ΠΡΑΚΤΙΚΑ ΤΗΣ ΑΚΑΔΗΜΙΑΣ ΑΘΗΝΩΝ

ΣΥΝΕΔΡΙΑ ΤΗΣ 31ΗΣ ΟΚΤΩΒΡΙΟΥ 1985

ΠΡΟΕΔΡΙΑ ΛΟΥΚΑ ΜΟΥΣΟΥΛΟΥ

ΣΕΙΣΜΟΛΟΓΙΑ.— **Spreading of felt shaking of recent interplate earthquakes of the Hellenic arc in Africa (Egypt and Libya) evidences the reliability of older seismic data,** by *Angelos G. Galanopoulos* *.

ABSTRACT

Several new intensity data well authenticated prove beyond any doubt that the abnormal area of felt shaking observed repeatedly in interplate earthquakes of the Hellenic arc is a real fact indicating the larger seismic conductivity of the subducted plate of Africa compared with that of the overlying plate of Eurasia. The data clearly suggest the existence of a colder slab along the Benioff zone of the Hellenic arc. This additional evidence for the existence of the cold slab lends independent support to the entire concept of the subduction of the Eastern Mediterranean plate.

INTRODUCTION

Several great earthquakes in the collision zone of the converging plates of Africa and Eurasia occurred in the two last centuries have been associated with extra large areas of felt shaking (Sieberg, 1932). The extra large felt areas observed during the great earthquakes of 1856, October 12 (35 1/2° N, 26°E), 1886, August 27 (37° N, 21 1/4° E), 1903, August 11 (36° N, 23° E) and 1926, june 26 (36 1/2° N, 27 1/2° E), termed by A. Sieberg "Levantinische Riesenbeben", have been attributed to the large magnitude (M_s =

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8 1/4) and intermediate focal depth (h = 100 km) of the shocks (Gutenberg and Richter, 1954).

Similar extra large areas of felt shaking have been assigned by A. Sieberg (1932) to the earthquakes of 1810, February 16 (35 1/2° N, 25° E), 1846 March 28 (36°N, 25°E) and 1863, April 22 (36 1/2° N, 28°E). A common feature of the enormous felt areas of the above cited earthquakes is their southward spreading as far as Egypt (1810, 1846, 1856, 1863, 1886, 1903, 1926) and eventually as far as Cyrenaica (1863, 1903, 1926), Malta (1846, 1856, 1886, 1903, 1926) and Palestine (1846, 1856, 1863, 1926). A northward elongation of the shaken area as far as Gallipoli, Broussa, Constantinople (1856, 1863, 1886, 1903) and Trieste (1886, 1903), and not rarely an extension of it to the west as far as Naples, Italy (1810, 1856, 1886, 1903, 1926) and Sicily (1846, 1856, 1903, 1926) are also observed (see Figures 1, 2, 3 and 4).

The abnormal felt areas of the 19th century earthquakes compare well with those of 1903 and 1926 earthquakes to which Ch. Richter (1958) assigned a surface wave magnitude 8.3. On the ground investigation of the effects of 1926 earthquake by A. Sieberg (1932) leaves little room for doubt that the above cited 19th century earthquakes had indeed an abnormal felt shaking in comparison particularly with that (Io = XI; r = 650 km) of the 8.3 magnitude earthquake (s. Fig. 5) in San Francisco, California (1906, April 18). N. Ambraseys' view (1981) that the 1810 earthquake occurred on 29 January and the effects of three separate events, having occurred about the same period in Southern Italy, in Northern Africa and in the Aegean, have been erroneously attributed to the Aegean earthquake is not substantiated by a simple reference (Stürmer, 1810), considering that the 1810 earthquake was also felt in Cyprus and the well authenticated felt area of more recent Aegean earthquakes (1903, 1926) shows nearly the same pattern.

The incongruous differences between observed and theoretical slip rates of Eurasia and Africa, amounting to more than an order of magnitude (Ambraseys, 1981) are rather due to the underestimation of the magnitude he has assigned to the large and great earthquakes of the two last centuries than to the assumed accomodation of the plate motions predominantly by aseismic creep to such a large amount.

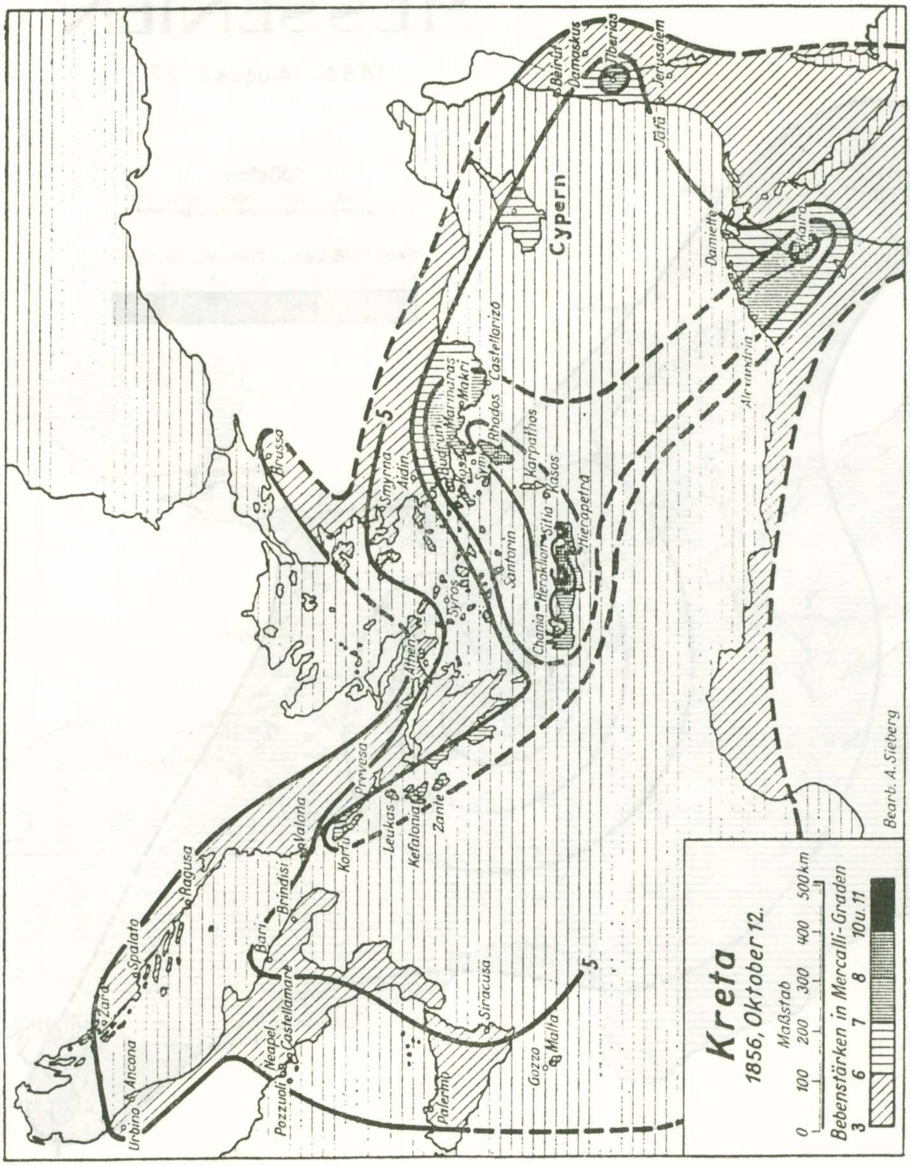

Fig. 1. The area shaken by the great earthquake of Heraklion, Crete, 1856, after A. Sieberg (1932).

