ΦΥΣΙΚΗ. — **Determination of the epicenter of an earthquake,** *by P. Varotsos - K. Alexopoulos - K. Nomicos - G. Papaioanou - M. Lazaridou-Varotsou - E. Dologlou-Revelioti* *. Ἀνεκοινώθη ὑπὸ τοῦ Ἀκαδημαϊκοῦ κ. Καίσαρος Ἀλεξοπούλου.

A B S T R A C T

Transient changes of the electrotelluric field have been detected at stations far apart. They occur simultaneously at all stations around 7 hours before each earthquake. The intensity is found to decrease with epicentral distance, approximatively, with a 1/r - law. Using such a connection and the values of the intensity, epicenters can be located with a minimisation procedure. They agree in a satisfactory way with those determined by seismological methods.

In the preceding paper [**1**] the latest experimental results were described on transient changes of the electrotelluric field that precede each earthquake (EQ) by about 7 hours. From observations at a single station it is not possible to obtain any information as to the epicenters. This can be done however by studying, simultaneous electric signals (ES) at a number of stations.

Changes of the electric field propagate in the earth with a velocity of the order of the velocity of the light. Signals therefore should appear (almost) at the same time even for stations installed far apart. In an older experiment with two stations such coincident signals were actually detected [**2**]. Later a two day experiment with three stations about 45 km apart was repeated [**2**].

In a more recent experiment 5 stations operated during 9 days continuously; they were situated at Nemea (●), Alfiousa (×, near Olympia), Astakos (Δ) and Zakynthos (+) [**2**]. All EQ ($M_s \geqslant 3.2$) gave simultaneous signals at least at some of the stations. Some examples are given in Ref. 2 from which the epicenters were determined with the help of apollonian circles. The present paper gives a fuller account of these results.

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The stregth of a signal can be expressed by :

$$I_{max} = \frac{\Delta V_{max}}{R}$$

where ΔV_{max} is the largest change of the measured telluric voltage (on a 50 m line) and R the resistance between the measuring electrodes[1]. The values of I_{max} of the signals measured during this experiment were given in Table I of Ref. 1. For any given earthquake they were found to decrease approximatively with epicentral distance. Assuming that I_{max} is proportional to 1/r the comparison of the intensities I_{max} collected for each pair (i, j) of stations leads to a determination of the epicenter. It is achieved by a computer minimisation procedure according to :

$$\sum_{i,j} (I_{max,i}\, r_i - I_{max,j}\, r_j)^2 = \min$$

where r_i and r_j are the unknown epicentral distances. The epicentral distance r_i of each station is expressed in terms of the known coordinates (x_i, y_i) of each station and the unknown coordinates (x_0, y_0) of the epicenter and hence the computer minimisation procedure leads to the determination of (x_0, y_0). This has been done for the earthquakes given in Table I of the present paper. For reasons explained in Ref. 1 we have not used the Zakynthos measurements for earthquakes Sept. 29th 20 : 11 GMT and Oct. 1st 11 : 23 GMT. On the other hand the measurements I = 0.08 μA and 0.23 μA at the Glyfada station (■, near Athens) were available for the earthquakes Oct. 1st 11 : 23 and Oct. 2rd 01 : 52 and hence were used in the computation.

In the table we give the computed coordinates of the epicenters along with those determined from seismological data ; they are given in the sequence EW and NS whereas the origin has been arbitrarily selected to be at Athens. The results are shown in Figs 1 to 4 in which the computed epicenter and the seismologically determined epicenter are indicated with an asterisk and a circle respectively. The sites of the stations have also been inserted. One sees that the errors (i. e. the distance Δr between the calculated and the seismological epicenter) are

1. In case of inhomogenuities see the previous paper.

TABLE 1.

Determination of epicenters from electric signals. **(1981)**

EARTHQUAKE				Calculated epicenter	Δr (km)	Number of Stations
Date	Time	M_s	Epicenter (km)			
27 - 9	19 : 58	3. 9	—150, + 135	—207, + 79 or —198, + 85	80 or 70	3
27 - 9	21 : 45	3. 9	— 25, + 48	— 75, — 57	116	3
29 - 9	20 : 11	3. 9	— 27, + 40	—148, + 51	121	3
30 - 9	20 : 52	3. 3	—120, — 28	—131, — 30	11	4
1 - 10	11 : 23	3. 8	—245, — 65	—157, — 26	96	3
1 - 10	21 : 43	3. 8	— 85, + 35	— 97, + 15	23	4
2 - 10	01 : 52	3. 2	— 92, + 45	—100, + 50	10	4

The epicenters of the fourth column have been calculated by using some recordings of the network of the Observatory of Athens.

