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Application of Magnetotelluric and DC Electrical Resistivity Methods in the Neapolitan Geothermal Area

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Abstract. In 1977 a number of electrical dipole-dipole deep soundings, magnetotelluric and geoelectrical Schlumberger soundings were carried out in the Neapolitan volcanic region in order to test the application of these electrical techniques in a geothermal area.

The geothermal anomalies in this area, which are bordered by faults and magnetic intrusions, are correlated with a decrease of the electrical resistivity of the carbonate basement and a broadening of one of the upper layers, which has a low resistivity.

The limestone basement morphology deduced from magnetotellurics agrees with that obtained from gravity interpretation. The methods applied, especially the magnetotelluric method, can evidently be very valuable in a geothermal area.

Key words: Magnetotellurics – Geoelectric dipole-dipole soundings – Geothermal areas.

Introduction

The Neapolitan volcanic area, in common with most of the areas affected by active or recent volcanic activity, is a very promising area for geothermal exploitation. The geothermal potential of this area has been recognized since 1940 and several bore holes have been drilled at Phlegraean Fields and Ischia.

The geological and tectonic situation of the area has been caused by continuing geodynamic processes, which have built up the Apennine chain on one side and the Thyrrenian bathyal plane on the other.

Four main volcanic systems are present in this area: Somma-Vesuvio, the Phlegraean Fields, Ischia and Roccamonfina (Fig. 1). Besides these main centers, several other volcanic displays or tracks of aborted volcanism have been identified.

Radiometric ages of the Campanian volcanic products show that activity started here between 1 and 2 m.y. ago.

In particular the Phlegraean Fields volcanism is very recent, its oldest outcrop being the Campanian ignimbrite about 30,000 years old. Activity has continued up to present, the last eruption being that of 1538 (Monte Nuovo).

A number of geological, geophysical and vulcanological studies have been carried out in recent years, aimed at the reconstruction of the main structural trends and the relationship between volcanic and tectonic activity, the evaluation of the vertical and the horizontal temperature distribution and the study of the tectonic state of the area (Barberi et al. 1977). The aim of such research was both the correct planning of the local volcanic surveillance and the evaluation of the geothermal potential of the area.

One of the main targets in both cases is the detection and physical characterization of hot magmatic bodies which are, in some way, intruded into the crust. Such bodies may stay at shallow or moderate depths and heat the host rock to create a thermal reservoir.

During 1977 a geophysical survey was carried out in this area as part of the European Community research program for geothermal energy development. Financial support was also granted by the German Ministry for Research and Technology and the Italian National Research Council, Special Energy Program. This research was planned and carried out jointly by research teams of the Institute of Geology and Geophysics of Naples, the Institute of Geophysics and Meteorology of the University of Braunschweig and the Vesuvian Observatory. Magnetotelluric and Schlumberger geoelectrical soundings were made with the aim of testing these methods in a geothermal area of sufficiently well known general structure. A number of dipole-dipole electrical deep soundings were carried out to compare this technique with others that could be used in an area of this type.

In this paper the conclusions of previous geological and geophysical research are reported briefly together with the results of the present geoelectrical and magnetotelluric campaign.

The aim of this paper is to define a general model of the area which takes into account all the available geophysical results and may represent a working model for the small scale detailed surveys which will be carried out in the area for geothermal exploration.

Structural Setting

Seismic refraction data together with long wavelength gravity anomalies show that, in the Neapolitan region, the Moho discontinuity is at a depth of about 30 km, with a dip toward the Apennine chain, and that the top of the crystalline layer is at about 9–10 km (Corrado et al. 1974).

Magnetic data show that the crust in the Italian western side is characterised by a low susceptibility indicating a continental crust. Magnetic anomaly maps indicate, in the Neapolitan area, the presence of conspicuous igneous masses within the crust and the sedimentary layers (Corrado et al. 1977).

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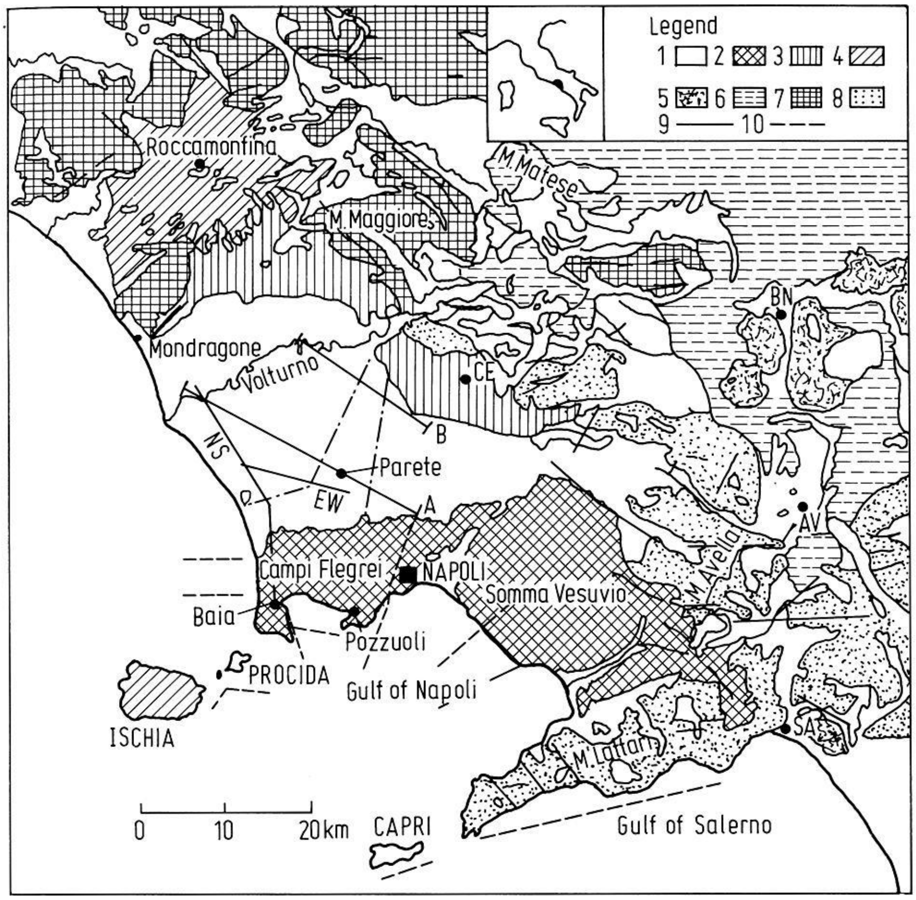