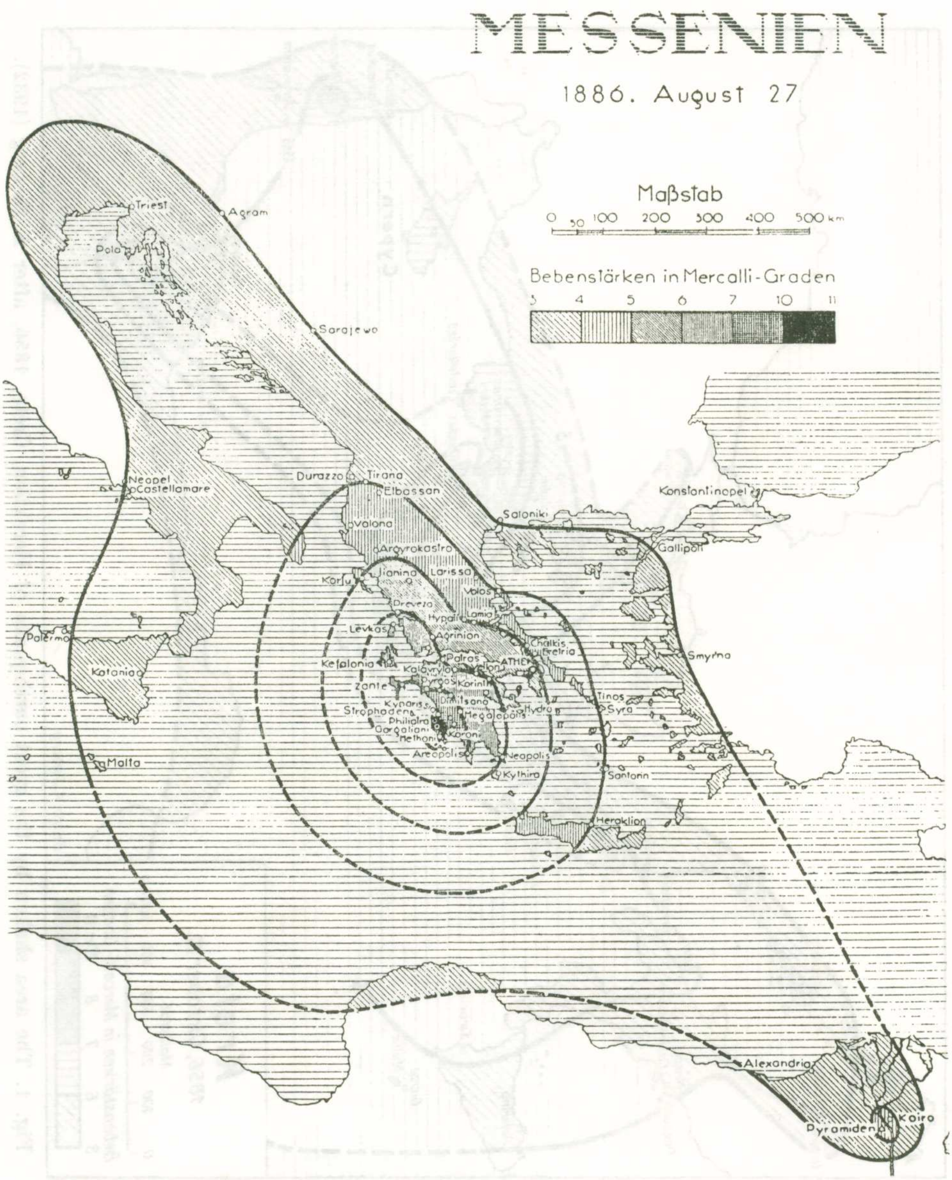

Fig. 2. The area shaken by the great earthquake of Philiatra, Messinia, 1886, after A. Galanopoulos (1941).

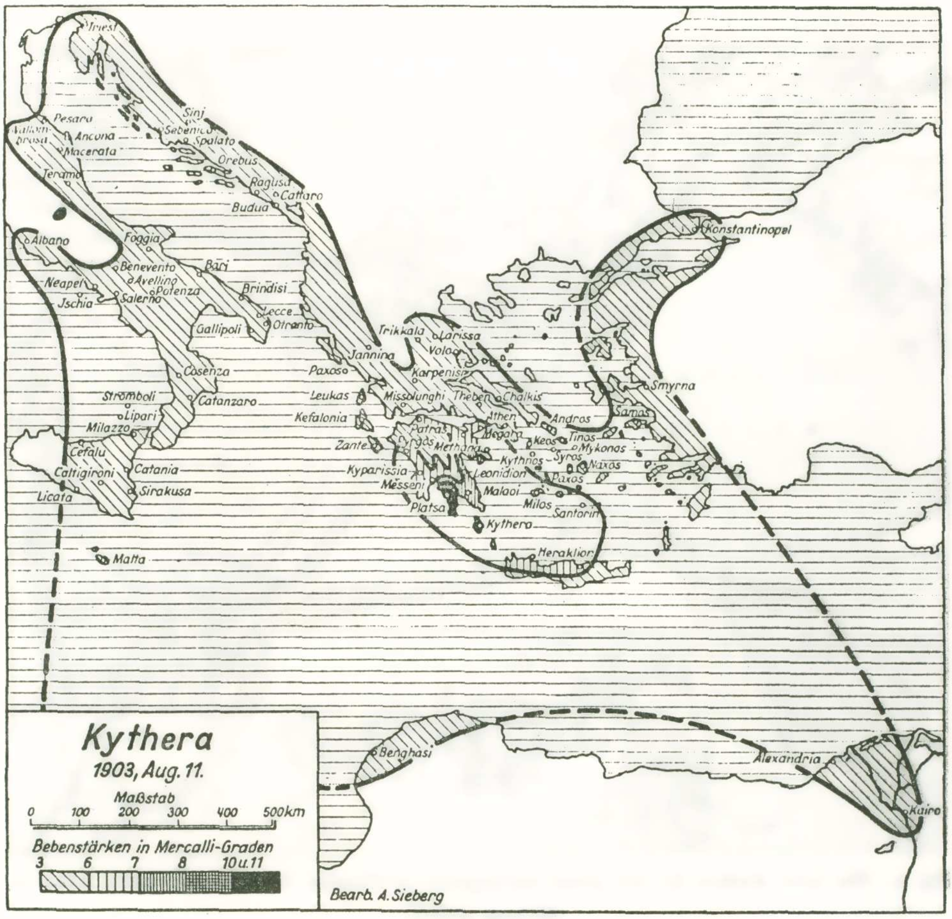

Fig. 3. The area shaken by the great earthquake of Cythera, Aegean, 1903, after A. Sieberg (1932).