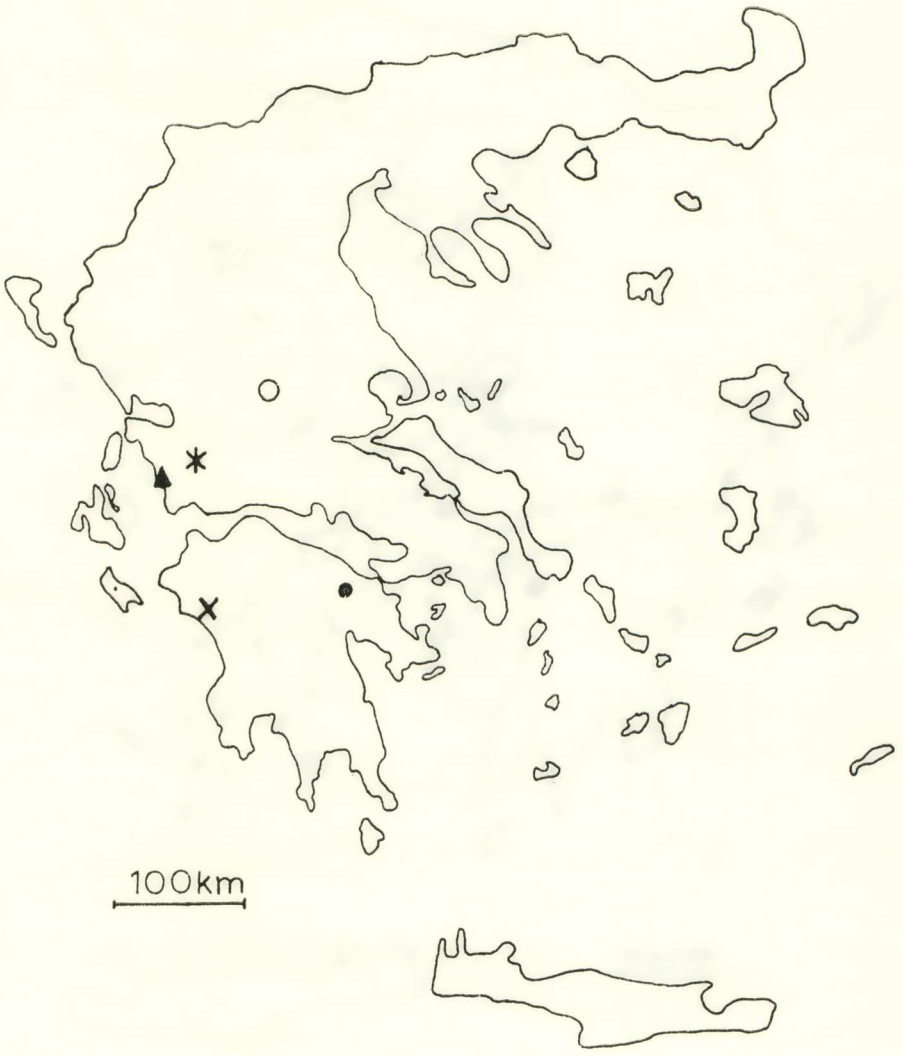

Fig. 1. Computed epicenter from 3 stations for earthquake Sept. 27th 1981 19 : 58 GMT.

Fig. 2. Computed epicenter from 3 stations for earthquake Sept. 29th 1981 20 : 11 GMT.

