GEOTHERMAL EXPLORATION OF KOS ISLAND, GREECE: MAGNETOTELLURIC AND MICROSEISMICITY STUDIES

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Abstract—This paper reports the results of magnetotelluric (MT) and microseismicity studies, conducted as part of a multi-disciplinary project to explore the geothermal potential of the island of Kos, Greece. The MT survey, comprising 18 soundings, was carried out in the bandwidth 128 Hz–40 s, in order to determine the deep conductivity structure in the geothermally prospective western part of the island. Rigorous dimensionality analysis has indicated that the geoelectric structure could adequately be approximated with 1-D interpretation tools. Two significant and seemingly communicating conductive zones of potential geothermal interest were found within the first 2 km. The first is extensive and shallow, detected at depths of 400–600 m, the second is deeper (1000–1300 m), but of considerably smaller lateral dimensions. A very deep relative conductor (<25 Ωm) was also detected at depths of 7–10 km, which is thought to comprise part of an old magma chamber with brine-saturated rocks. The microseismicity studies revealed the partial or total attenuation of shear waves in many microearthquake records. The analysis of these observations determined the vertical and lateral extent of that attenuation zone, the greatest part of which is located underneath the marine area between western Kos and Nissyros island to the south, extending approximately from near the surface to about 1.5 km depth. The nature of this zone is discussed in terms of fluid concentration due to the geothermal system of the area.

Key words: Kos island, magnetotellurics, microseismicity, geothermal exploration.

INTRODUCTION

The present paper reports the results of the microseismicity and magnetotelluric (MT) studies conducted as part of a multi-disciplinary research project aimed at investigating the geothermal potential of the west part of Kos island, Greece (See Fig. 1).

The search for electrically conductive zones and structures is indispensable in the exploration of geothermal prospect areas. However, the first attempts to explore the geoelectric structure of western Kos with conventional DC resistivity (Schlumberger) surveys proved unsuccessful, as they were unable to penetrate to depths greater than 500–700 m, mainly due to the limited area available for spreading sufficiently long current lines. As a consequence, the MT method was used to investigate the deep geoelectric structure.

Magnetotellurics, in combination with other geophysical methods, has also been successfully implemented during the last decade in Greece by the Universities of Athens (GR) and Edinburgh (U.K.) in the exploration of targets with significant geothermal potential. This research included extensive surveys in the Nissyros (Dawes and Lagios, 1991; Lagios, 1991) and Milos (Fytikas et al., 1989) geothermal fields, as well as in the Sousaki and Methana geothermal areas at the NW end of the Hellenic Volcanic Arc.

Our seismological studies have been limited by the small number of seismographs available for the project, as well as the small number of recorded earthquakes and their inadequate
Fig. 1. The geographical location of Kos island in the Aegean Sea. Kos is the largest island at the centre of the shaded area, with Kalymnos located immediately to the north, and Nissyros to the south.

distribution. Thus, only a brief account of this experiment will be presented. Conversely, more emphasis is given to the MT studies, which provided very interesting images of the geoelectric and geological structure underneath west Kos. Our paper includes a detailed description of the analysis and interpretation procedures.

THE SEISMOLOGICAL EXPERIMENT

The seismicity study was carried out with a small network of five portable, vertical-component seismograph stations (MEQ-800). Three stations were installed in Kos and one in each of the nearby islands of Kalymnos and Nissyros (Fig. 2). The network operated for a period of 2 months and recorded several hundreds of events. However, only a little more than 170 earthquakes could be located with adequate precision. The epicentres of these well-determined events are plotted in Fig. 2, and their majority occurred within the first 10 km of the crust. The relatively small number of earthquakes does not allow their correlation with the principal faulting zones of the area. Nevertheless, it was possible to study the S-wave attenuation effects, which provided useful information in spite of the small number of earthquakes detected by the network.