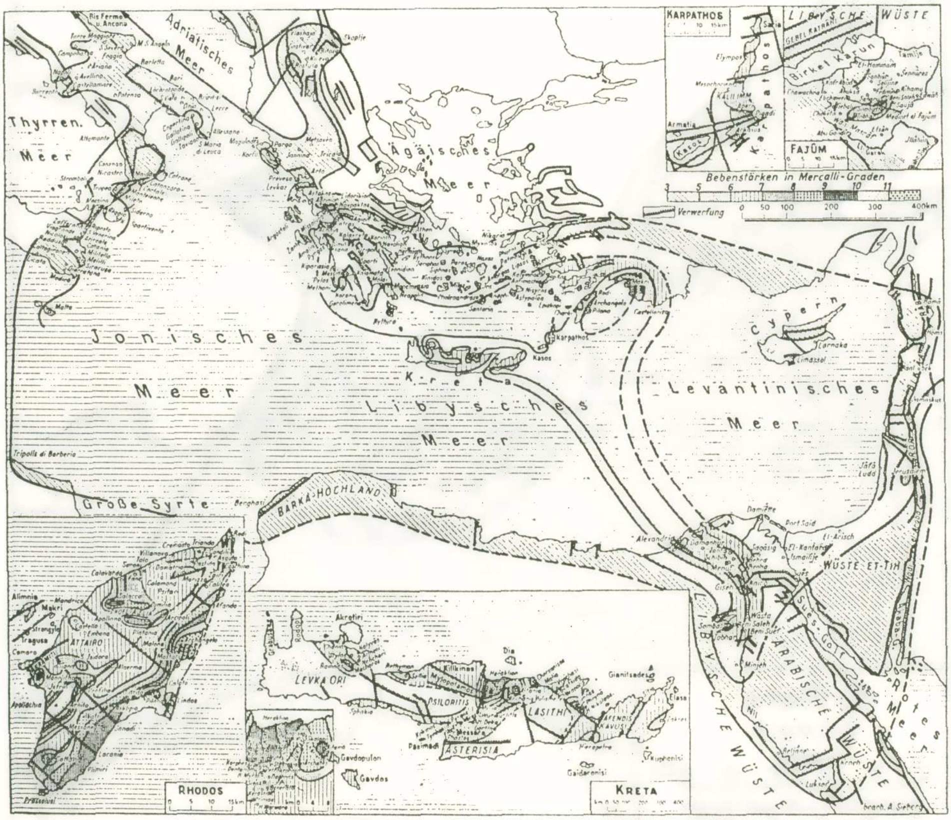

Fig. 4. The area shaken by the great earthquake of Rhodos, Dodecanese, 1926, after A. Sieberg (1932).

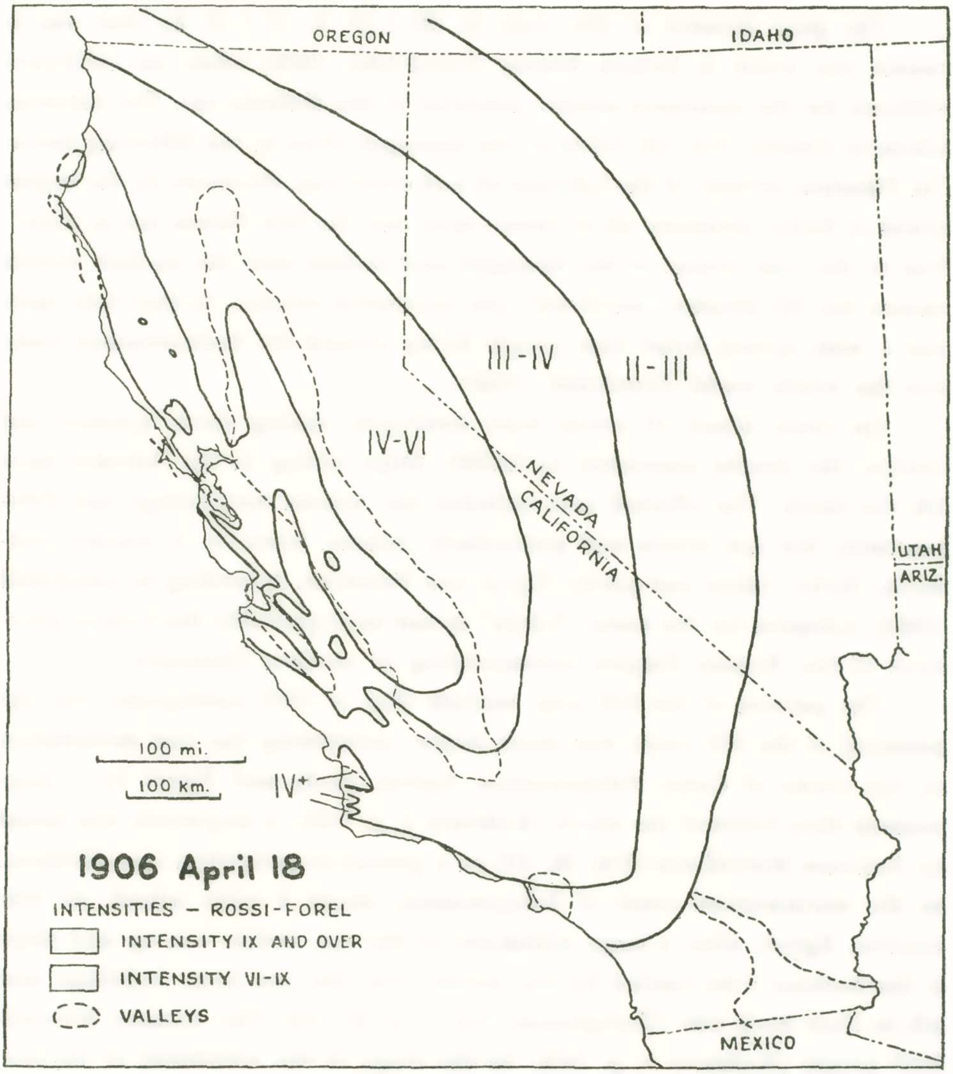

Fig. 5. The area shaken by the California earthquake of April 18, 1906, after Ch. Richter (1958).

AN OLDER CASE

The great disaster of 365, July 21 (35 1/2° N, 23 1/2° E) that was to remain the worst in human history (Goodchild, 1966) offers an additional evidence for the enormous seismic potential of the Hellenic arc. The historian Libanius (Oratio, Vol. 18) refers to the damaged cities in the following terms: "In Palestine several, of the Libyans all and every one. Prostrate lie the largest towns of Sicily, prostrate all of Greece save one; the fair Nicaea lies in ruins". Due to the vast extent of the damaged and shaken area the ancient writers termed the 365 disaster "universal" (per universum orbem). At that time there was a wide spread belief that people living around the Mediterranean basin was the whole world (Goodchild, 1966).

On Crete island 10 towns were destroyed, among them Knossos and Gortys; the deaths amounted to 50.000. Ships sailing in the Adriatic have felt the shock. The affected area included the Aegean Archipelago and Peloponnesus, but not Attica and particularly Athens; however, it reached Dalmatia, Sicity, Libya and partly Egypt and Palestine. According to Goodchild (1966), Libanius by the name "Libya" meant most probably the Lybian provinces of the Roman Empire corresponding to modern Cyrenaica.

The pattern of the felt area reminds that of 1903 earthquake, but the potential of the 365 event was much larger, considering the vast devastation on the coasts of Crete, Peloponnesus, Epirus, Sicily and Egypt by a huge tsunami that followed the shock (Kedrinos 1, p. 549). A shipwreck was found by Amianus Marcellinus (Vol. 26, 10) on a ground investigation near Methoni, on the southwestern coast of Peloponnesus, about 2 miles inland. In Alexandria, Egypt, after a large withdrawl of the sea, waters run up and ships in the harbour were carried by sea waves over the sea front buildings and left in their back side (Theophanes, Vol. 1, p. 87, 10). The tsunami drowned 5000 people (Kedrinos 1, p. 549). In the stage of the withdrawl of the sea, ships in the Adriatic touched for a little while the sea bottom (Theophanes, Vol. 1, p. 87, 10).

