ΦΥΣΙΚΗ.— **Determination of the epicenter of inpending earthquakes from precursor changes of the telluric curent,** *by P. Varotsos - K. Alexopoulos - K. Nomicos - G. Papaioannou - M. Varotsou and E. Revelioti - Dologlou* *. Ἀνεκοινώθη ὑπὸ τοῦ Ἀκαδημαϊκοῦ κ. Καίσαρος Ἀλεξοπούλου.

ABSTRACT

Telluric precursor electric signals of earthquakes have been measured at stations far apart. For a given earthquake they arrive at all stations within experimental error simultaneously. The intensity is found to decrease with epicentral distance, approximatively with a 1/r law.

Using a 1/r law and the values of the intensity of the signals from three stations the epicenters can be located in a satisfactory way.

In a preceeding article [**1**] transient changes of the telluric current were described; they occur about 7 hours before an earthquake (EQ). The strength of these signals was found to increase with the magnitude of the earthquakes (for a given epicentral distance), so that it can serve as a measure of the intensity of the EQ at the measuring station; it can not give, however, information as to the epicentral distance. The present paper describes a method by which the site of the epicenter can be determined from measurements at three or more stations.

Changes of the electric field propagate in homogeneous materials with a velocity of the order of the velocity of light and therefore should give simultaneous signals even at stations far apart. Figure 1 reproduces the signals from two practically simultaneous eartquakes, each of 4.2 R, collected at Vrachneika (near Patras) and Strava (near Korinth) at distances about 120 and 230 km from the epicenter near Zakynthos. In this first experiment the signal started at both stations within 2 - 3 minutes, which is anyhow the accuracy with which the start of a signal can be determined on the recording chart. In this example it happened that the

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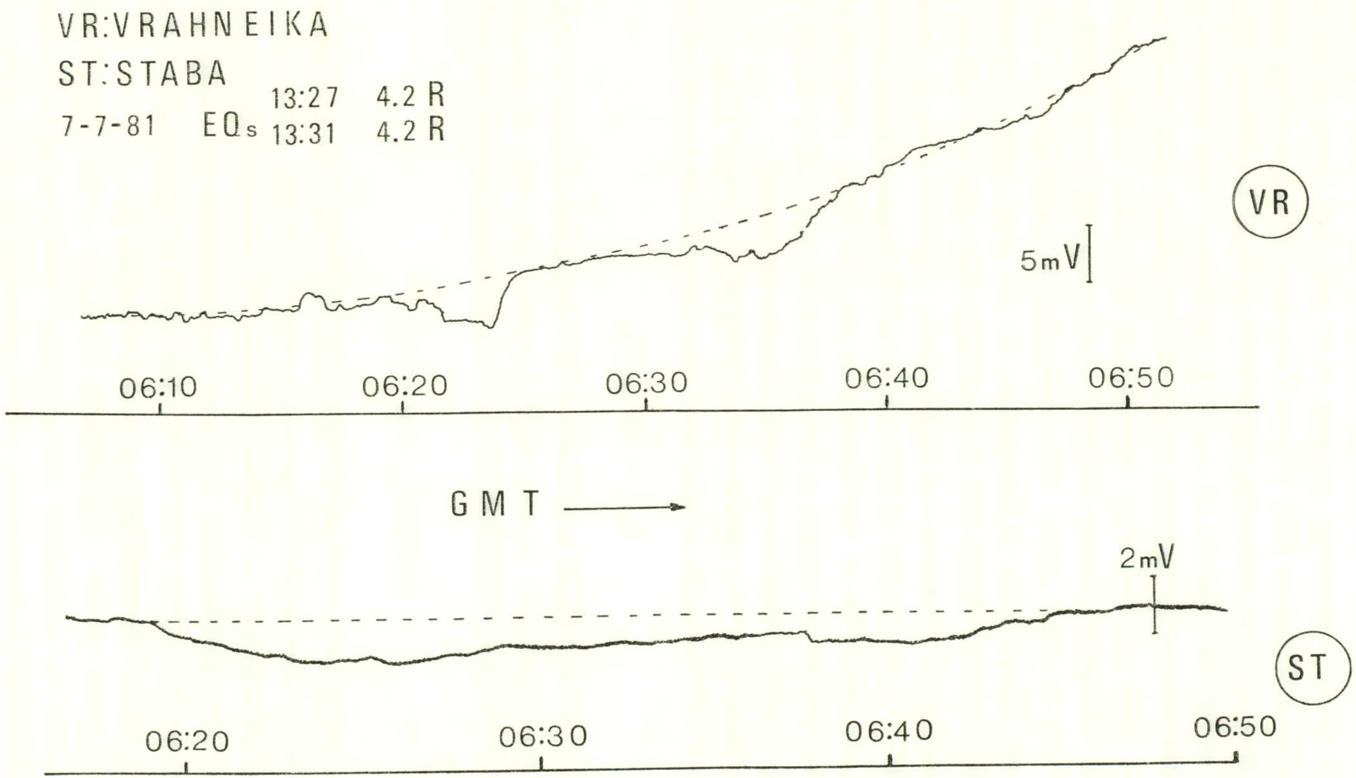