Fig. 1. Geological and structural sketch map of the Campanian volcanic area. *1* Alluvium deposits; *2* volcanics of Somma-Vesuvio and Phlegraean fields; *3* Campanian ignimbrite; *4* volcanics of Roccamonfina, Ischia and Procida; *5* Ariano units; *6* Irpine unit, Sicilid units; *7* Matese-M. Maggiore units; *8* Alburno-Cervati units; *9, 10* faults. *A, B:* gravimetric and magnetic profiles of Fig. 2. NS, EW: profiles shown in Fig. 6. –·–·– boundaries of structural high in Fig. 2

A detailed gravity survey carried out in the Neapolitan volcanic area, along profiles crossing the main gravity trends normally, allows a detailed reconstruction of the morphology of the carbonate Mesozoic basement (Carrara et al. 1973). It is interpreted as showing that the basement is divided by several normal faults into two structural lows. In the middle there is a structural high which approaches to within 1.5 km of the surface. The depth to the basement is about 4 km north and south of the central high (Fig. 2).

A detailed seismic reflection survey was carried out in the bays of Naples and Pozzuoli and the seismic data confirm the above interpretation (Finetti and Morelli 1974).

Intense magnetic short wavelength anomalies were recognized along the same profiles, often located where the gravity data indicate a fault. Figure 2 shows an example for this good correlation on the two parallel profiles, A and B. The boundaries of the structural high are shown in Fig. 1. As indicated in this figure, the northern boundary can be extended westward, to where Carrara et al. (1974) inferred another magnetic intrusion from a magnetic anomomaly near Lago Patria, which is shown in Fig. 12. This is an important result as it demonstrates first, that considerable magmatic activity is present in the whole Campanian region and in areas where no volcanic surface activity is recognized and second, that a close relationship exists between tectonic and magmatic activity, where the main faults are the preferential feeding channels of the local magmatism.

Taking into account the ages of both the neotectonic dilatant activity and of the volcanic products, it may be concluded that magmatic activity in this area depends strictly, in both space and time, on the Quaternary dilatant tectonic activity (Carrara et al. 1973).

Stratigraphy

The main units of the rock sequence constituting the sedimentary series of the Campanian area are the following (see Fig. 3):

Carbonaceous Mesozoic series (basement): made up of dolomitic rocks under limestone rocks with an overall thickness, inferred geologically, of about 6 km. Both the dolomite and the limestone have a high permeability due to the presence of a large number of fissures, as evident in outcrops and wells in the Apennine area. Impermeable marls and clay horizons are also present in the series, but they do not modify the general high permeability of the sequence.

Tertiary flysch complex: of variable thickness, generally some several hundred meters, with marls and clay horizons with variable, but generally low, permeability. This represents the main impermeable layer of the Campanian area.

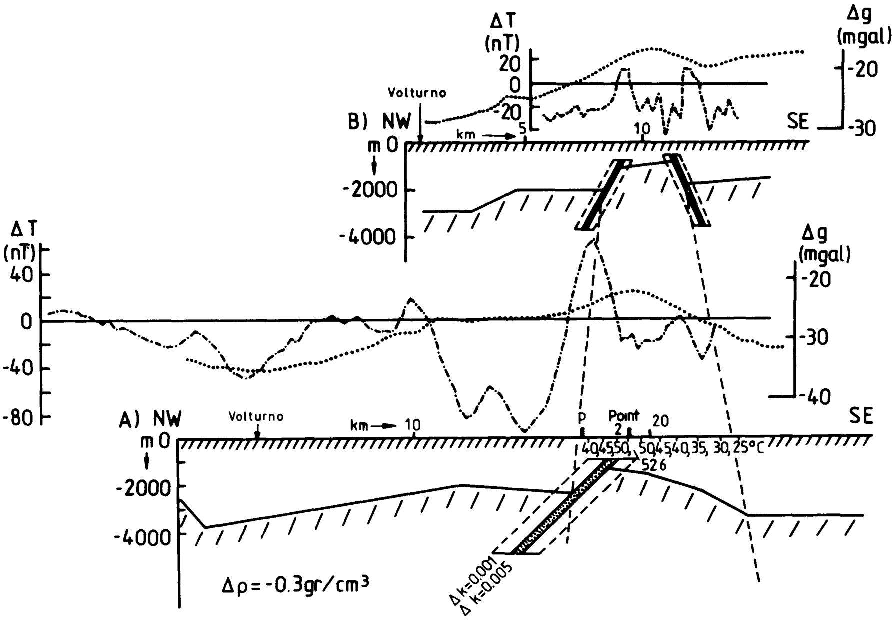

Fig. 2. Magnetic and gravimetric profiles in the geothermal area of Parete-Naples. In the figure the *ΔT* and *Δg* anomalies along profile **A** and **B** of Fig. 1 and the resulting models are shown. Carbonate basement deduced from gravity interpretation; igneous intrusions deduced from magnetic interpretation (Carrara et al. 1973, 1974). Temperature data from 5 different drillings are taken at a depth of 250 m (Baldi et al. 1976). *Point 2* has the highest thermal gradient. *Point P* is a deep well near Parete (1,800 m depth)