Abnormal S-wave attenuation was clearly observed in the records of more than 140 local events, but distant earthquakes did not exhibit this type of attenuation. Depending on the location of the hypocentres with respect to the site of each seismograph station, partial or total attenuation of shear-wave amplitudes was observed. This phenomenon was attributed to the
transmission of shear waves through a domain with abundant presence of fluids, such as extensive deep reservoirs or geothermal convection zones. It was, therefore, considered necessary to undertake a detailed analysis of the available earthquake records, in an attempt to resolve the horizontal and vertical extent of the S-wave attenuation zones. In doing so, the broader area of Kos was divided into zones as shown in Fig. 2, Zones A and B being the most important. The shear-wave propagation characteristics between each of the receiver stations K1, K2, K3, and the hypocentres of well-determined earthquakes in each zone, were then systematically recorded and plotted. This process resulted in diagrams outlining the anomalous S-wave attenuation domain in three dimensions.

The horizontal dimensions of the anomalous domain zone can be determined from the S-wave attenuation characteristics along the horizontal projections of propagation paths joining the hypocentres of earthquakes within Zones A and B of Fig. 2, and each of the seismograph stations K1, K2 and K3. The shaded area in Fig. 2 indicates the lateral extent of the anomalous domain, which can be seen to occupy a large part of the marine area between west Kos and Nissyros Island; this area is believed to comprise an old major volcanic centre. An example of how the vertical extent of the anomalous domain can be outlined is shown in Fig. 3, which illustrates the S-wave attenuation characteristics along the propagation paths from earthquake hypocentres occurring within Zone B, and each of the seismograph stations K1, K2 and K3.

Applying the same analysis to earthquakes occurring within the other zones of Fig. 2, it was possible to outline the anomalous S-wave attenuation domain in three dimensions. As can be...
seen in Fig. 3, the upper parts of this domain lie at relatively shallow depths and apparently are considerably more extensive than its lower parts, which extend to a depth of approximately 1300 m. If more seismograph stations had been available and the network operated for longer than 2 months, it might have been possible to determine this energy-absorption domain with better accuracy.

THE MAGNETOTELLURIC SURVEY

The survey comprised a total of 18 soundings over the bandwidth 128 Hz–40 s and was carried out with the improved version (Mk IIb) of the Short Period Automatic Magnetotelluric (SPAM) system of Edinburgh University (Dawes, 1984). The sounding locations are shown in Fig. 4. The majority were located on a WSW-ENE traverse codenamed T1.

The estimation of the experimental MT tensor impedance (MTTI) and GDS Magnetic Transfer Functions (MTFs) followed fairly standard, least-squares, frequency-domain procedures (Sims et al., 1971), with special attention paid to the reduction of biasing effects from random noise. A preliminary interpretation of the MT data based on Bostick transforms and simple layered 1-D models has already been reported by Lagios and Dawes (1989).

Spatial analysis and dimensionality tests

An inherent property of the passive EM operators (i.e. the MTTI and the MTFs) is that they incorporate information about the spatial characteristics of the geoelectric structure in the vicinity of the measurement point. The experimental MTTI may yield this information with appropriate transformations, which rotate the experimental coordinate system until it coincides with coordinate system(s) intrinsic to the geoelectric structure. The term spatial analysis is used here to describe the process of rotation and mapping of the results. The spatial information contained in the MTF can be recovered by means of the induction vector pair, which comprises an equivalent representation.