Fig. 1. Simultaneous signals detected at Vrachneika and Strava. Two Earthquakes (4.2 R) occured on Sept. 7th, 13:27 and 13:31 GMT. Note the different chart velocity.

continuous background was shifting, probably due to rain. In a second experiment three measuring stations were installed about 45 km from each other at Xilokastron (XI) Thisvi (TH, near Thiva) and St. Isidoros (SI, near Megara) thus encircling the seismic area of the Alkyon Islands. Figure 2 shows the signals of a 2.8 R earthquake that occured near Thisvi collected simultaneously at the three stations. In a recent 9-day experiment four stations were installed at Zakynthos (ZAK), Alfiousa (ALF, near Olympia), Nemea (NEM) and Astakos (AST) at distances of about 100 km to each other. They intended to surround, as well as possible, the seismic area of Zakynthos. At the same time, a station at Glyfada (GLY, near Athens) was continuously operating (but only on one line). A number of simultaneous signals were collected (Fig. 3). Signals from weaker EQ could only be detected from the most adjacent stations. In most cases the form of the signals is not the same, although they usually start and finish within a few minutes of each other. Strong signals appear within experimental error exactly coincident.

The intensity of the signals for a given EQ is found to depend on the epicentral distance. As a measure of the intensity we use the quantity

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

where ΔV_{max} is the largest amplitude of the registered change of voltage and R is the resistance of the earth between the pair of measuring electrodes. When the signal appears on both electrode - pairs (NS, EW) I is given by

$$\left\{(\Delta V/R)^2_{EW} + (\Delta V/R)^2_{NS}\right\}^{1/2}$$

The errors are usually between 30 and 50%. In Table I we give preliminary results of these experiments and in Fig. 4 we plot values of I_{max} collected simultaneously at various stations in function of epicentral distance for four earthquakes. We have only included measured values which have errors smaller than 100%. The general appearance of Fig. 4 speaks for a signal intensity that is proportional to 1/r.

If one knows the law that connects intensity of the signal to epicentral distance, the coincident measurements from a number of station can be used for the determination of the epicenter. In view of the rela-