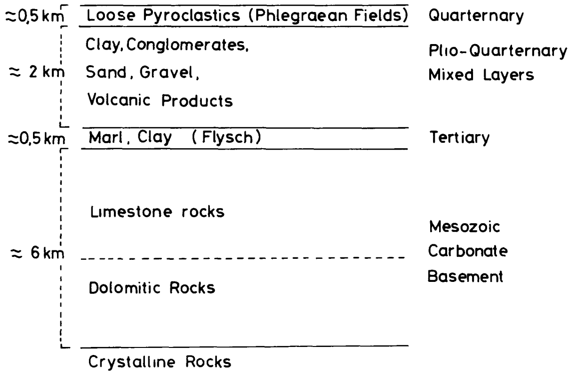

Fig. 3. Rough sketch of the sedimentary series of the Campanian area

Plio-Quaternary detritic complex. with impermeable (clays) and permeable (conglomerates, sand and gravel) horizons. Recent volcanic rocks are included in this complex. The main volcanic products are: ignimbrite and tuffs (Campanian grey tuff, Ischia green tuff, Phlegraean yellow tuff), incoherent pyroclastics, often altered by hydrothermal processes, scoriae and lava flows. The ignimbrite, tuffs and the other pyroclastic rocks show a high porosity and a low permeability.

In particular, the Phlegraean Fields area is covered mostly by loose pyroclastics; welded tuffs with variable porosity constitute the skeleton of the Phlegraean Fields and outcrops in the older volcanic centers. A few lava flows of limited extent are present at the surface. All these rocks often show chemical alteration due to the high temperature of the geothermal fluids.

Seismic Activity and Soil Deformation

The seismic activity is restricted mainly to the very center of the Phlegraean Fields area. Since 1970 attention has focussed on this area due to the exceptional ground uplift, reaching a maximum of 1.5 m in 1972. Results of the studies by Corrado et al. (1976–1977) also give valuable data for the evaluation of geothermal modelling of this area. Several epicenters are concentrated around the town of Pozzuoli and several others seem to be aligned parallel to the Baia coast (see Fig. 1). The focal depth data show that the great majority of quakes originated at depths less than 5 km, in most cases less than 3 km.

Several simple deformation source models were computed to fit experimental horizontal and vertical deformation trends. The best fit was obtained for a 75° inclined dike, having its top at the depth of about 3 km where most of the focal depths are located.

Seismic and deformation data are therefore compatible with the hypothesis of a dike-shaped magmatic mass intruded at shallow depth during that time interval.

Temperature Data

The anomalous thermal state of the area can be deduced from a number of high temperature fumaroles and hot springs. Moreover, several temperature measurements have been carried out in drill holes located in the Neapolitan area and particularly in the Phlegraean Fields and Ischia (Penta 1949; Penta and Conforto 1951 a, b; Minucci 1964).

Data from the Phlegraean Fields (Penta 1949) area have been re-analyzed and the isotherm distribution based on data from the 8 most significant holes is reported in Fig. 4 (Rapolla 1977). It shows a drastic uplift of the isotherms in the center of the Phlegraean Fields.

On the basis of the isotherm pattern and assuming that the rocks at depth have similar thermal and hydrological properties, it can be hypothesized that temperatures higher than 300° C can be found at depths of about 2 km. It should be pointed out that a temperature higher than 300° C was measured at the bottom (1,842 m) of the Agnano well (CF23), which is located on the periphery of the geothermal system shown in Fig. 4.

Recently five test holes and a deep well (P in Fig. 2) were drilled north of the Phlegraean Fields. Gradients of geothermal

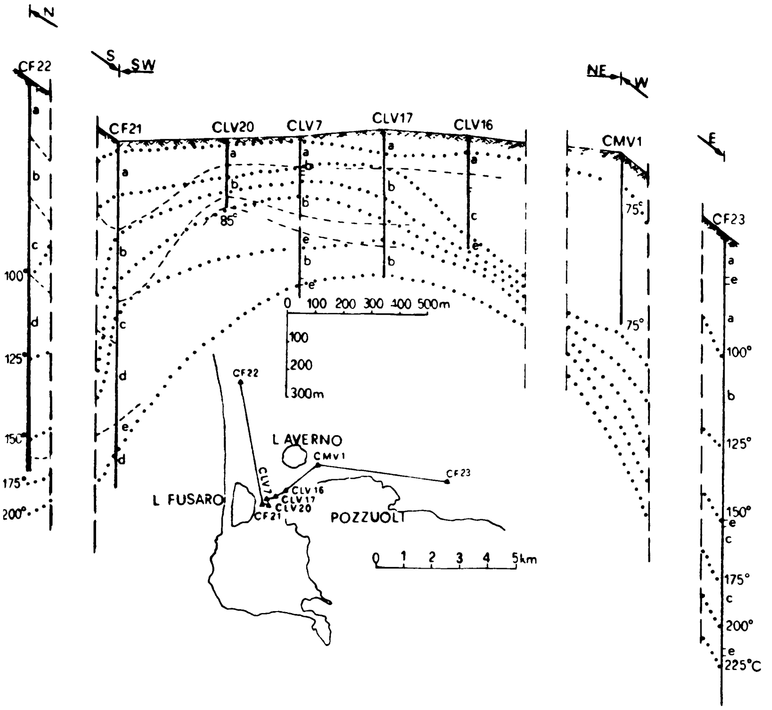

Fig. 4. Isotherm pattern in the Phlegraean Fields (after Rapolla 1977). **a, b, c, d, e** are different layers of volcanic products. ··· isotherms

interest were found only in an exploratory drilling (see Fig. 2) just south of Parete (≈150° C/km, point 2). West and east of this area temperature values decrease rapidly to normal. The deep well was located at about 2 km north-west of point 2 and a temperature of only 70° C was measured at the well bottom (1,800 m), confirming the normal gradient in this area.