The rotation of the MTTI followed the procedure introduced by Tzanis (1988, 1992), which generalizes the conventional method (Word et al., 1970) in three dimensions by utilizing the symmetries of the three-dimensional pure rotation group SU(2) of $2 \times 2$ unitary matrices. Because the MTTI $Z$ is a $2 \times 2$ complex matrix, its 3-D rotation can only be accomplished if it is performed in a 2-D complex space isomorphic to the 3-D real Cartesian experimental space and
is incomplete (i.e. involves rotations about the vertical and one of the horizontal axes). It turns out that the appropriate 2-D complex space is defined by the vector basis

\[ T = \sigma_1 x + \sigma_2 y + \sigma_3 z = \begin{bmatrix} 1 & 0 \\ 0 & -1 \end{bmatrix} x + \begin{bmatrix} 0 & 1 \\ 1 & 0 \end{bmatrix} y + \begin{bmatrix} 0 & -i \\ i & 0 \end{bmatrix} z = \begin{bmatrix} x \\ y + iz \end{bmatrix} \]

formed by the Pauli spin matrices \( \sigma_j \) in a right-handed coordinate system, where \( x, y \) and \( z \) are unit vectors in a Cartesian coordinate system. The suitable SU(2) rotation operator in this space assumes the form

\[ U_{zy}(\Theta, \Phi) = \begin{vmatrix} \cos \Theta \cos \Phi + isin \Theta \sin \Phi \\ cos \Theta \sin \Phi - isin \Theta \cos \Phi \end{vmatrix} \begin{vmatrix} -\cos \Theta \sin \Phi - isin \Theta \cos \Phi \\ \cos \Theta \cos \Phi - isin \Theta \sin \Phi \end{vmatrix} \]

and performs rotations about the \( iz \) and \( y \) axes, with \( \Phi \) and \( \Theta \) real parameters (the rotation angles). The 3-D rotation results to the decomposition

\[ Z = U_E(\Theta_E, \Phi_E) \cdot M \cdot U_H^*(\Theta_H, \Phi_H) = U_E(\Theta_E, \Phi_E) \cdot \begin{bmatrix} 0 & \mu_1 \\ \mu_2 & 0 \end{bmatrix} \cdot U_H^*(\Theta_H, \Phi_H) \]

where the superscript + denotes the transposed complex conjugate, which transforms the experimental frame of reference into two intrinsic frames that carry orthogonal electric and magnetic waves, defined by the rotation angles \( \Theta_E, \Phi_E \) and \( \Theta_H, \Phi_H \), respectively. \( \Phi \) represents an azimuthal direction (\( 0^\circ \leq \Phi \leq 90^\circ \)) and \( \Theta \) an inclination (\( 0^\circ \leq \Phi \leq 45^\circ \)); it can be shown that an

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**Fig. 4.** Distribution of the MT stations in western Kos. \( T_1 \) is the WSW-ENE traverse with sounding locations.
equivalent representation of $\theta$ in real Cartesian space is the ellipticity of EM field components in the horizontal plane. $\mathbf{M}$ is an antidiagonal matrix containing the non-increasing extremal (characteristic) values of the impedance tensor ($\mu_1 \geq \mu_2$). The electric and magnetic field components in the intrinsic frames are related as

\[
E(\Theta_E, \Phi_E) = \mu_1 H(\Theta_H, \Phi_H + \pi/2) \quad \text{and} \quad E(\Theta_E, \Phi_E + \pi/2) = \mu_2 H(\Theta_H, \Phi_H)
\]

and comprise the two characteristic states (3-D modes of propagation) of the EM field within the Earth. The two complex extremal values, together with the four rotation angles, comprise a complete set with eight degrees of freedom providing an equivalent description of $\mathbf{Z}$. The two intrinsic frames are not necessarily horizontal or mutually orthogonal. It can easily be shown that:

\[\Rightarrow \text{In the general case of 3-D geoelectric structures, } \Phi_E \neq \Phi_H \text{ and } \Theta_E \neq \Theta_H \neq 0^\circ.\]

\[\Rightarrow \text{In the limiting case of 2-D geoelectric structures, } \Phi_E = \Phi_H \text{ and } \Theta_E = \Theta_H = 0^\circ.\]

A detailed description of the analysis, together with theoretical and experimental comparisons with other acknowledged methods of spatial MT analysis, will be given elsewhere. It should be noted, however, that the physical meaning of the rotation angles $\Theta$ and $\Phi$ in Cartesian space is very similar to the meaning of angles $\beta$ and $\gamma$, respectively, of La Torraca et al. (1986).