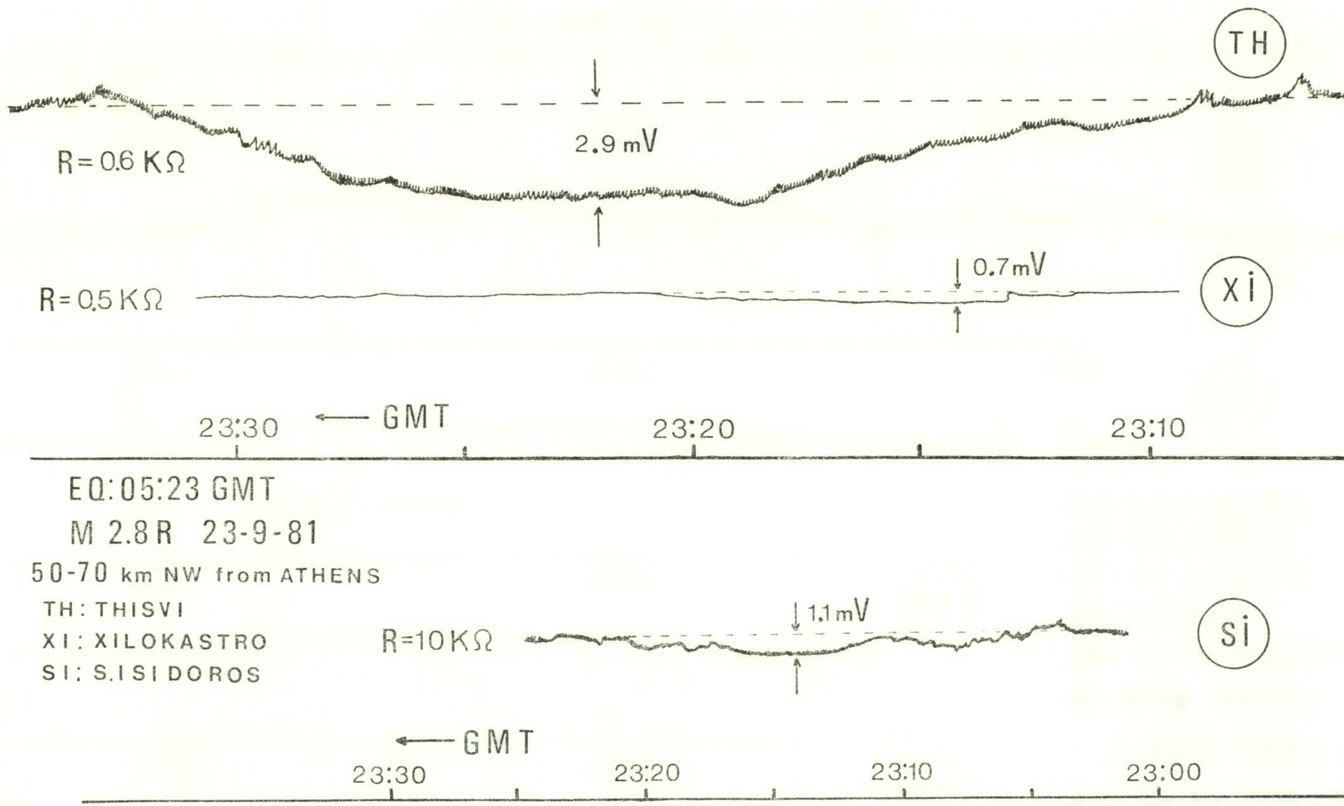

Fig. 2. Simultaneous signals at Thisvi, Xylokastron and S. Isidoros. An earthquake (2.8 R) occured on Sept. 23rd 05 : 23 GMT.