DC Electrical Soundings

Shallow and deep Schlumberger vertical soundings were made in the Phlegraean Fields and surrounding areas. The results of these soundings reveal that the resistivity of the local volcanics is extremely variable. The electrical resistivity of the local pyroclastics is in the range 50–500 Ωm, and is reduced to less than 20 Ωm when the rocks are thermally altered or filled with saline water. Outcropping lava flows and compact ignimbrites show a resistivity as high as 3,000 Ωm (Carrara and Rapolla 1972).

About 25 deep Schlumberger soundings were carried out north of Phlegraean Fields by Baldi et al. (1976). Low resistivity areas were found between Parete and Giugliano (about 5 km south-east of Parete) with an electrode separation of about 1,000 m. The tendency toward high resistivity values at the longest electrode distances (AB/2 = 3,000 m and more) was interpreted by these authors as due to the resistive carbonaceous Mesozoic basement.

During the present survey nine DC electrical soundings were made using a polar dipole-dipole configuration (Alfano 1974). The distance between the two dipoles reached a maximum of 18 km (No. 2). The locations and directions of receiving dipoles are indicated in Fig. 6. The ground was energized by a current commutated at a period of 60 s, which was sufficiently low to avoid skin effects. The signal at the potential dipole was recorded digitally. The final evaluation of the potential differences was made subsequently by an autocorrelation computer analysis.

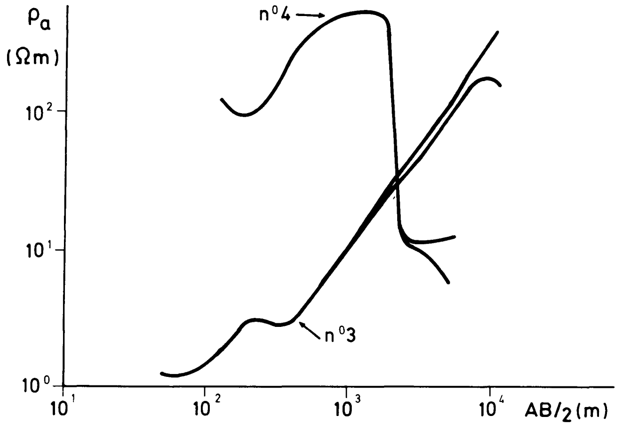

Fig. 5. Half-Schlumberger transformed dipole-dipole soundings nos. 3 and 4, Phlegraean Fields area (see Fig. 6 for location)

Dipole-dipole data were transformed into half Schlumberger data, as shown in Fig. 5, for interpretation. As both the dipole-dipole and the half Schlumberger configuration are asymmetrical, the soundings should be referred not to the receiving dipole centre, but to a zone located towards the source dipole. But obviously, as the layering may not be horizontal, this criterion does not always hold. In spite of the limitations such as lack of geoelectrical stations and lateral control, a preliminary interpretation was attempted.

The interpretation of the field data shows that highly conductive layers (< 20 Ωm), clearly correlated with the presence of sea water, are found in most cases at shallow depth in the area investigated. An example is curve No. 3 in Fig. 5. The thickness of the low resistivity layer is variable, from a few hundred meters to 1.5 km. At this depth a high clay content layer is generally found. Underneath this layer the resistivity increases. It seems probable that the geological sequence corresponding to the first part of the geoelectrical curve is the post-Mesozoic sedimentary sequence in Fig. 3, whereas the highly resistive layer corresponds to the Mesozoic carbonate basement. The Tertiary flysch layer cannot be identified. Because of the very low resistivity of the surface layers, it was impossible to discriminate the increasingly resistive layers.

The whole resistive sequence reaches a depth of at least 5 km, which is the maximum depth explored. A different picture was found near the Cuma crater (sounding No. 4) where a clear lateral discontinuity occurs, indicated by the steep decrease of the ρ_a-curve at an AB/2 of 2 km. In this case it is not clear whether the low resistivity layer is covered by a high resistivity layer or whether this is an effect of the lateral discontinuity. Nevertheless the low resistivity layer seems to reach a much greater depth of at least 4 km. Because of a lack of data, we have been unable to interpret the soundings fully.

In conclusion, the results of these deep geoelectrical soundings can be considered only as preliminary. Although several technical and interpretative problems arise in the application of this configuration, it has proved to be the most convenient DC geoelectrical method for investigations down to several kilometers depth.

Magnetotelluric Soundings

In order to probe the structure of the crustal sections of the area down to about 10 km, 17 magnetotelluric measurements were carried out along two profiles as shown in Fig. 6 (Musmann et al. 1977; Hunsche and Duske 1978). The well-known geothermal anomaly of the Phlegraean Fields is located on the NS profile from point MT9 southward and the supposed geothermal anomaly of Lago Patria is located between points MT4 and MT6. The EW profile starts from this anomaly (MT5). The well-known thermal anomaly of Parete has its center at point MT 2/1, which corresponds within 100 m to point 2 of Baldi et al. (1976) and which has the highest gradient in this anomaly (see Fig. 2). The measurements were carried out with 3 MT stations, all measuring two orthogonal components of the electric field and the three components of the magnetic field by induction coils. Two stations (IFN0 and IGM1) worked completely automatically and were powered by batteries. The third (BGR) was equipped with a computer and was able to evaluate the complete ρ_a and phase curves in the field, which is very important for control of the quality of the results and for optimisation of measuring times. The stations operated in a frequency range 0.2–1,000 s (BGR), or 2–1,000 s (IFN0 and IGM1). The data were evaluated by statistical frequency analysis. The computed impedance tensors were rotated into the principal directions and the ρ_a and phase curves for the two orthogonal directions were calculated for each point. These were the basis for the model calculations, which were a combination of direct model calculations and an inversion method based on the Marquard algorithm, for which both, ρ_a and phase curves were used.