The most impressive description of the tsunami occurrence has been given by the historian Amianus Marcellinus. R. G. Goodchild (1966) quotes his records as follows: "For a little while before sunrise there was a terrible earthquake, preceded by incessant and furious lightning. The sea was driven backwards, so as to recede from the land, and the very depths were uncovered, so that many marine animals were left sticking in the mud . . . Many ships were stranded on the dry shore, while people straggled about the shoal water and picked up fishes and things of that kind in their hands. In another quarter the waves, as if raging against the violence with which they had been driven back, rose, and swelling over the boiling shallow, beat upon the island and

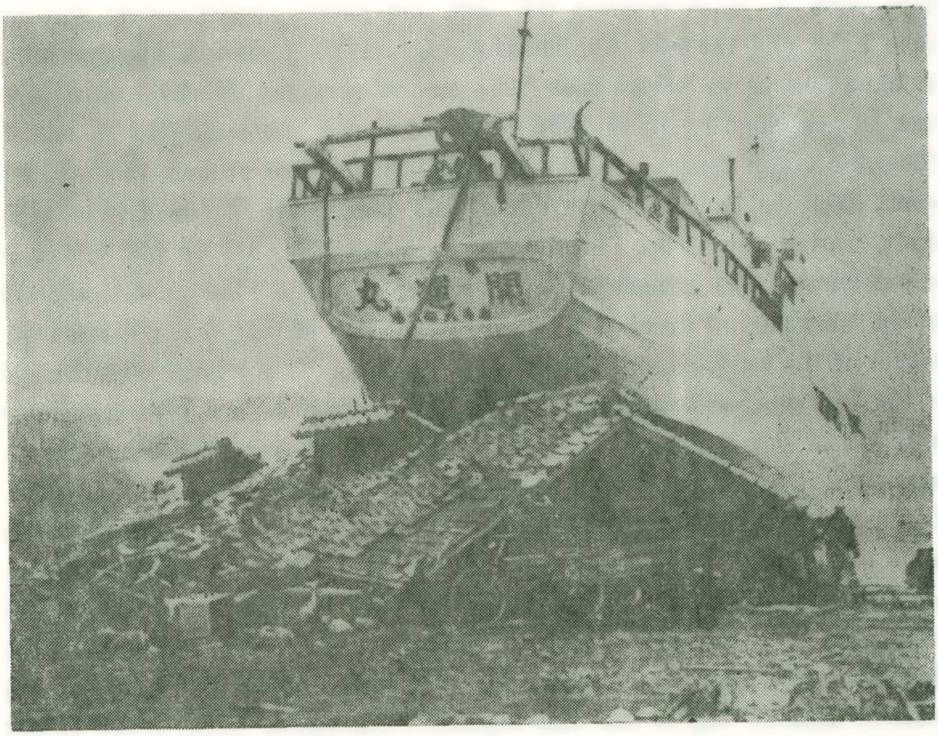

Fig. 6. At Ofunato on the Sanriku coast of Japan, a tsunami that began on the continental shelf on the coast of Chile tossed this fishing boat on top of a house. The tsunami took 22 hours to make the 11, 500 mile journey at an average speed of 500 miles per hour. The earthquake (magnitude 8.5) occurred on May 22, 1960 (Photo by A. Shimbun, courtesy of K. Ishida, reproduced from James M. Gere and Haresh C Shah, 1984).

the extended coasts wherever they encountered them . . . Even ships were shallowed up in the furius currents of the returning tide, and were seen to sink when the fury of the sea was exhausted. Other vessels of great size were driven on shore by the violence of the wind, and cast upon the housetops as happened in Alexandia (s. Fig. 6) and some were even driven two miles inland of which we ourselves saw one in Laconia, near the town of Mothone, which was lying and rotting where it had been driven".

There is geomorphological evidence (Y. and J. Thommeret et al., 1981) that around 1550 yr. BP a sudden uplift of about 9m took place in the southwestern coast of Crete. As one might see in the reproduction of Thommeret's Fig. 1 (numbered here as Fig. 7), "the average direction of the upheaval slope (axis A - A) is oriented NE - SW and passes approximately through Cape Krios and the islet Ay. Théodori (Loc. 12)". Y. and J. Thommeret et al. have reasons to believe that "The zone of maximal upheaval must have been at sea, slightly off the SW corner of Crete". According to Y. and J. Thommeret and their associates "The upheaval dated around 1550 yr. BP seems likely to have occurred, during the earthquake in 438 A.D. or, less likely, during one of the following earthquakes: 365, 374 or 448 A.D.". It was deduced "that altogether the upheaval of about 1550 yr. BP affected all the west part of Crete as a whole block". Considering that a sudden upheaval of the reported size should have triggered a very large tsunami and of the four suggested agents only the 365 earthquake has been associated with a vast devastation by a tsunami observed all over the eastern Mediterranean, it seems imperative to assign the 9m upheaval to the 365 event. This extraordinary event and the distribution pattern of the tsunami affects make the location 35.3° N, 25.7° E asigned to the 365 earthquake (Comninakis and Papazachos, 1982) invalid. The wide - spread effects of the 365 event present an additional evidence that the southwestern segment of the Hellenic arc is capable of producing great earthquakes ($M_s \geqslant 7\ 3/4$), and eventual aseismic slip in the said segment (Ambraseys, 1981) is not indeed large enough to prevent the occurrence, in due time, of extraordinary events.

An interplate earthquake is generated by elastic rebound motion of the plates. It is worth noting that the uplift of the western part of Crete is dying out from the southwestern to the northeastern coast of Crete, in the postulated direction of plunging of the underthrusting African plate. This coincidence does not seem to be circumstantional. It might be due to the buoyancy exerted by the asthenosphere on the downward plunging northern marging, i.e the frontal part of the African plate. The mechanism of tsunamigenic earthquakes is itself understood to often involve thrust faulting with a resultant crustal uplift generated by upper plate rebound in a plate to plate interaction area (Plafker, 1979). In this area, the Mediterranean minor plate