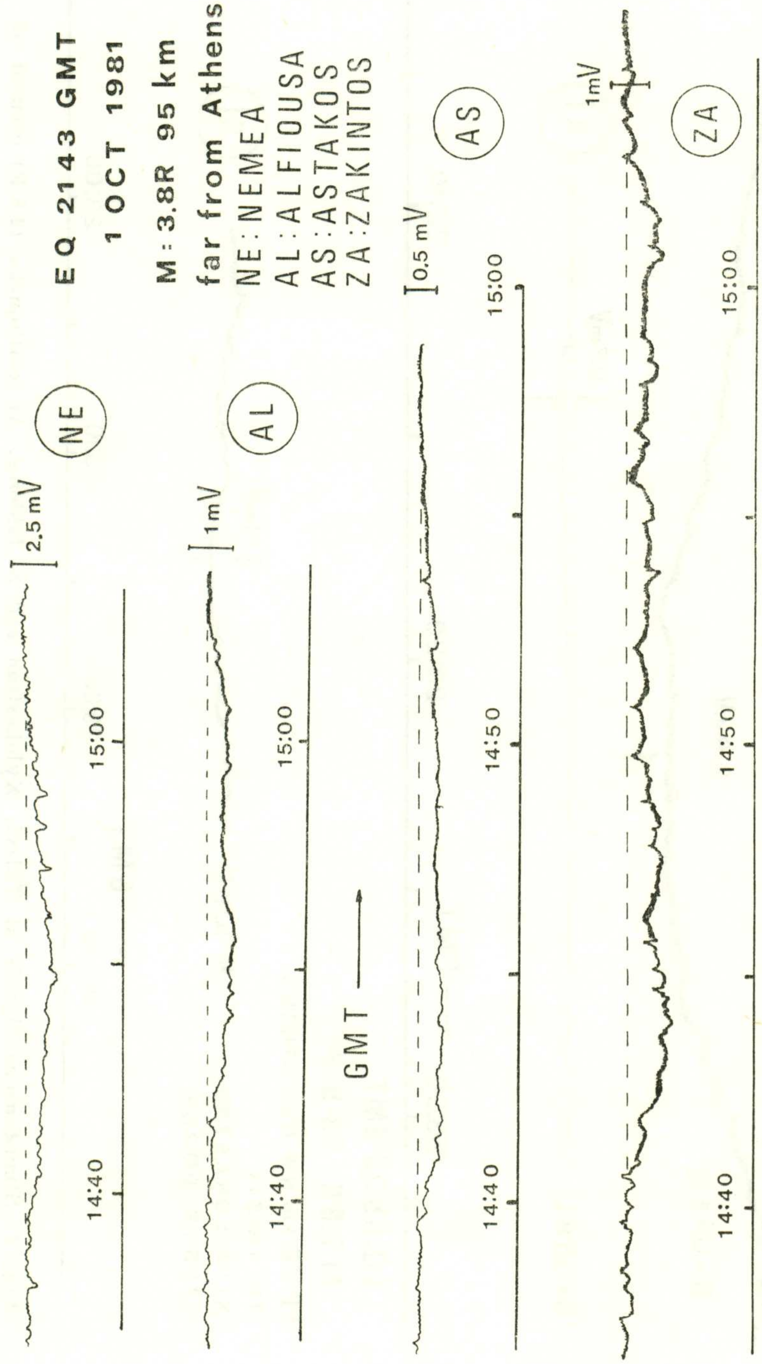

Fig. 3. Simultaneous signals at remote stations. An earthquake (3.8 R) occured on Oct. 1st, 21:43 GMT, 95 km far from Athens probably near Distomo.

TABLE I

Table simultaneous signals.

	Earthquake		Signal intensity (μA)				Error of epicentral distance (km)	Number of stations
	Date and time	Magnitude	AST	ALF	NEM	ZAK		
a	Sept. 27th 19 : 58	3.9	1.25	0.22	0.24	—	65	3
b	Oct. 1st 21 : 43	3.8	0.17	0.18 ± 100 %	0.83	0.11	35 - 45	4
c	Sept. 30th 20 : 52	3.3	0.11	0.29	0.37	0.11	10	4
d	Oct. 2nd 01 : 52	3.2	0.24	0.23 (Glyfada)	0 42	0.09	10	4

tively large errors of I_{max}, we have used the simple assumption that it is exactly proportional to 1/r. From the data I_i/I_j of each pair (i, j) of stations one can draw an Apollonius circle. All such circles should intersect at the same point.