The derived ρ_a and phase curves are of high quality. Examples are shown in Fig. 7a and b. In most cases the ρ_a values have a standard deviation of less than 3% and the phases of less than 5° The ρ_a and phase curves for the two orthogonal measuring directions at one point, have very small differences in most cases. In addition, the corresponding skewness coefficients are very small (<0.1). These parameters indicate that the subsurface is essentially one-dimensional. In order to get an idea of the influence of the coast effect, two-dimensional model calculations with 3 different frequencies were carried out (Steveling, Göttingen, private communication). The results are not shown here, but they show that the coast effect has an influence on the ρ_a curves of 20% in the worst case. For these reasons one-dimensional model calculations are suitable.

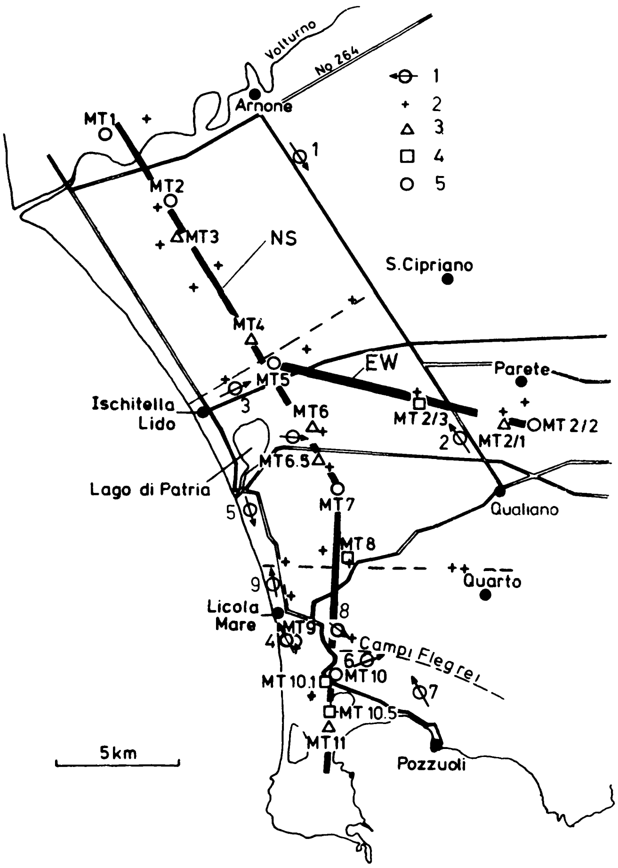

Fig. 6. Location of measuring points, magnetotelluric and geoelectric deep soundings in the area of Volturno-Campi Flegrei, 1977. *1* dipole-dipole soundings, location and direction of receiving depole; *2* Schlumberger soundings; *3, 4, 5* MT soundings (IFN0, IGM1, BGR); NS, EW· profiles of Figs. 8–13

To get a first overview of the results, pseudo-cross-sections of both orthogonal ρ_a and both orthogonal phases are drawn for each profile. Because of the small differences, the results for only one direction are shown in Figs. 8a, b, 9a, and 9b. The magnetotelluric method is based on the electromagnetic skin-effect: the period T is a distorted depth scale and the ρ_a pseudo-sections are rough and distorted cross-sections of the subsoil. The phase cross-sections are more difficult to understand, but they show nearly the same information.

The most striking characteristics in Figs. 8a and 9a are the local minima of ρ_a at MT 5 (1.8 Ωm), MT 9 and MT 10 (1 Ωm) and MT 2/2 (4.8 Ωm). The minimum at MT 2/2 coincides quite well with the thermal anomaly at Parete which is centered on MT 2/1 and with the structural high, together with the dike shaped magnetic intrusion (see Fig. 2 and Fig. 13). The minimum at MT 9 and MT 10 correlates with the geothermal anomaly of the Phlegraean Fields and the minimum at MT 5 coincides with the magnetic anomaly and the inferred magnetic dike, shown in Fig. 12. These are promising results which have to be verified by exact model calculations.

In order to find out the resistivity of the upper 300 m, which are not covered by magnetotellurics, 23 Schlumberger soundings