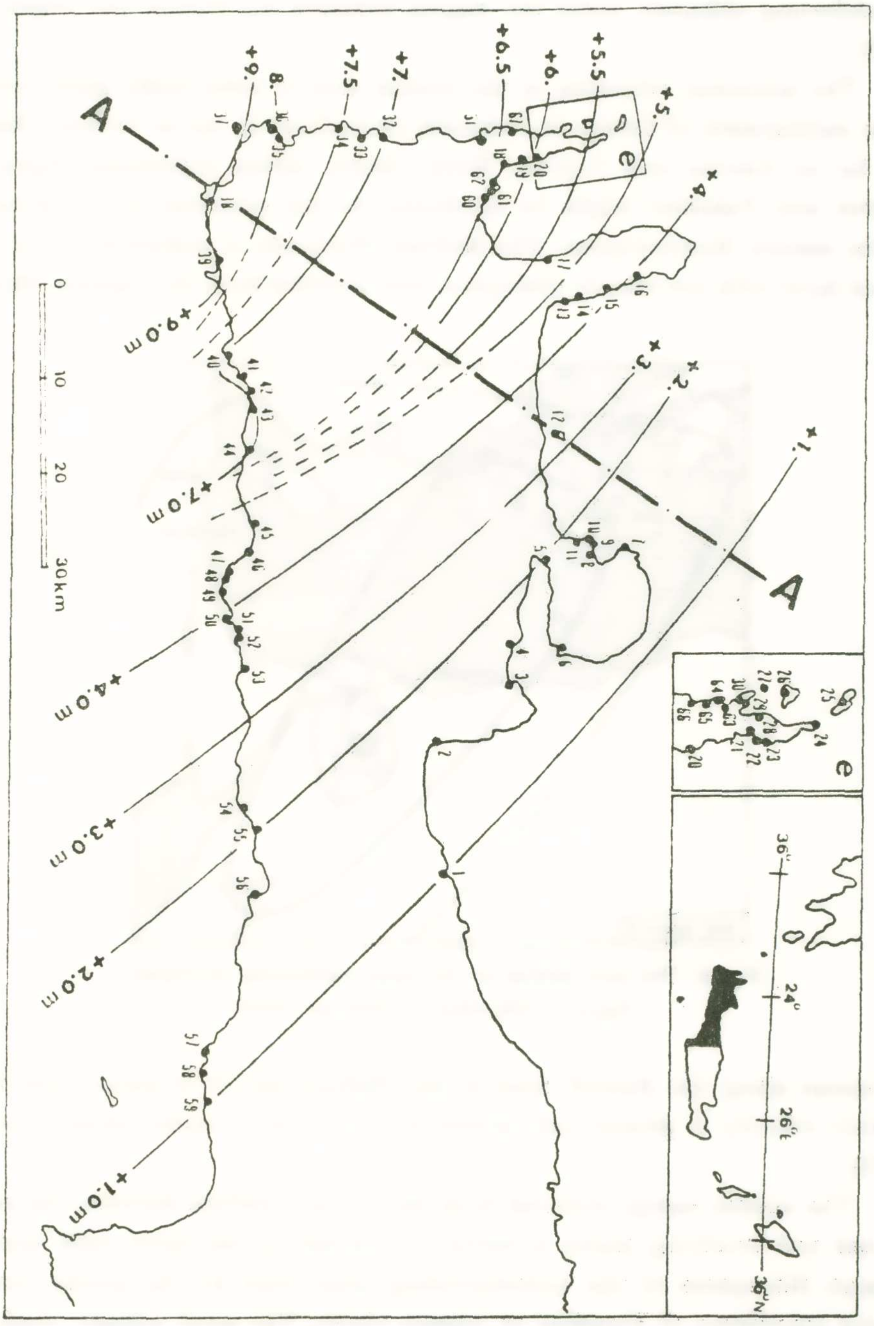

Fig. 7. Reproduction of Thommeret's Fig. 1. Localities (site numbers) and contours of elevation of the uppermost Holocene marine marks relative to present sea level in western Crete. The highest elevations (+9 m) were measured near the south - western corner of the island. A - A inticates the average direction of the uplift gradient, after Y. and J. Thommeret et al. (1981).

is subducting obliquely under the Aegean subplate (Le Pichon and Angelier, 1979).

The abnormal extension of the shaken area of some really great inter-plate earthquakes of Greece in Dalmatia (sometimes as far as Trieste), Italy (as far as Ancona and Naples), Sicily, Malta, Africa (Cyrenaica, Egypt), Cyprus and Palestine might be attributed to the semi-oceanic lithosphere of the eastern Mediterranean. The Hellenic Peninsula is underlaid by an inclined layer with low seismic absorption that intrudes from the eastern Mediterranean along the Benioff zone of the Hellenic arc. It is known that the seismic velocity is greater and absorption is lower in cooler rocks (Uyeda, 1978).

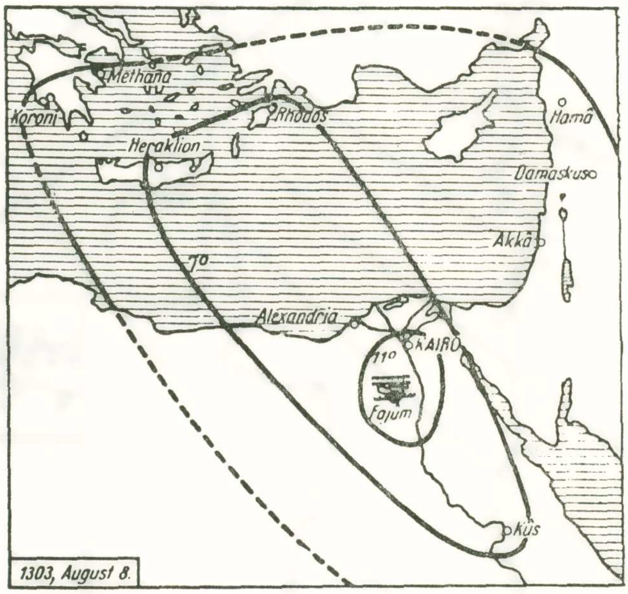

Fig. 8. The area shaken by the large earthquake of Fajum, Egypt, 1303, after A. Sieberg (1932).

The seismic energy radiated from the contact surface between the subducted and overlying plates is better conducted by the more rigid semi-oceanic lithosphere of the underthrusting plate than by the purely continental lithosphere of Eurasian or Aegean plates. The good seismic conductivity of the eastern Mediterranean lithosphere is asserted by the shaken area (s. Fig. 8 and 9) of two earthquakes in Fajum (1303, August 8) and

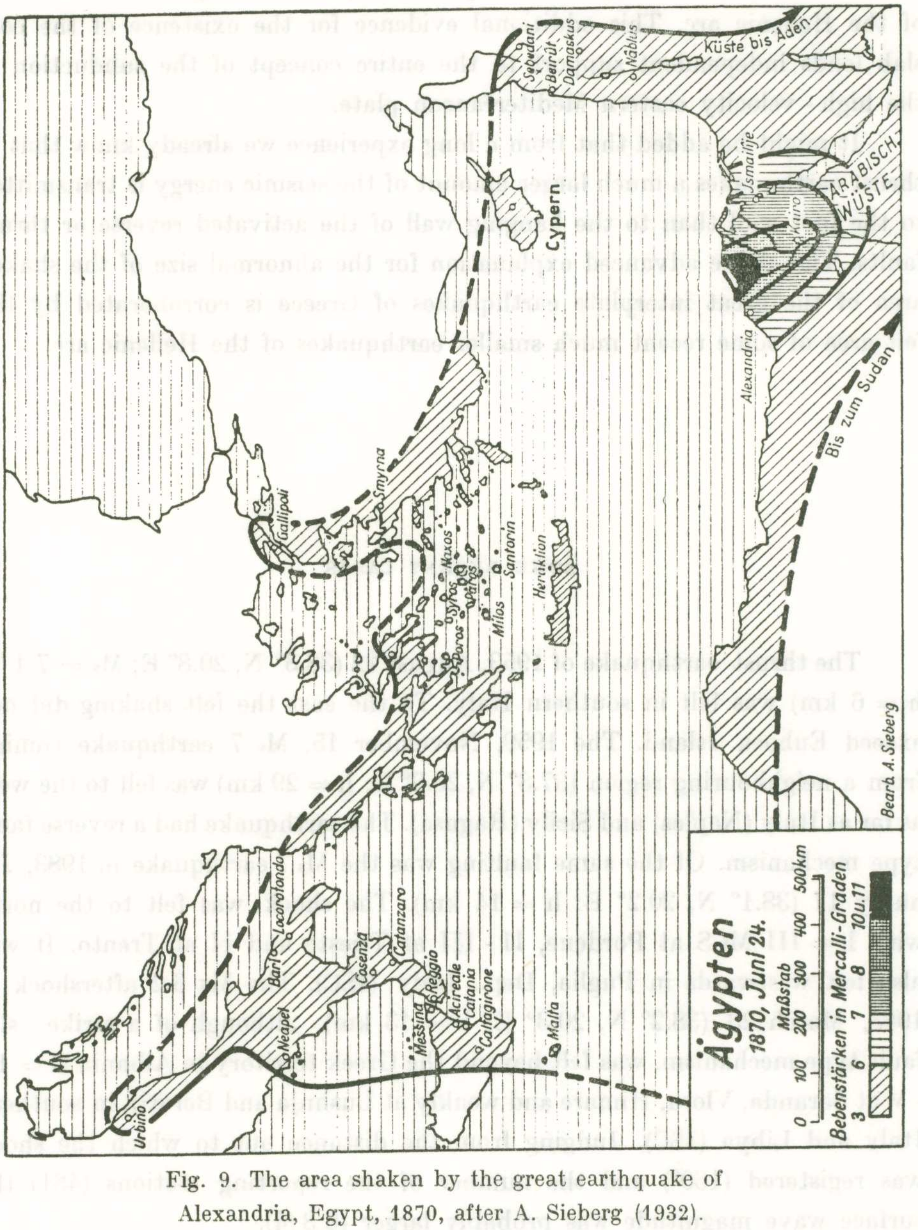

Fig. 9. The area shaken by the great earthquake of Alexandria, Egypt, 1870, after A. Sieberg (1932).