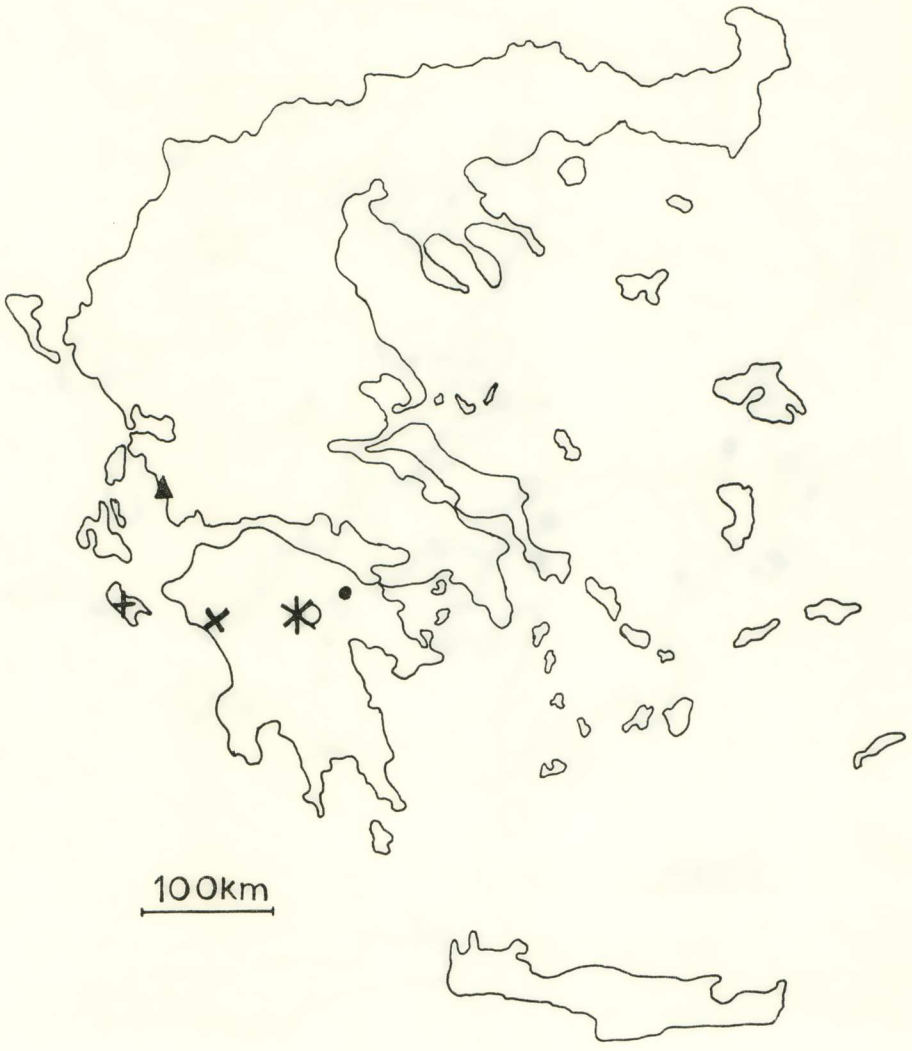

Fig. 3. Computed epicenter from 4 stations for earthquake Sept. 30th 1981 20:52 GMT.

