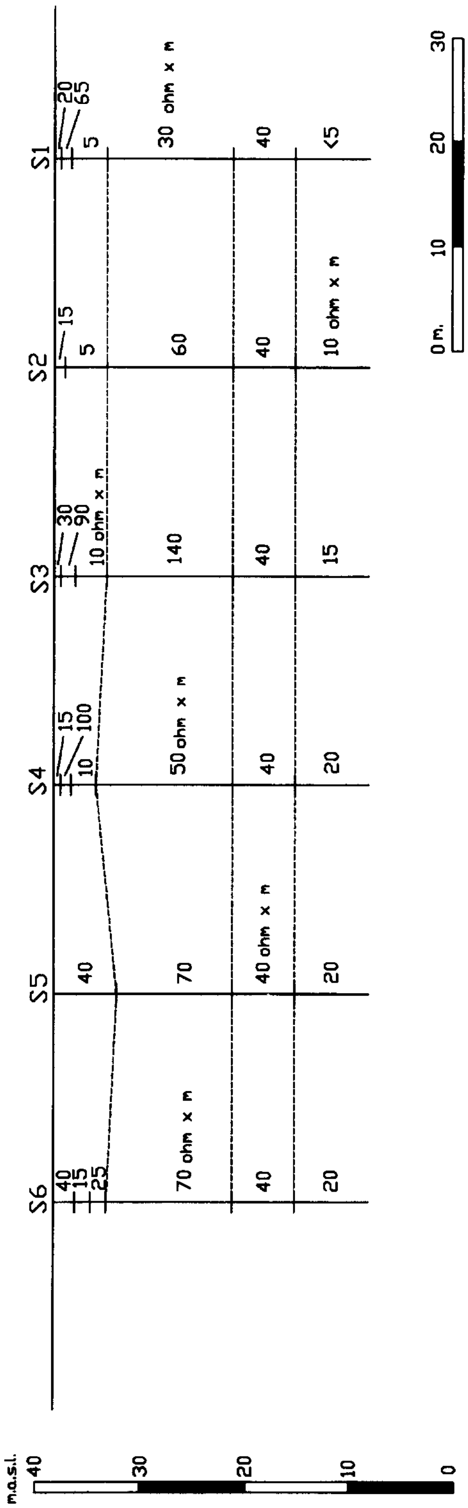

Fig. 7. Electrostratigraphic section of the second electric profile (soundings S_1 and S_6). The resistivity values of the strata are expressed in Ω m.

ings carried out within the area of the presumed dump site show similar characteristics but with greater resistivity (60–140 Ω m) at the intermediate layer (5–15 m) (sounding S_{15}, Fig. 5). In the interpretation, which presents numerous conditions of equivalence, the thickness of the waste site was assumed to be the same as that of the seismic intermediate layer with 0.5 km/s velocity. The geoelectric sections (Figs. 6 and 7), obtained from the best fitting curve between the field and theoretic curves, show a geological picture consistent with other results and with our knowledge of the geological characteristics of the area.

The waste is characterized by very low velocity values of the longitudinal waves whilst the resistivity values are not very low, probably because the wastes were selected (organic material was eliminated) before the dump.

The general picture of the resistivity in the lower part of the section indicates a normal situation with respect to the surrounding areas and seems not to show the presence of pollution because of the impermeability of the terrain below the dump and the limited presence of organic material within the dump itself.

4. Conclusions

From these two cases and from others studied by seismic refraction surveys we deduced that the material which constitutes a dump usually presents lower velocity values with respect to the air (0.28 km/s in the first site). It increases in depth but with lower values with respect to the normal values of the weathered strata. Even in the second case, although the waste material was amassed and intercalated with soil, the velocity of the waste was less than that of the material of the surrounding area at the same depth. The low velocities of the waste material were confirmed by a comparison performed between the thickness calculated with refraction survey and those with direct investigations. This effect can be ascribed to a high porosity of the dumps and to the presence of air and gas produced by the organic material. These seismic characteristics have allowed us to identify the dump with the seismic refraction method and also to determine its thickness and limits. The lateral limits of the dumps were, in some cases, controlled by analyzing the wave form of the seismic records. This is because they change their wave form passing from the outside to the inside of the dump. This was because dumps appear to present greater attenuation for high frequencies.

Geoelectric surveys, together with seismic ones, have made it possible to understand better the characteristics of the waste material and the geological formation of the zone. The different values of the resistivity are due to the different materials of which the dumps are composed. In the first site the low resistivity values (25 Ω m) can be ascribed to the organic fluids that are in the dump. These fluids arise from the decay of the organic materials. They are in the dump with a low degree of saturation, which justifies the low velocity values detected. They determine a considerable reduction of the resistivity values that we noticed in the tuff below and around the dump. In the second site the resistivity values of the dump are higher than outside, because the dump is composed with a selected material which presents a higher resistivity than the surrounding clayey area.

The research carried out has allowed us to conclude that the integrated use of well known geophysical methods such as seismic refraction and VES can provide useful results identifying dumps and determining their characteristics.

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