Alexandria, Egypt (1870, June 24). These observations clearly suggest the existence of a descending colder high velocity slab along the Benioff zone of the Hellenic arc. This additional evidence for the existence of the cold slab lends independent support to the entire concept of the subduction of the high - velocity eastern Mediterranean plate.

It might be added that from a long experience we already know that in thrust earthquakes a much larger amount of the seismic energy is transmitted to the foot wall than to the hanging wall of the activated reverse or thrust faults. The above advanced explanation for the abnormal size of the shaken area of the great interplate earthquakes of Greece is corroborated by the felt area of some recent much smaller earthquakes of the Hellenic arc.

SOME RECENT CASES

The thrust earthquake of 1953, August 12 (38.3° N, 20.8° E; $M_s = 7\ 1/4$; $h = 6$ km) was felt in southern Italy. To the east the felt shaking did not exceed Euboea Island. The 1959, November 15, M_s 7 earthquake coming from a neighbouring region (37.8° N, 20.9° E; $h = 29$ km) was felt to the west as far as Italy (Naples) and Sicily (Ragusa). The earthquake had a reverse fault type mechanism. Of the same faulting was the M_s 7 earthquake in 1983, January 17 (38.1° N, 20.2° E; $h = 14$ km). The shock was felt to the north with I = III MCS at Pordene, II - III at Trieste and II at Trento. It was also felt westwards in Puglia, Dep., Italy (ISC). The Ms 6.2 aftershock in 1983, March 23 (38.2° N, 20.3° E; $h = 13$ km), although of a strike - slip fault type mechanism, was felt beyond the Greek territory in Albania (I = IV - V at Saranda, Vlora, Himare and weakly at Lushnja and Berati), in southern Italy and Libya (ISC). Judging from the distance out to which the shock was registered (160°) and the number of the reporting stations (481) the surface wave magnitude was probably larger (6 3/4).

In any way, the shaken area of recent earthquakes of M_s 6 1/4 to 7 1/4 in the Ionian Sea was certainly abnormal, in comparison with that of the normal earthquake of 1956, July 9, in the Aegean (36.7° N, 25.9° E; $M_s = 7\ 1/2$;

h = 10 km). The area of felt shaking of the Aegean (Amorgos) earthquake in 1956 did not surpase 200.000 km^2.

The two intermediate shocks of 1962, August 28 (37.8° N, 22.9° E; Ms = 6 3/4; h = 95 km) and 1972, September 13 (38.0° N, 22.4° E; M_s = 6 1/2; h = 75 km), both of reverse fault type mechanism (Drakopoulos and Delibasis, 1982), were felt in southern Italy and the second reached reportedly as far as Malta. On the contrary, the normal earthquake of 1981, February 24, in a neighbouring region (38.2° N, 22.9° E; M_s = 6 3/4; h = 18 km) was felt from southern Yugoslavia to Crete and Rhodes and from Cephalonia to Chios, i.e. in a relatively limited area.

On March 19, 1983, a M_b 5.7 earthquake in the southern coast of Crete (35.0° N, 25.3° E), coming from a focal depth of 59 km, was felt as far as Egypt (ISC). If the felt shaking of I = IV MM at Alexandria and Cairo was reported 170 years ago or so (Stürmer, 1810), it would probably enter in a chronicle as a separate event from that observed in the whole island of Crete (Io = V - VI), considering the mediocre intensity of the earthquake. Although the shaking was registered by 462 stations as far as 156°, the empirically calibrated surface wave magnitude could not be higher than 6 1/2 (MOS: M_b 6.3; UPP: M_s 6.2).

The interplate earthquake of 1957, April 25 (36.4° N, 28.7° E;M_s = 7 1/4; h = 80 km), of a reverse fault type mechanism (Drakopoulos and Delibasis, 1982) was felt as far as Lebanon (Beirut) and Palestine (Tel Aviv).

CONCLUDING REMARKS

All the above cited new intensity data, well authenticated (ISC), prove beyond any doubt that the enormous area of felt shaking observed repeatedly in interplate earthquakes of the Hellenic arc is a real fact indicating the larger conductivity of the subducted plate of Africa compared with that of the overlying plate of Eurasia.

It might be added, that ground motion characteristics of intermediate focal depth earthquakes may be significantly different from those of shallow crustal earthquakes. Quoting K. Sadigh and R. R. Youngs (1985): "For S.Z. (=Subduction Zone) earthquakes source characteristics, source depths, and geologic structures that influence seismic wave propagation are widely different from those of T.Z. (= Transform Zone) earthquakes". It is noted that: "Most notable differences in ground motion characteristics are substantially higher PGA (=Peak Ground Acceleration) as well as substantially larger ground motion dispersion for S.Z. earthquakes compared to T.Z. earthquakes".

The 8.3 magnitude earthquake of San Francisco, California, in 1906 April 18, was produced in a shallow depth by the activation of a long segment (about 270 miles) of the very known San Andreas fault, which is considered a transform fault zone. The right lateral strike slip faulting along the San Andreas fault might be responsible for the smaller size of the shaken area of the 1906 earthquake in comparison with that being observed in thrust earthquakes of about the same magnitude in the subduction zone of the Hellenic arc.

ΠΕΡΙΛΗΨΗ

ΜΑΚΡΟΣΕΙΣΜΙΚΗ ΕΠΕΚΤΑΣΗ ΠΡΟΣΦΑΤΩΝ ΔΙΑΤΕΜΑΧΙΚΩΝ ΣΕΙΣΜΩΝ ΤΟΥ ΕΛΛΗΝΙΚΟΥ ΤΟΞΟΥ ΣΤΗΝ ΑΙΓΥΠΤΟ ΚΑΙ ΛΙΒΥΗ ΕΠΙΒΕΒΑΙΩΝΕΙ ΤΗΝ ΑΚΡΙΒΕΙΑ ΠΕΡΙΓΡΑΦΩΝ ΠΑΛΑΙΟΤΕΡΩΝ ΣΕΙΣΜΩΝ

Κατὰ τοὺς δύο τελευταίους αἰῶνες ἔλαβον χώραν (1810, 1846, 1856, 1863, 1886, 1903 καὶ 1926) εὐάριθμοι σεισμοί, ἐνδιαμέσου βάθους, στὸ δυτικό, νότιο καὶ ἀνατολικὸ τμῆμα τοῦ Ἑλληνικοῦ τόξου, οἱ ὁποῖοι ἐγένοντο αἰσθητοὶ σὲ ἀσυνήθως μεγάλη ἔκταση ποὺ φθάνει ἀπὸ τὴν Μάλτα μέχρι τὴν Παλαιστίνη, ἀπὸ τὴν Δαλματία μέχρι τὴν Κυρηναϊκὴ καὶ Αἴγυπτο, καὶ ἀπὸ τὴν Κωνσταντινούπολη καὶ τὴν Δυτικὴ Μικρὰ Ἀσία μέχρι τὴν Νότιο Ἰταλία (Νεάπολη) καὶ Σικελία.