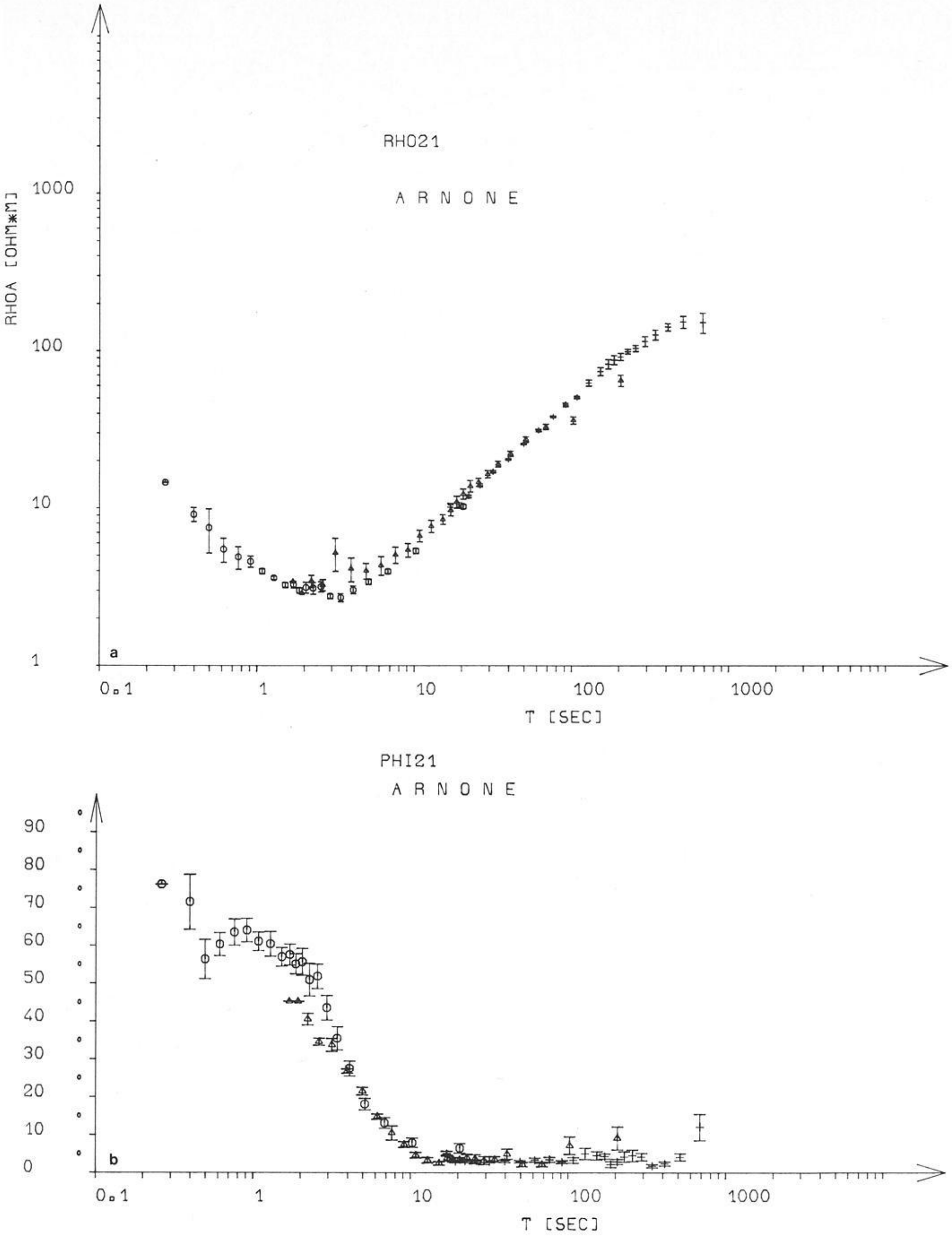

Fig. 7. **a** ρ_a curve for magnetotelluric sounding MT2. **b** Phase curve for magnetotelluric sounding MT2

with electrode separations up to 1.8 km were carried out. The results are described by Musmann et al. (1977). The measuring locations are shown in Fig. 6.

The final result of the one-dimensional magnetotelluric and DC-Schlumberger interpretation for the NS profile is shown in Fig. 10. Five layers were detected in the area; it was not possible to interpret the data by a consistent model with fewer layers.

1. The top layer is derived mainly from geoelectric soundings. It has a thickness varying between 30 m and 270 m and represents the freshwater layer. The resistivity and thickness is dependant on the distance from sea.

2. The second layer is a sedimentary and volcanic layer filled with saline or brackish water; its resistivity ranges between 4 and 20 Ωm. This layer reaches a maximum depth of about 1,600 m. It covers the most part of layers 1 and 2 in Fig. 3 and was also found by the DC dipole-dipole measurements.

3. The third layer has very low resistivities between 0.9 and 3 Ωm and a thickness up to 900 m. It is highly probable that it consists of clay deposits which are found in several wells. The thickness and the resistivity of this layer can be evaluated in nearly all cases within an accuracy of about 20%. Normally the parameters for low resistivity layers can be determined very well using magnetotellurics. It seems not to represent the Tertiary flysch layer which lies deeper, on top of the carbonate basement (see Fig. 3).

4. The fourth layer seems to be filled again with saline or brackish water, like layer two. In both layers (2 and 4) it is not

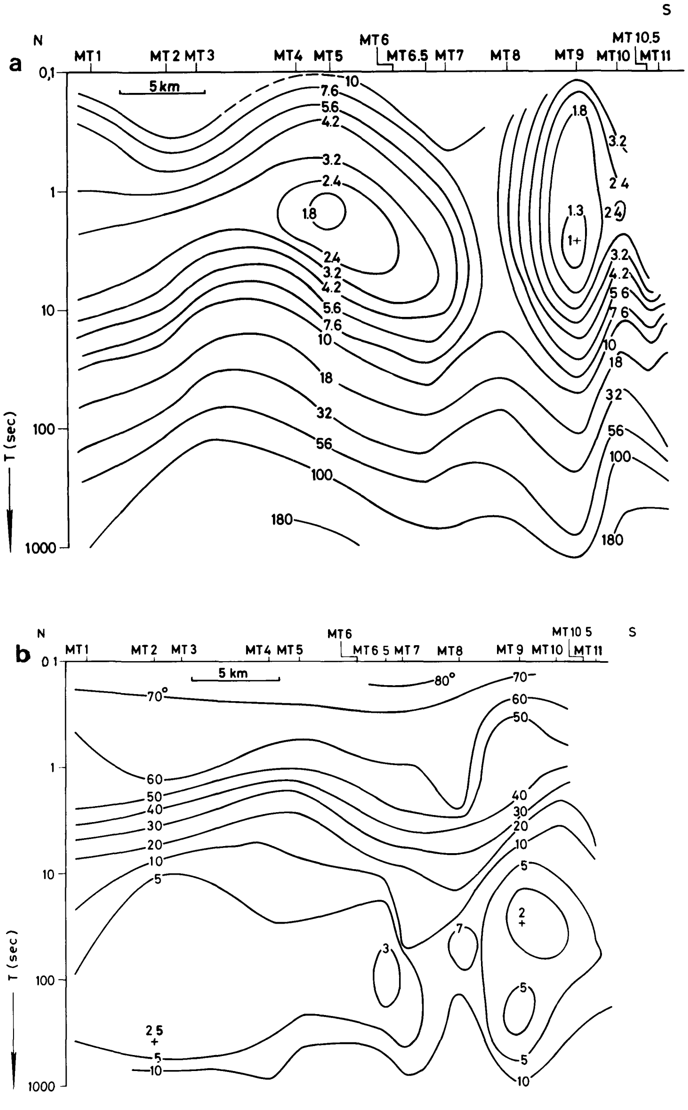

Fig. 8. a Magnetotelluric pseudo-cross-section of ρ_{a21} for the NS profile. The isolines of ρ_a in Ωm are shown as a function of period T. **b** Magnetotelluric pseudo-cross-section of phases φ_{21} for the NS profile. The isolines of φ in ° are shown as a function of period T