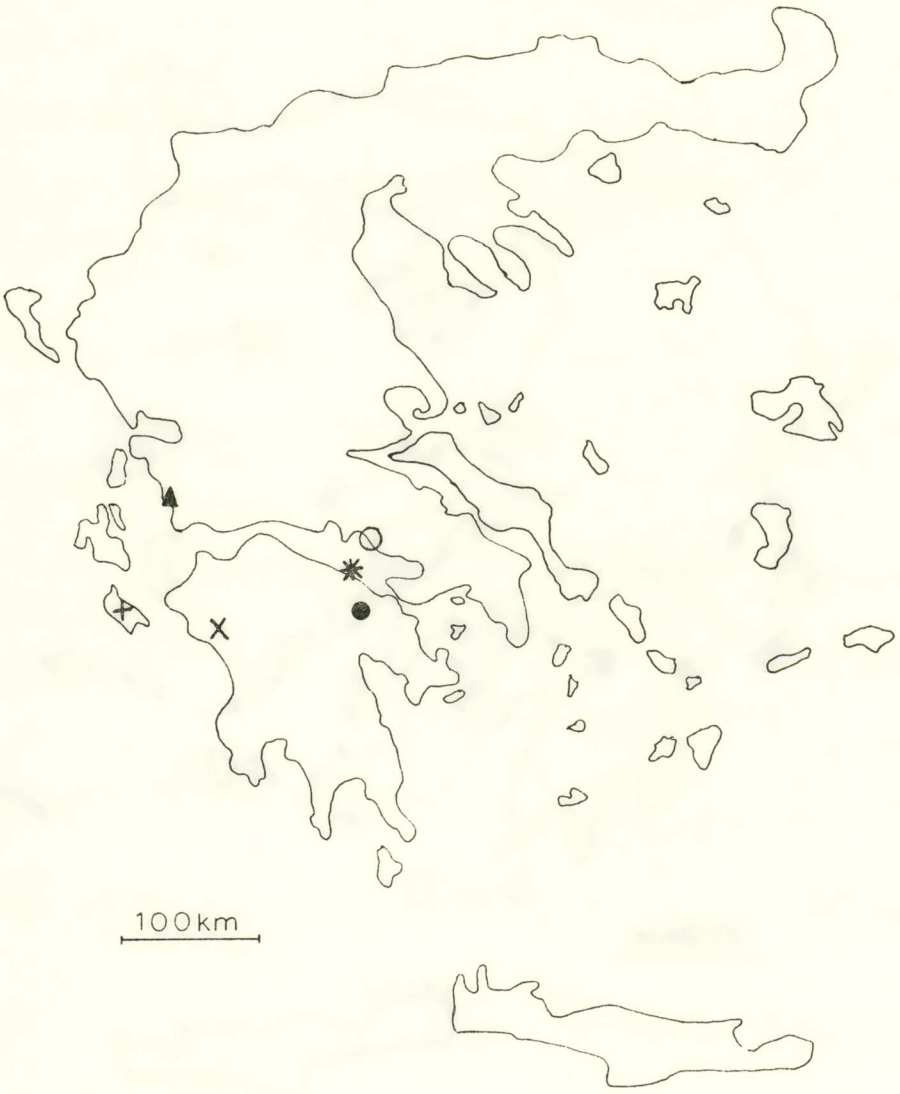

Fig. 4. Computed epicenter from 4 stations for earthquake Oct. 1st 1981 21:43 GMT.

smaller for the cases where the measurements from a larger number (e. g. 4) of stations could be used. Further the errors are smaller when the epicenter happens to lie within or near the triangle or polygon formed by the stations. Even in cases with large errors, as in Fig. 2, the method succeeds in giving correctly the general direction of the epicenter in relation of the sites of the stations. Values of Δr smaller than 30 km are fortuitous. The accuracy is expected to have been much better if stronger EQ had happened to occur within or near to our network. In some cases the signals at a certain station could not be determined because of intense noise. If a network of more stations was installed the signals of stronger earthquakes ($M > 4$) would be collected by larger number of stations and thus insure a good determination of the epicenter.

The satisfactory determination of epicenters exclusively from measurements of electrotelluric signals is a further proof of a true correlation between ES and EQ. This would have been completely impossible if the two types of events were not related.

ΠΕΡΙΛΗΨΙΣ

Πρόσκαιροι μεταβολαὶ τοῦ γηίνου ἠλεκτρικοῦ πεδίου ἔχουν παρατηρηθῆ ταυτοχρόνως εἰς σταθμοὺς ἀπέχοντας ἀλλήλων περίπου κατὰ 80 km. Ἐμφανίζονται περίπου 7 ὥρας πρὸ ἑκάστου σεισμοῦ. Ἡ ἔντασις τοῦ ἠλεκτρικοῦ σήματος ἐλαττοῦται μετὰ τῆς ἐπικεντρικῆς ἀποστάσεως περίπου μὲ ἕνα νόμον $1/r$. Χρησιμοποιοῦντες αὐτὴν τὴν σχέσιν καὶ τὰς πειραματικὰς τιμὰς τῆς ἐντάσεως τῶν διαφόρων σταθμῶν προσδιορίζεται τὸ ἐπίκεντρον διὰ τῆς μεθόδου τῆς ἐλαχιστοποιήσεως. Τὰ ὑπολογιζόμενα ἐπίκεντρα συμφωνοῦν ἱκανοποιητικῶς μὲ τὰ σεισμολογικῶς προσδιοριζόμενα.

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