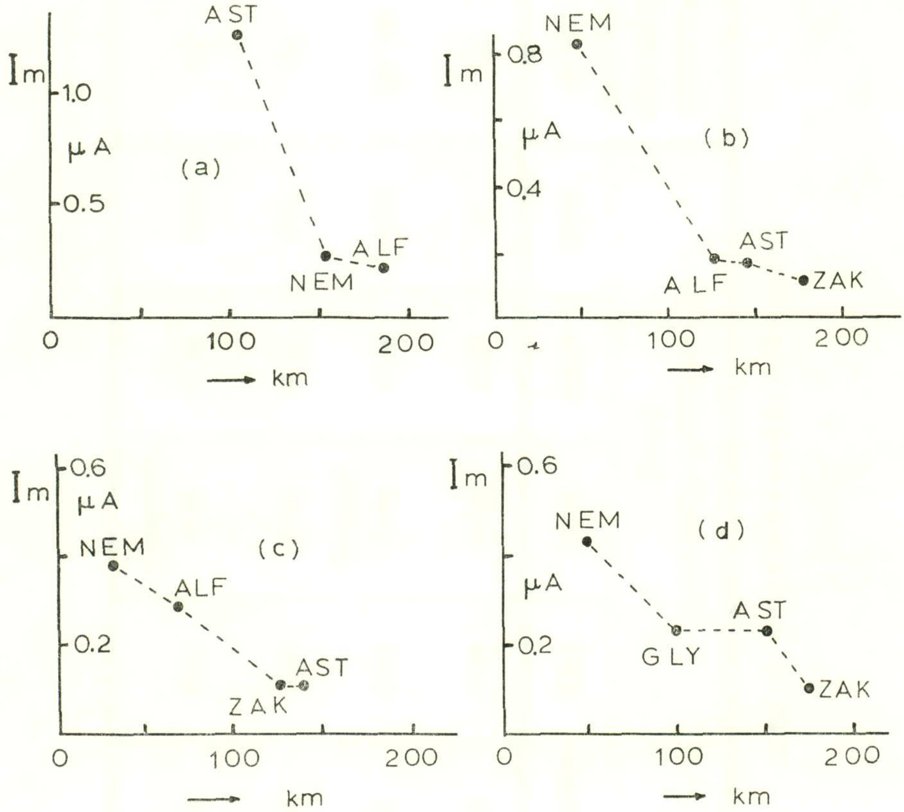

Fig. 4. Maximum signal strength in function of epicentral distance. See Table I.

In Fig. 5 the signals of Fig. 3 can define four circles; they do not intercept at a single point although this could be achieved by slightly changing the values of the intensities within experimental error. We have determined the probable points of intersection for each pair of circles and the center of weight of these points. The result is marked with an asterisk. A small circle (o) shows the epicenter as

Fig. 5. Apollonian circles for earthquake (b).

Fig. 6. Apollonian circles for earthquake (a).