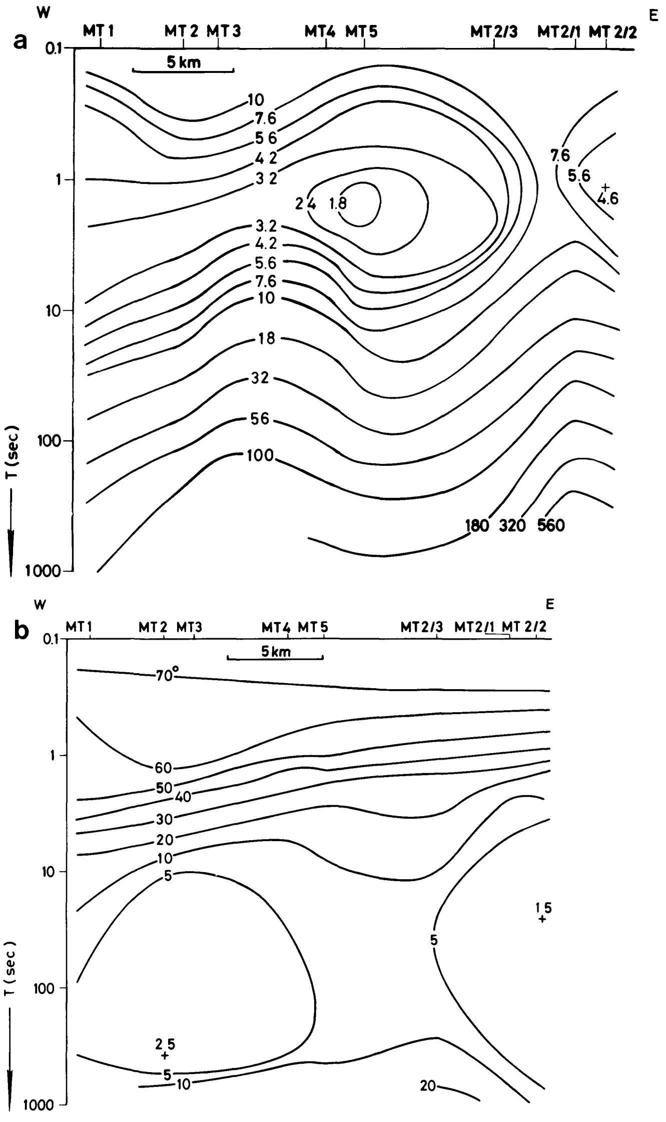

Fig. 9. a Magnetotelluric pseudo-cross-section of ρ_{a21} for the EW profile. The isolines of ρ_a in Ωm are shown as a function of period T **b** Magnetotelluric pseudo-cross-section of φ_{21} for the EW profile. The isolines of φ in ° are shown as a function of period T

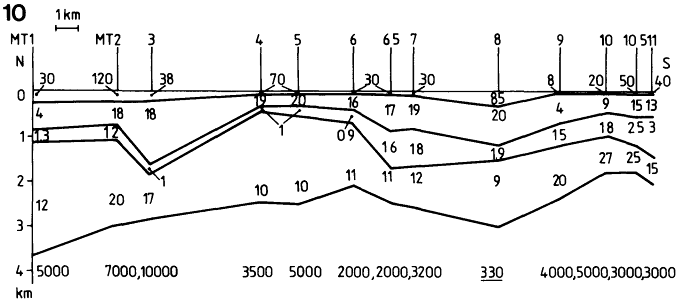

Fig. 10. Results of model calculations for the NS profile derived from Schlumberger soundings and magnetotelluric deep soundings. ρ values in Ωm

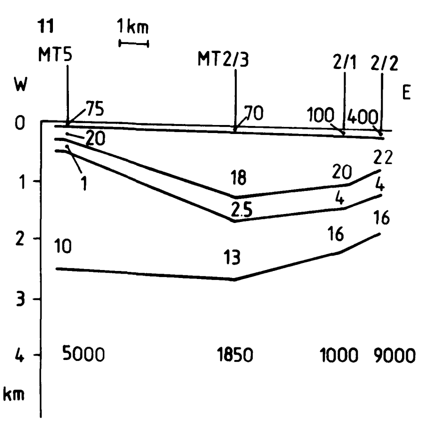

Fig. 11. Results of model calculations for the EW profile derived from Schlumberger soundings and magnetotelluric deep soundings. ρ values in Ωm

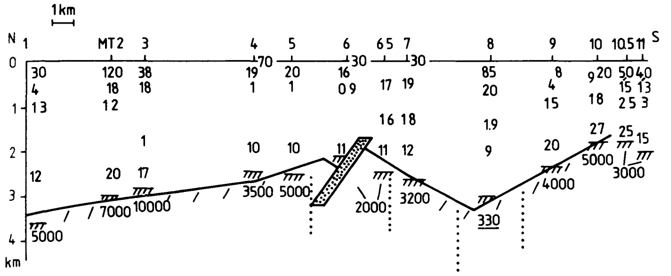

Fig. 12. Crustal section along NS profile (see Figs. 1 and 6 for location). Numbers: ρ in Ωm. ////// top of carbonate basement from magnetotellurics; ——— top of carbonate basement from gravity; ▨ magnetic intrusion. Low resistivity zones in the carbonate basement are also indicated

possible to find the further subdivisions suggested by drilling. Its resistivity ranges between 9 and 27 Ωm and its thickness reaches 2.5 km. This layer consists of the lower part of layer 2 and of layer 3 in Fig. 3. The layer could not be differentiated by the DC dipole-dipole measurements.