Prior to engaging in any qualitative and quantitative interpretation, the experimental impedance tensors should be subjected to rigorous testing, in order to assess the dimensionality of the geoelectric structure. We consider this an essential step in the course of data analysis, because it will clearly indicate the appropriate strategy for optimal quantitative analysis and interpretation.

The rotation analysis provides direct dimensionality indicators by means of the dual inclination/ellipticity angles $\Theta_E$ and $\Theta_H$ and the skew angle $\alpha = \Phi_E - \Phi_H$. For dominant 2-D structures, $\Theta_E$ and $\Theta_H$ are small; when they become significant (e.g. $>10^\circ$), the existence of a 3-D structure can be inferred. Likewise, for dominant 2-D structures $\alpha \approx 0^\circ$, so that when it becomes observable or significant, the existence of 3-D structures may be suspected. Furthermore, when $\mu_1$ and $\mu_2$ do not differ significantly, a strong 1-D structural contribution is evident. It is important to note, however, that all the above parameters are sensitive to galvanic distortion of the electric field.

Additional, independent information about the spatial properties of the geoelectric structure can be obtained by means of the GDS Magnetic Transfer Functions (MTFs). The single-site MTFs used here consist of a pair of complex quantities $[A(\omega), B(\omega)]$, which map the horizontal magnetic field components $H_x$ and $H_y$ onto the vertical component $H_z$ according to the relationship $H_z(\omega) = A(\omega)H_x(\omega) + B(\omega)H_y(\omega)$. The most common method of presentation of MTFs is the induction vector, which comprises a magnitude and an azimuth that defines the normal to the strike of a local geoelectric lateral gradient, producing an anomalous concentration of current. Two such vectors are defined for vertical fields responding in-phase (real) and out-phase (imaginary) with the horizontal component with which the vertical field exhibits maximum correlation. If $x$ and $y$ are unit vectors in the intrinsic coordinate system, the real and imaginary induction vectors are defined, respectively, as:

\[G_r = \text{Re}(A)x + \text{Re}(B)y \quad \text{and} \quad G_i = \text{Im}(A)x + \text{Im}(B)y.\]

The induction-vector method of presentation has a simple interpretation when the structure is 2-D; in such circumstances the $G_r$ and $G_i$ will be parallel or anti-parallel and perpendicular to the lateral conductivity inhomogeneity (e.g. Rokityansky, 1982). In the case of 3-D geoelectric structures, the induction vectors define the normal to the local strike of the anomalous
concentration of current that produces the anomalous magnetic field and are oblique to each other; in environments producing very strong 3-D effects, $G_r$ and $G_i$ may even become orthogonal (e.g. Rokityansky, 1982). In this presentation we use the Parkinson convention, according to which the induction vectors point towards current concentrations (i.e. towards the conductive side of the inhomogeneous structure).

Results

The spatial analysis of the MTTI is summarized in Figs 5a–c, with graphical representations of the absolute value of the maximum characteristic state, i.e. the equation

$$|E(\Theta_E, \Phi_E)| = |\mu H(\Theta_{H}, \Phi_{H} + \pi/2)|$$

as viewed from above on the horizontal plane of the Cartesian experimental frame of reference. The maximum characteristic states (MCSs) are averaged over the respective depth intervals 0–2 km and 2–10 km. Depth here is the equivalent skin depth computed from the invariant impedance function $Z_r = 0.5(Z_{yx} - Z_{xy})$, which represents the trace of the MTTI and has the physical meaning of an equivalent (spatially smoothed) 1-D variation of resistivity with depth. In Figs 5a,b the MCSs are scaled with respect to the maximum, to allow a qualitative

Fig. 5a. Maximum states of the MTTI corresponding to depths of 0–2 km, normalized with respect to the maximum electric field. Domains A, B and C are defined in the text.
representation of the resistivity distribution over the survey area. Figure 5c is the same as Fig. 5b, but here the MCSs are unscaled, so as to facilitate the study of their polarization characteristics.