Ἀνάλογη μακροσεισμικὴ ἔκταση εἶχε καὶ ὁ κατὰ Θεοφάνην «μέγας καθ' ὅλης τῆς γῆς» σεισμὸς τῆς 21 Ἰουλίου 365. Κατὰ τὸν Λιβάνιον ἐδοκιμάσθησαν ὀλίγες πόλεις στὴν Παλαιστίνη, ὅλες οἱ πόλεις τῆς Λιβύης, οἱ μεγαλύτερες πόλεις τῆς Σικελίας, ἡ Νίκαια, καὶ στὴν Ἑλλάδα ὅλες ἐκτὸς μιᾶς. Στὴν Κρήτη κατεστράφησαν ἡ Κνωσσὸς καὶ ἡ Γόρτυς καὶ 8 ἄλλες πόλεις. Ὁ ἀριθμὸς τῶν νεκρῶν στὴν Κρήτη ἀνῆλθε σὲ 50.000.

Τὸν πολύνεκρο αὐτὸ σεισμό, τὸν μεγαλύτερο ποὺ ἔχει σημειωθεῖ μέχρι τοῦδε στὴν ἀνατολικὴ Μεσόγειο — ποὺ τὴν ἐποχὴ ἐκείνη πολλοὶ ἐπίστευαν ὅτι ἦταν ὁλόκληρος ἡ γῆ — ἀκολούθησε κατὰ Μαρκελλῖνον, Κεδρηνὸν καὶ Θεοφάνη πρωτοφανοῦς ἐντάσεως θαλάσσιο κῦμα ποὺ ἐπέφερε μεγάλες καταστροφὲς στοὺς παρακτίους οἰκισμοὺς τῆς Κρήτης, τῆς Πελοποννήσου, τῆς Ἠπείρου, τῆς Σικελίας, τῆς Κυρηναϊκῆς καὶ τῆς Αἰγύπτου.

«Ἐν Ἀλεξανδρείᾳ», γράφει ὁ Θεοφάνης, «πλοῖα προσορμισάμενα τῷ αἰγιαλῷ ἐπαρθῆναι εἰς ὕψος, καὶ ὑπερβῆναι τὰς ὑψηλὰς οἰκοδομὰς καὶ τὰ τείχη, καὶ μετατεθῆναι ἐνδὸν εἰς τὰς αὐλὰς καὶ τὰ δώματα τὰ πλοῖα· ὑπαναχωρησάσης δὲ τῆς θαλάσσης ἔμεινον ἐπὶ ξηρᾶς· οἱ δὲ λαοὶ ἐκ τῆς πόλεως φεύγοντες διὰ τὸν σεισμόν, θεωρήσαντες τὰ πλοῖα ἐπὶ τῆς ξηρᾶς, εἰς ἁρπαγὴν τῶν ἐν τοῖς πλοίοις ἐπῆλθον, καὶ ἐπιστρέψαν τὸ ὕδωρ πάντας ἐκάλυψεν· ἄλλους δὲ ναυτικοὺς διηγήσασθαι, ὡς κατ' ἐκείνην τὴν ὥραν ἐν μέσῳ τοῦ Ἀδρία πελάγους πλέοντες καταληφθῆναι ἐξαίφνης δὲ ἐν τῷ πελάγει εἰς τὸ ἔδαφος καθίσαι τὸ πλοῖον· καὶ μετὰ βραχὺ χρόνον ἐπανελθεῖν τὸ ὕδωρ καὶ οὕτω πλεῦσαι».

Κατὰ τὸν Γεώργιον Κεδρηνὸν «σεισμὸς ἐν Ἀλεξανδρείᾳ γέγονεν ἐπὶ τοσοῦτον ὡς ἐπὶ τὸ πολὺ ὑποχωρῆσαι τὴν θάλασσαν καὶ τὰ πλοῖα ἐπὶ ξηρᾶς ἱστάναι. Πλήθους δὲ πολλοῦ, ἐπὶ τῷ παραδόξῳ θεάματι συνδεδραμηκότος, τῶν ὑδάτων ἀθρόως ἐκδραμόντων πέντε μυριάδες ἀνθρώπων κατεποντίσθησαν, καὶ τῆς Κρήτης δὲ καὶ Ἀχαΐας καὶ Βοιωτίας, Ἠπείρου τε καὶ Σικελίας πλεῖστα μέρη ἀπολέσθαι, τῆς θαλάσσης ἀνελθούσης καὶ ἐπικλυσάσης αὐτά, ὡς καὶ ἐπὶ τῶν ὀρέων ἀπορριφθῆναι πλοῖα ἄχρι σταδίων ἑκατόν».

Ὁ Ἀμμιανὸς Μαρκελλῖνος γράφει μεταξὺ ἄλλων: Ἀκόμη καὶ πλοῖα κατεποντίσθησαν ἀπὸ τὰ μανιώδη ρεύματα, κατὰ τὴν ἀπόσυρση τῶν ὑδάτων, καὶ εὑρέθησαν βυθισμένα ὅταν ἐξαντλήθηκε ἡ μανία τῆς θαλάσσης... ἄλλα πλοῖα μεγάλου μεγέθους ἐτινάχθησαν στὴν ἀκτὴ καὶ ἐρρίφθησαν στὴ στέγη τῶν οἰκιῶν, ὅπως συνέβηκε στὴν Ἀλεξάνδρεια. Μερικὰ ἤχθησαν σὲ ἀπόσταση 2 μιλίων ἀπὸ τὴν ἀκτή· ἕνα τοιοῦτο πλοῖο εἶδε ὁ ἴδιος ὁ Μαρκελλῖνος στὴν Μεθώνη.

Πρόσφατες γεωμορφολογικὲς ἔρευνες ἔδειξαν ὅτι πρὶν ἀπὸ 1550 χρόνια περίπου συνέβηκε ἔξαρση περὶ τὰ 9 μέτρα στὴν νοτιοδυτικὴ ἀκτὴ τῆς Κρήτης. Ὅπως φαίνεται ἀπὸ τὸν χάρτη τῶν Thommeret καὶ τῶν συνεργατῶν των, ἡ ἀνύψωση ἔβαινε φθίνουσα ἀπὸ τὸ ἀκρωτήριο Κριὸς πρὸς τὴν νησῖδα Ἅγιοι Θεόδωροι, ἐπὶ τῆς βορείας ἀκτῆς τῆς Κρήτης, κατὰ τὴν ΒΑ - ΝΔ διεύθυνση. Ὑπάρχουν ἐνδείξεις ὅτι ἡ ζώνη μεγίστης ἐξάρσεως πρέπει νὰ ἦταν στὴν θάλασσα, ὀλίγον ἔξω ἀπὸ τὴν νοτιοδυτικὴ ἄκρη τῆς Κρήτης. Κατὰ τοὺς Thommeret καὶ τοὺς συνεργάτας των ἡ ἔξαρση ὁλοκλήρου τοῦ τεμάχους τῆς δυτικῆς Κρήτης φαίνεται νὰ συνέβηκε πιθανῶς κατὰ τὸν σεισμὸν τοῦ 438 μ.Χ., καὶ ὀλιγώτερο πιθανῶς κατὰ τοὺς σεισμούς: 365, 374 ἢ 448 μ.Χ.

Λαμβάνοντες ὑπόψη ὅτι αἰφνιδία ἔξαρση τοῦ θαλάσσιου πυθμένος τοῦ ἀναφερθέντος μεγέθους πρέπει νὰ προκάλεσε τεράστιο θαλάσσιο κῦμα μεταφορᾶς καὶ ὅτι ἀπὸ τοὺς τέσσαρες ὑποδειχθέντες σεισμοὺς μόνον ὁ σεισμός του 365 συνοδεύθηκε ἀπὸ ἐρημωτικὸ κῦμα στὶς ἀκτὲς τῆς ἀνατολικῆς Μεσογείου, φαίνεται μᾶλλον βέβαιον ὅτι ἡ ἀπότομη ἔξαρση τῶν 9 μέτρων ποὺ εὑρέθηκε παρὰ τὴν νοτιοδυτικὴ ἄκρη τῆς Κρήτης συνέβηκε κατὰ τὸν μεγαλύτερο καὶ πλέον πολύνεκρο μέχρι τοῦδε γνωστὸ σεισμὸ τῆς ἀνατολικῆς Μεσογείου τῆς 21 Ἰουλίου 365.