5. The highly resistive basement (generally 3,000 Ωm and more) represents the limestone and crystalline sequence which cannot be differentiated. The high resistivities of the carbonate and dolomitic rocks have been confirmed by two additional magnetotelluric measurements in the Appenine mountains, where the basement, as deduced from magnetotellurics, outcrops. The depth to the top of the carbonate basement varies between 3.7 and 1.8 km. The depth can be determined with an accuracy of ±400 m taking into account the high quality of data and the assumption that the lateral differences of the resistivities in layers 2 and 4 in Fig. 10 have to be small. This fifth layer was also found by DC dipole-dipole measurements.

It can be seen clearly in Fig. 10 that the supposed limestone basement is closer to the surface toward the Phlegrean Fields area and shows special highs at the anomalies of Lago Patria and the Phlegraean Fields. This can also be said of the low resistivity layer 3. Moreover in the southern part the resistivity of layer 3 is higher by a factor of 2 or 3 and the layer is also much thicker. These results are not changing due to the principle of equivalence, and could not be found by the DC dipole-dipole measurements. The EW profile (Fig. 11) shows a very similar situation approaching the Parete anomaly. At first glance it is surprising that the striking ρ_a-minima in Figs. 8a and 9a do not appear so clearly in Figs. 10 and 11, but they can, in fact, be explained mainly by a rise in the level of layers 3 and 5 and a broadening of layer 3. As a final result Fig. 12 shows a crystal section of the NS profile obtained by magnetotelluric, gravity and magnetic data. It can be seen that there is good agreement between the gravity and magnetotelluric depths to the top of the carbonate basement. Moreover it is remarkable that lower resistivities result in the basement in the vicinity of the magnetic dike, which is situated on a tectonic fault. Another deep, low resistivity zone is at point MT 8, which lies on the north-western boundary of the Phlegraean Fields and may be due to a fault.

Figure 13 shows an equivalent crustal section for the EW profile. The agreement between the two top depths of the carbonate basement is a bit worse than for the NS profile. But again a low resistivity zone results in the vicinity of the magnetic dike just on the boundary of the above mentioned structural high. Moreover this is the area of the geothermal anomaly of Parete.

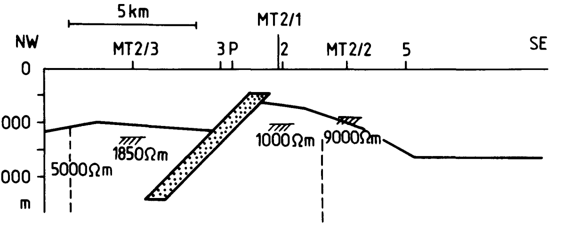

Fig. 13. Crustal section along EW profile (see Figs. 1 and 6 for location) ////// top of carbonate basement from magnetotellurics; ——— top of carbonate basement from gravity; ▨ magnetic intrusion. A low resistivity zone in the carbonate basement is also indicated

Conclusions

One of the results of this survey is the delineation of the local limestone basement morphology by magnetotelluric soundings. The picture obtained agrees fairly well with that deduced by gravity interpretation. The agreement between two independent geophysical methods makes the final picture very reliable. It should be stressed that magnetotellurics obtain deep results in a geological setting where the DC dipole-dipole sounding method seems to fail.

The resistivity of the Mesozoic basement is generally between 3,000 Ωm and 10,000 Ωm. Low values are found in the Lago Patria area (2,000 Ωm), on the western side of the Parete structural high (1,000 Ωm, 1,850 Ωm) and on the northwestern side of the Phlegraean Fields (330 Ωm). These values may be related to a local increase of the water content due to a higher amount of fissures in the vicinity of tectonic faults together with a possible increase of temperature and salinity.

Comparing the results obtained on the structure in the Phlegraean Fields and Parete areas and the available temperature distribution, a number of conclusions can be proposed:

1. In both geothermal areas there is a connection between the structural high and the welling up of the isotherms.

2. At least at Parete and most probably in the Phlegraean Fields area, the presumed heat sources are magmatic masses intruded in the faults which border this structural high.

3. Related with these faults there is a decrease of the basement electrical resistivity.

4. A hot magmatic body could not be detected as was hoped in the beginning of the investigation. Probably no magmatic body exists but there the problem of discriminating between the effects caused by water and by high temperature remains.

5. It should be mentioned moreover that the low resistivity layer 3, detected by the magnetotelluric survey, broadens in the Phlegraean Fields and Parete areas. This may be due to the alteration of the sediments as found by drillings in the Phlegraean Fields area. If this hypothesis holds the broadening of this layer at points MT 6.5 and MT 7 just south of Lago Patria can be explained in the same way.

6. The Lago Patria and Parete areas are characterized by magnetic anomalies. The anomalies centered between points MT 6.5 and MT 6 as well as between MT 2/3 and MT 2/1 were interpreted as caused by dike shaped intrusions into the limestone. Note that no thermal anomaly has yet been detected at Lago Patria. Although the tectonic situation is similar to the two other areas,

no magnetic anomaly seems to be present at the northern border of the Phlegraean Fields where the volcanic activity is much more recent and the thermal anomaly bigger.

7. As shown, the electrical methods applied, especially the magnetotelluric method, can be valuable tools for the exploration of areas of geothermal interest, if combined with other methods.

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