Considering Fig. 5a first, we note that the polarization characteristics of the MCSs indicate that the geometry of the shallow structure cannot be higher than 2-D, because the skew angles $\alpha$ and the dip/ellipticity angles $\Theta_E$ and $\Theta_H$ are very small or insignificant. The deeper structure, however, (Figs 5b,c), appears to contain weak 3-D inhomogeneities, as attested by the increasing ellipticities and observable skew angles. The most significant 3-D influences appear in the vicinity of Vulcania and Hellinika areas. In Figs 5a,b, the configuration of the MCSs separates the study area into three structural domains, which are indicated by different shading and annotated as A, B and C. Domains A and C (light grey) are defined by a dominant NW–SE strike of the maximum electric axis. Domain B (dark grey) is defined by a dominant N–S strike of the corresponding maximum electric axis and considerably higher resistivity than domains A and C.

The same conclusions can be reached from GDS observations. In Fig. 5d we present the average induction vectors for the deeper (2–10 km) part of the structure, where the depth of the MTF is taken to be equivalent to the skin depth of the invariant effective impedance function.
As can be seen, the magnitudes of the induction vectors are low; in general \( G < 0.3 \), with exception of sounding 862, where it reaches the value of 0.4. \( G_r \) and \( G_i \) are neither parallel nor anti-parallel; they form an angle which varies in the range 5–40°, with the larger values observable in the vicinity of Vulcania and Hellinika regions. These observations again indicate the existence of a weak 3-D structure, thus confirming the conclusions from the spatial analysis of the MITI. Domains A, B and C can be observed again in Fig. 5d, albeit with some differences compared to Figs 5a, b. Here, domains A and C are defined by real and imaginary induction vectors pointing to the SW. Domain B is defined by real induction vectors pointing to the SE and imaginary induction vectors pointing to the SW.

A qualitative interpretation was also made of the geoelectric structure, based on the MCS and induction vector data. As indicated in the foregoing analysis, the geoelectric structure underneath the survey area is at most 2-D (i.e. at domains A and C) or weakly 3-D (domain B). The term “weakly 3-D” implies that the corresponding electrical inhomogeneities do not generate strong 3-D effects in the response of the Earth. As a consequence, and for the purposes of this qualitative analysis, the structure can be considered approximately two dimensional. In the case of 2-D transversal geoelectric inhomogeneities, the physical definition of the MITI necessitates that the maximum electric field be tangential to the strike of maximum resistivity. This leads to the following simple rules (Swift, 1971):
Fig. 5d. Induction vectors corresponding to depths of 2–10 km. Domains A, B and C are defined in the text.

- In the conductive side of the inhomogeneity the maximum electric axis is parallel to the strike of the inhomogeneity and belongs to the Transverse Electric mode of propagation.
- In the resistive side of the inhomogeneity the maximum electric axis is normal to the strike and belongs to the Transverse Magnetic mode of propagation.
- The real and imaginary induction vectors will be normal to the strike of the inhomogeneity and point towards current concentrations.

Application of the above rules to the results of Figs 5a–d shows that:

1. Domains A and C are located on the relatively conductive side of a 2-D structure, which responds, approximately, in the Transverse Electric mode, with electric currents flowing in a NW–SE direction.
2. Domain B is located on the relatively resistive side of a 2-D structure, which responds, approximately, in the Transverse Magnetic mode, with electric currents flowing in an E–W direction, just off the south coast of Vulcania and Hellinika areas.