Θὰ πρέπει ν' ἀναφερθεῖ ὅτι ἡ μέση διεύθυνση ἀποσβέσεως τῆς ἐξάρσεως συμπίπτει μὲ τὴν νοτιοδυτικὴ διεύθυνση ἐφιππεύσεως τοῦ Αἰγαίου κρατονικοῦ τεμάχους στὴν Ἀφρικανικὴ πλάκα. Ἡ διεύθυνση ἀποσβέσεως ὑποδεικνύει ὅτι ἡ ἀνύψωση τῆς νοτιοδυτικῆς Κρήτης κατὰ 9 μέτρα ἦταν ἀποτέλεσμα τῆς ἀνωστικῆς πιέσεως ποὺ ἀσκεῖ ἡ ἀσθενόσφαιρα στὴν συνεχῶς βυθιζόμενη ἐντὸς αὐτῆς βόρεια παρυφὴ τῆς Ἀφρικανικῆς πλάκας.

Ἡ ἀνωμάλως μεγάλη μακροσεισμικὴ ἔκταση εὐαρίθμων μεγάλων σεισμῶν τοῦ Ἑλληνικοῦ τόξου στὴν Δαλματία, Ἰταλία, Σικελία, Κυρηναϊκή, Αἴγυπτο, Κύπρο καὶ Παλαιστίνη, καὶ ἡ ἀνάλογος μορφὴ ἰσοσείστων νεωτέρων διατεμαχικῶν σεισμῶν (1953, 1957, 1962, 1972 καὶ 1983) μικροτέρου μεγέθους (6 1/4 - 7 1/4) ὑποδεικνύει τὴν μεγάλη σεισμικὴ ἀγωγιμότητα τῆς ἡμι-ωκεανίου λιθοσφαίρας τῆς ἀνατολικῆς Μεσογείου. Ἡ ἀγωγιμότης αὐτὴ ἐπιβεβαιώνεται καὶ ἀπὸ τὴν μακροσεισμικὴ ἔκταση μεγάλων σεισμῶν τῆς Αἰγύπτου (1303, Αὐγούστου 8 καὶ 1870, Ἰουνίου 24), σὲ σύγκριση μὲ αὐτὴ ἰδίως ἀναλόγων ἐνδοτεμαχικῶν σεισμῶν, μεγέθους 7 1/2 - 7/34, τοῦ Αἰγαίου (1956, Ἰουλίου 9 καὶ 1968 Φεβρουαρίου 19). Εἶναι γνωστὸ ὅτι ἡ σεισμικὴ ταχύτης εἶναι μεγαλύτερη καὶ ἡ ἀπορρόφηση τῆς σεισμικῆς ἐνεργείας μικρότερη στὰ ψυχρότερα πετρώματα τῆς ἀνατολικῆς Μεσογείου. Αὐτὸ ὑποδεικνύει τὴν ὕπαρξη μιᾶς ψυχρῆς πλάκας ποὺ βυθίζεται καθ' ὅλο τὸ μῆκος τῆς Ἑλληνικῆς τάφρου, κάθετα ἐν μέρει πρὸς τὸν ἄξονά της.

Ἡ σεισμικὴ ἐνέργεια ποὺ ἀκτινοβολεῖται ἀπὸ τὴν ἐπιφάνεια ἐπαφῆς τῆς βυθιζόμενης μικρότερης πλάκας τῆς ἀνατολικῆς Μεσογείου καὶ τῆς ὑποβασταζόμενης ὑποπλάκας τοῦ Αἰγαίου ἄγεται προφανῶς μὲ μικρότερη ἀπώλεια ἀπὸ τὴν ψυχρότερη λιθόσφαιρα ποὺ εἰσδύει κατὰ μῆκος τῆς ζώνης Benioff τοῦ Ἑλληνικοῦ τόξου. Ἀπὸ μακρὰ πεῖρα γνωρίζομεν ἀκόμη ὅτι ἡ σεισμικὴ ἐνέργεια στοὺς σεισμοὺς ἀπὸ ἀναστρόφους διαρρήξεις μεταδίδεται γενικῶς καλύτερα ἀπὸ τὴν κάτω πτέρυγα τῆς ἐπωθήσεως. Ἡ ὕπαρξη ψυχρῆς πλάκας κάτωθεν τῆς Ἑλληνικῆς χερσονήσου παρέχει πρόσθετη ἀνεξάρτητη ὑποστήριξη τῆς ὅλης ἰδέας περὶ βυθίσεως τῆς μικρότερης πλάκας τῆς ἀνατολικῆς Μεσογείου κατὰ μῆκος τοῦ Ἑλληνικοῦ τόξου, κάθετα ἐν μέρει πρὸς τὸν ἄξονά του.

REFERENCES

N. N. Ambraseys, On the long term seismicity of the Hellenic arc. "Boll. di Geof· Teor. ed Appl.", Vol. XXIII, N. 92, pp. 355 - 359, 1981.

P. E. Comninakis and B. C. Papazachos, A Catalogue of historical earthquakes in Greece and surrounding area, 479 B.C. - 1900 A. D., Geoph. Lab., Univ. Thes., Mimeographed Publ., No 5, pp. 1 - 24, Thessaloniki, 1982.

J. Drakopoulos and N. Delibasis, The focal mechanism of earthquakes in the major area of Greece for the period 1947 - 1982, Seism. Lab., Univ. Athens, Mimeographed Publ. No. 2, pp. 1 - 72.

A. G. Galanopoulos, Das Riesenbeben der Messenischen Küste vom 27. August 1886, "Prakt. Acad. Athènes", Vol. 16, pp. 127 - 134, 1941.

J. M. Gere and H. G. Shah, Terra non Firma: Understanding and preparing for earthquakes, W. H. Freeman and Co., New York, 1984.

G. R. Goodchild, Earthquakes in ancient Cyrenaica, "Geology of Cyrenaica", pp. 41 - 44, 1966.

B. Gutenberg and Ch. Richter, Seismicity of the earth and associated phenomena, Princeton, 1954.

X. Le Pichon and J. Angelier, The Hellenic arc and trench system. A key in the neotectonic evolution of the eastern Mediterranean area, "Tectonophysics", Vol. 60, pp. 1 - 42, 1979.

G. Plafker, Fault mechanisms and frequency of occurrence. Tsunami. "Proc. NSF workshop", Li-San Hwang and Y. Ken Lee, Editors, Tetra Tech., Inc., Pasadena, California, pp. 7 - 9, 1979.

Ch. Richter, Elementary Seismology, W. H. Freeman and Co., San Fransisco, 1958.

K. Sadigh and R. R. Youngs, Special consideration in specifying design ground motions from subduction zone earthquakes, "Earthquakes Notes", Vol. 55, No. 1, pp. 1 - 32, 1985.

A. Sieberg, Untersuchungen über Erdbeben und Bruchschollenbau im östlichen Mittelmeergebiet, "Denkschr. Med. - Naturw. Ges.," Vol. 18, Jena, 1932.

I. Stürmer, Haus-, Hof- und Staats- archiv, Turkei 7:4, fol. 85 v., Wien, 1810.

Y. and J. Thommeret, J. Laborel, L. F. Montaggioni and A. P. Pirazolli, Late holocene shoreline changes and seismotectonic displacements in western Crete (Greece), "Geomorph. N. F.", Suppl. Bd. 40, pp. 127 - 149, 1981.

S. Uyeda, The new view of the earth, W. H. Freeman and Co., San Francisco, 1978.