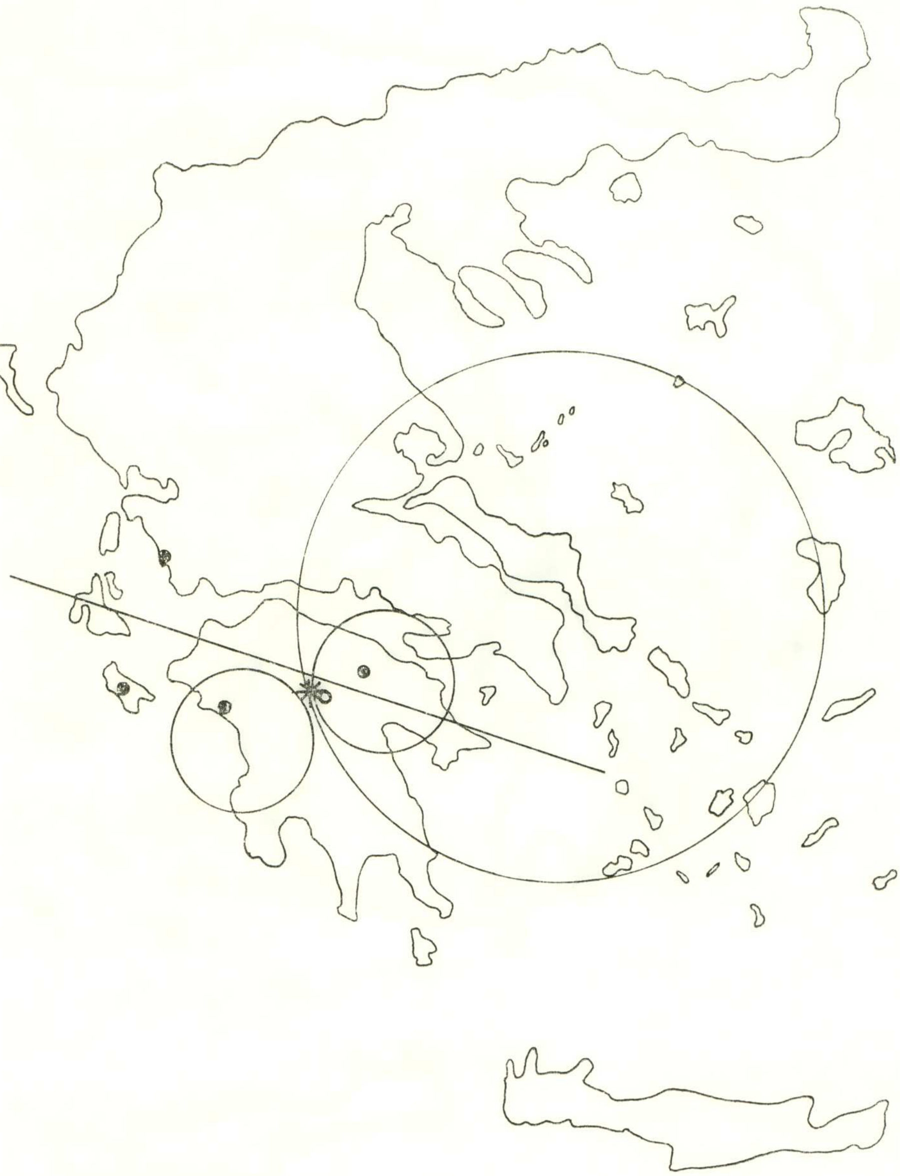

Fig. 7. Apollonian circles for earthquake (c).