Thus, the spatial analysis of EM induction data in western Kos describes two conductive structures, which, in Fig. 4, are shown with light grey shading and comprise the major geoelectric structural features of the survey area.
Quantitative interpretation

The strategy for quantitative interpretation should be chosen very carefully because of the differences observed in the geoelectric structural characteristics of domains A, C and B. Note also that the observations are arranged along one traverse only, which is somewhat restrictive for proper implementation of 3-D modelling procedures. Moreover, the three-dimensionality of the structure appears to be rather weak. Both of these factors advise against using 3-D modelling, which will inevitably be crude, computationally expensive and time-consuming. Likewise, the implementation of 2-D modelling and/or inversion procedures would be difficult and should be applied with great caution. The complication here again arises from the fact that the EM responses of domains A and C appear to be generated by different structures from the response of domain B.

Given an MT response with either 2-D or 3-D characteristics, it is still considered acceptable in some cases to establish equivalent 1-D models of the geoelectric structure, provided that the results of the appropriate forward models are considered. The reliability of the 1-D models will be a function of the magnitude of 2-D and 3-D effects. In general, the dimensionality indicators considered in the foregoing do not recognize the existence of 1-D geoelectric structural components in the data; formally speaking, they can only detect the departure from a pure 2-D to a 3-D structure. This problem can partially be overcome by utilizing the Kao and Orr (1982) normalized dimensional indices, which facilitate a simultaneous assessment of the relative contribution of 1-D, 2-D and 3-D structural components to the constitution of the experimental MTTI (e.g. Beamish, 1986).

The analysis according to Kao and Orr (1982) is summarized in Fig. 6. For the sake of brevity, only the relative 1-D index (D1) is presented as a function of frequency along traverse T1. As can immediately be seen, a strong 1-D geoelectric structural component exists in the data, producing values of D1 in excess of 0.8 at most sites and over the greatest part of the recorded bandwidth. Only at frequencies $f < 0.2$ Hz, corresponding to the deepest part of the geoelectric
structure, does D1 assume lower values (0.6--0.8). At three sites however, 861, 850 and 854, D1 assumes low values (<0.8) for all f > 10 Hz. The results of Fig. 6 compare very well with the analysis presented in Figs 5a–d and establish the fact that discernible multi-dimensional electrical structures exist only at depths greater than a few km and also underneath sites 861, 850 and 854. It appears that the geoelectric structure underneath western Kos can be treated with 1-D interpretation tools, which are expected to yield reliable models of the first few km and a fair approximation of the deeper structure.

In order to confirm this important conclusion, we have also investigated the problem of the existence of 1-D solutions to the MT inverse problem, using unequivocal means of inference. These are based on the non-linear inverse theory of Parker (1980), who has shown that for a 1-D geoelectric structure generating the measured data, if any solution of the inverse 1-D problem exists at all, there must be one in the space of δ-positive functions that he calls D+. The existence of an inverse solution in D+ is therefore a necessary and sufficient condition for the existence of a 1-D geoelectric structure underneath the point of measurement. Parker and Whaler (1981) provided an algorithm to find this optimal solution from the experimental data, the convergence of which is, in itself, proof for the existence of 1-D structure. Since the experimental data are always subject to uncertainty (observational errors), the acceptability (convergence) of a solution can be measured by a χ² misfit. The problem of existence of a 1-D solution is reduced to finding a solution in D+ with the smallest possible misfit; if this solution is rejected, so will any other solution capable of reproducing the data.

The test for the existence of 1-D structure with D+ solutions was based on the invariant impedance function \( Z_i(\omega) \). For the sake of brevity we shall not attempt a detailed demonstration of the results, which appear to confirm the conclusions derived from Kao and Orr's D1 index (Fig. 6). In general, 1-D solutions exist for the invariant impedance of all observation sites, except 861, 850 and 854.

The rigorous dimensionality analysis indicates that for the most part, the geoelectric structure underneath the survey area can safely be interpreted with 1-D inversions. Here, we use the fully analytic and non-linear method of Parker (1980) and Parker and Whaler (1981), referred to procedure \( C^{2+} \). The method is generically related to D+ and yields continuous conductivity vs depth profiles.

THE CONDUCTIVITY STRUCTURE—DISCUSSION

The vertical resistivity structure as reconstructed from collation of 1-D \( C^{2+} \) models along traverse T1 can be studied in Figs 7a and 7b. The details of the shallow structure (0–2 km) are illustrated in Fig. 7a, while the deeper structure, from ground surface to the depth of 10 km, is shown in Fig. 7b.

We can distinguish two very conductive features underneath domain C, with resistivities lower than 4.5 Ωm. The first, shallower one, can be seen at depths 400–600 m; it stretches between the 6th km to the west and the 18th km to the east, thus underlying the greatest part of the surveyed area. The second, deeper feature, is found at 1000–1300 m and has smaller horizontal dimensions (about 5 km only, extending between kilometres 10 and 16). Both these conductive features can be attributed to the abundant presence of fluids and it is possible that they communicate via permeable conduits (Fig. 7a). One such conduit may be associated with a faulting structure, located approximately at kilometre 11 between sites 855 and 868. This fault does not exhibit any surface manifestation, but its existence is also supported by the analysis (modelling) of gravity observations along a traverse parallel to T1 (Lagios et al., 1994). Note also that according to some researchers (e.g. M. Fytikas, personal communication, 1993), the shallower conductor may instead comprise a layer with abundant presence of wet-clay minerals.
Fig. 7. (a) Vertical resistivity pseudosection to a depth of 2 km. (b) Vertical resistivity pseudosection to a depth of 10 km.

Particular attention should be given to a 10–50 Ωm conductor located beneath C and extending laterally between kilometres 10 and 16 (sites 855–866) and vertically between kilometres 7 to 10 (see Fig. 7b). The nature of this conductor cannot be established with MT data only. It may be part of an old magma chamber that now comprises brine-saturated igneous
rocks. This conductor appears to be sealed by an overlying resistive (>100 Ωm) formation, which does not allow it to communicate with the shallow structure.

Another interesting feature that can be observed in Fig. 7b is a well-conducting (<6 Ωm) domain extending laterally between kilometres 8 and 11 (sites 852 to 855) and vertically between kilometres 1 and 4. This is believed to represent geoelectrically the signatures of partially sealed fault structures related to the Vulcana Fault system. It also appears to be linked with the shallow conductors of domain C and, possibly, with the "old magma chamber". Additional conductive features of limited lateral extent can be observed at shallow depths, to the west of site 854 (west of kilometre 4). These might also be interpreted in terms of the Vulcana Fault system facilitating the circulation and concentration of fluids.

The fluids circulating through the fault structures, or concentrating in the shallow reservoirs, are believed to be of meteoric origin, as concluded from the geochemical studies of Lagios et al. (1994). This water infiltrates through the fault structures of the Vulcana Fault system and possibly mixes with geothermal fluids ascending from greater depths.

The reliable reconstruction of the geoelectric structure underneath domain B is inhibited by the non-existence of 1-D solutions for soundings 861, 850 and 854. As a consequence, detailed discussions will not be made for this domain. Note, however, that the very high resistivities (>400 Ωm) detected at great depths may be associated with the crystalline basement of the area. Some apparently conductive features observed at various depths beneath this domain are believed to be insignificant from a geothermal point of view, mainly because of their limited extent. These may either be inversion artifacts, or may be attributed to small concentrations of water within the rock formations of that part of the island.

We believe that the anomalous S-wave attenuation zone outlined in Figs 2 and 3 is associated with the shallow conductive zones detected by the MT data. Both should be attributed to domains of increased (geothermal) fluid concentration, occurring at depths shallower than 1500 m. It also appears that the concentration of fluids extends under the marine area to the south of western Kos, so that their full extent cannot be investigated with the MT method. Given, however, that these fluids accumulate above an older major volcanic centre, it appears possible that they may be characterized by elevated temperatures. The magnitude of the excess temperature cannot be inferred from the data in hand.

REFERENCES