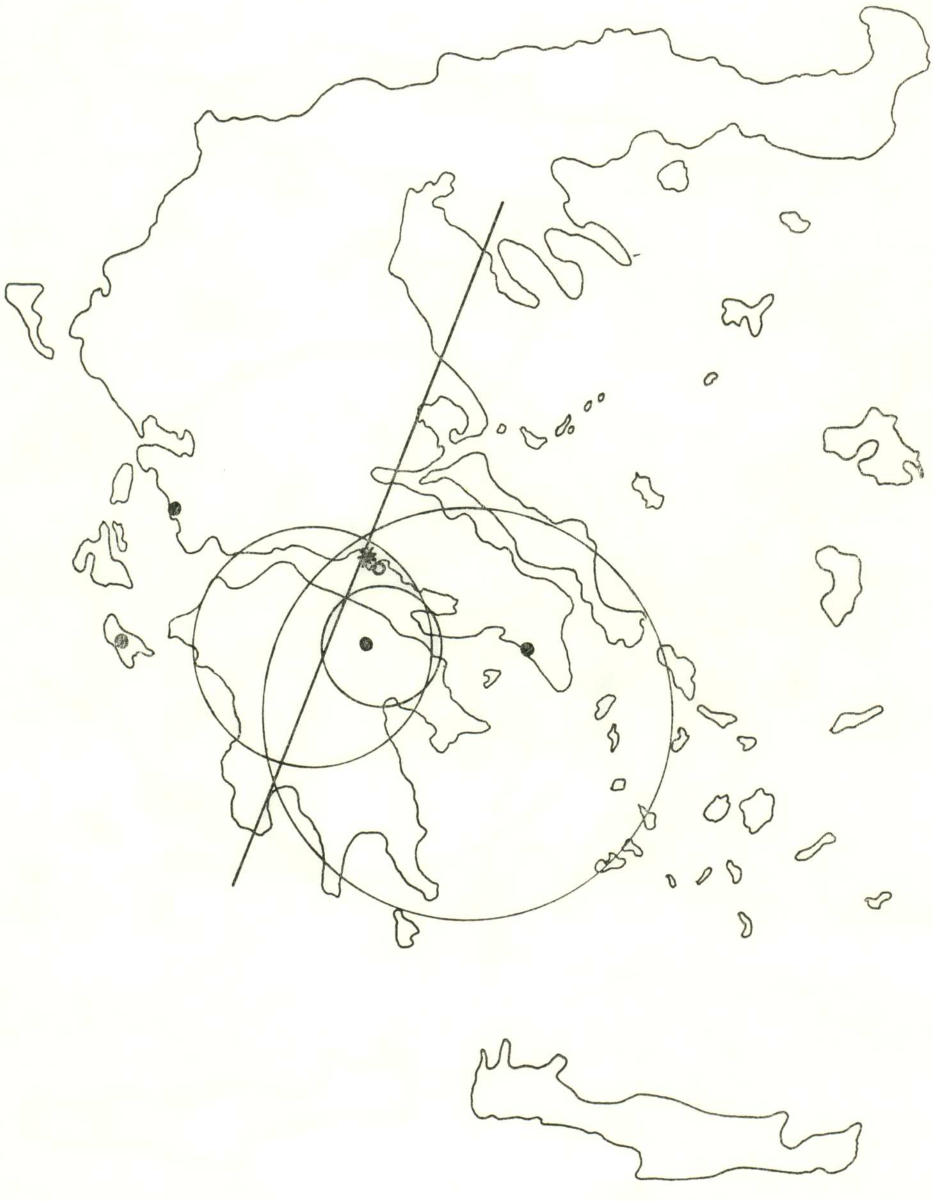

Fig. 8. Apollonian circles for earthquake (d).

determined with seismographic methods. The distance Δr between the asterisk and the circle is about 20 km.

The data of Table I have been used to draw the Apollonians of other earthquakes. Fig. 6 displays the result of earthquake (a). As the intensities at two stations are practically equal one circle degenerates into a straight line. The combination of the line with the circle gives an hypothetical intersection at the point marked with an asterisk. The true epicenter is localed to the north east by 65 km. It lies far outside the triangle formed by the three stations and therefore as expected the error Δr is larger. An exceedingly good intersection of the circles is achieved in Fig. 7. The error is 10 km. In Fig. 8 two circles and the straight line give intersections that are grouped in two groups. By considering the weight due to the smaller circles one could decide on the north-eastern grouping, thus determining an asterisk that lies within 10 km from the epicenter. The other grouping of intersections gives $\Delta r = 140$ km.

From the figures we see that the errors Δr depend on the number of stations and on the distance of the epicenter from the center of the polygon described by the sites of the stations. Values of Δr smaller than 30 km must be fortuitous. The accuracy is expected to have been appreciably better if stronger EQ had happened to occur, during the experiment because the errors in ΔV_{max} would have been much smaller.

The present paper constitutes a further proof that ES and EQ are correlated phenomena. Epicenters were determined with a satisfactory accuracy solely from the intensities of the ES. This would be absolutely impossible if the two type of events were independent.

We must acknowledge the help given us by the Army for field measurements at four rural stations.

ΠΕΡΙΛΗΨΙΣ

Ἐντὸς τῶν γεωρευμάτων ὑπάρχουν σήματα προαναγγέλλοντα σεισμούς. Τὰ σήματα ἑνὸς σεισμοῦ ἐμφανίζονται ταυτοχρόνως ἀκόμη καὶ εἰς σταθμοὺς ἀπομεμακρυσμένους ἀλλήλων. Ἡ ἔντασις τοῦ σήματος ἐλαττοῦται μὲ τὴν ἐπικεντρικὴν ἀπόστασιν καὶ εἶναι περίπου ἀντιστρόφως ἀνάλογος αὐτῆς.

Ἐὰν δεχθῶμεν τοιαύτην σχέσιν, τότε τὸ ἐπίκεντρον ἑνὸς σεισμοῦ εἶναι δυνατὸν νὰ προσδιορισθῆ ἐκ τῆς ἐντάσεως τοῦ σήματος εἰς τρεῖς σταθμούς. Αἱ προκύπτουσαι διαφοραὶ ἀπὸ τὰ πραγματικὰ ἐπίκεντρα εἶναι ἱκανοποιητικαί.

REFERENCES

1. P. Varotsos - K. Alexopoulos and K. Nomicos, Praktika of the Athens Academy, Session of November 26th 1981.