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TSUNAMI DATA BASE OF THE EASTERN MEDITERRANEAN

BY

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ABSTRACT

As a result of feasibility study of this paper, a concept and prototype of the Eastern Mediterranean Tsunami Data Base (EMTDB) has been established. This database introduces a careful description, revision and analysis of tsunamis events, in particular these ones that occurred along the Eastern Mediterranean. These kinds of events have been poorly studied so far, and need a check to verify their own reliability. The Tsunami Data Base contains in the digital form all available information on regional seismic tsunamis (source parameters, observed heights, original historical description, etc.) as well as basic reference information on regional seismic, regional geography, geology and tectonics.

The main disaster area of tsunamis activity is located between Greece, Crete and Turkey. The seismic tsunami activity is mainly depending on the accumulation rate of strain energy in the Eastern Mediterranean between the Hellenic and Cyprus Arcs. The maximum run-up height of the historical tsunami in the Eastern Mediterranean has documented about a 30 m in the west cost of Patmos-Greece in September 29,1650.

Preliminary results show how it is difficult to get a very clear definition of all those tsunamis, because of a lack in the historical sources. The distribution of population causes bad control of historical epicenter earthquake location, but the location of disaster area (related to the effect of tsunami) is reported more clearly.

INTRODUCTION

The purpose of the Eastern Mediterranean Tsunami Data Base (EMTDB) is performing a systematic study about the real tsunami-hazard in the Eastern Mediterranean. The first part of this work is to prepare a complete and reliable catalogue to permit a serious evaluation of the tsunami phenomena on Eastern Mediterranean. A large amount of information and sources are available for the most important events, which have been recently studied in detail. The second part aims to answer what the greatest disaster area would be according to a given tsunami height.

The data for the present analyses are collected from different sources such as the catalog of Greek tsunamis, the data of the World –Wide Tsunamis Database (2000 B.C-1996)- Colorado USA, and data collected from documents of tsunamis in East Mediterranean (i.e. Bulletin n°168 du Comité Français de Cartographie). Also, data from different published papers where the tsunamis in different places of the eastern Mediterranean have been investigated by some investigators, Galanopoulos 1960, Ambraseys 1962, Antonopoulos 1979 & 1980, Papadopoulos et al. 1984, Papazachos and Papazachou 1989, Soloviev et al., 1992, Papadopoulos and Gerassimos, 1993 and Ambraseys et al., 1995.

Historically, data on tsunami occurrence and coastal manifestation have been compiled and used in this data base (EMTDB). However, the data in this paper which were taken from catalogs take long time to be edited and updated. The basic requirements for the data base of the EMTDB (designed by the Author) are:

1- The system should include all available earthquakes which concerned with the tsunami data for The Eastern Mediterranean region with basic reference information on regional geography, geology and tectonics. The geographic database includes geographical contours within the region, isolines of underwater and land topography, and localities of the coastal cities.

2- The system should have a module structure allowing flexibility and adjustment for entering and providing the potential of growth and research advancement.

3- This system should provide the possibility to manipulate maps, models data for the different result analysis.

4- The tsunami database should exist in two forms which can be called conventionally as the parents form and the users form. The tsunami data set consists of four main blocks: detailed source data, coastal observations of tsunami wave height, original descriptions of tsunamis and bibliography. This data collected from original reports and records, scattered in numerous publications of very different nature.

5- It consists of different main parts: the source database (earthquake, landslide and volcano) the tsunami database, retrieval and mapping of data, and the standardized built-in software for data processing. The analysis of data done by the Fortran (IV) program. The Eastern Mediterranean Data Base (EMDB) is being developed for the user who may be unfamiliar with the graphics software (i.e. Front Page and Flash). This has predetermined the elaboration of the easy-to learn and easy to use interface based on the menu-driven approach and having on-screen buttons for process management and on-screen windows for input and out put of information. A specially elaborated graphic shell provides an ability to manipulate maps, models, data and results of computation in an efficient and convent manner. Some main examples of screen outputs produced by the graphic shell are shown in Figs. 1-11.

THE RESULTS OF EMTDB

1. Morphological Study

The Eastern Mediterranean Sea is dominated by an elongated NE-SW trending depression known as the Herodotus Abyssal Plain. South to the Hellenic arc, an "external trench" forming a discontinuous series of small bathyal plains (3800 to 4000m) included in basins of complicated topography. The Eastern Mediterranean can be divided in a Western part (Ionian Sea) and an Eastern part (Levantine Sea), separated by a higher zone between Crete and Cirenaica. Connected with the Ionian Sea is the Adriatic Sea, and the Levantine Sea is connected with the Aegean Sea.

Two major morphostructural domains characterize this closing oceanic basin in Eastern Mediterranean sea areas. These area the Mediterranean Ridge: a more than 1500 km long tectono-sedimentary-accretionnary prism, that results from offscrapping and pilling up of thick sedimentary sections, and which runs from Ionian basin, to the west, to the Cyprean arc to the east, and the Nile Deep Sea Fan: one of the world's major deep sea fan (about 140.000km^2) which consists in a thick terrigenous construction derived from the erosion of large areas of the African craton and transported to the Mediterranean sea trough the Nile river drainage system.

These two features show numerous evidences of ongoing tectonic deformation, as well as specific sedimentary processes and numerous cold seeps, often in association with massive or discrete mud flows, Fig. 1& 2.

2. Tectonics of the East Mediterranean

The present–day tectonic framework of the eastern Mediterranean is controlled by the last phase of collision between the African and Eurasian plates. The Agean/ Anatolian plate is pushed westwards along strike-slip faults, due to collision between the Arabian/Syrian and Eurasian plates along the bitlis-Zagros Suture. At its northeastern edge, the African plate is presently moving NNE relative to the Eurasian plate. The Hellenic Arc and Pliny-Strabo Trench in the West and the Cyprean Arc in the East, Fig.3, delineate the boundary between the African and the Anatolian plates.

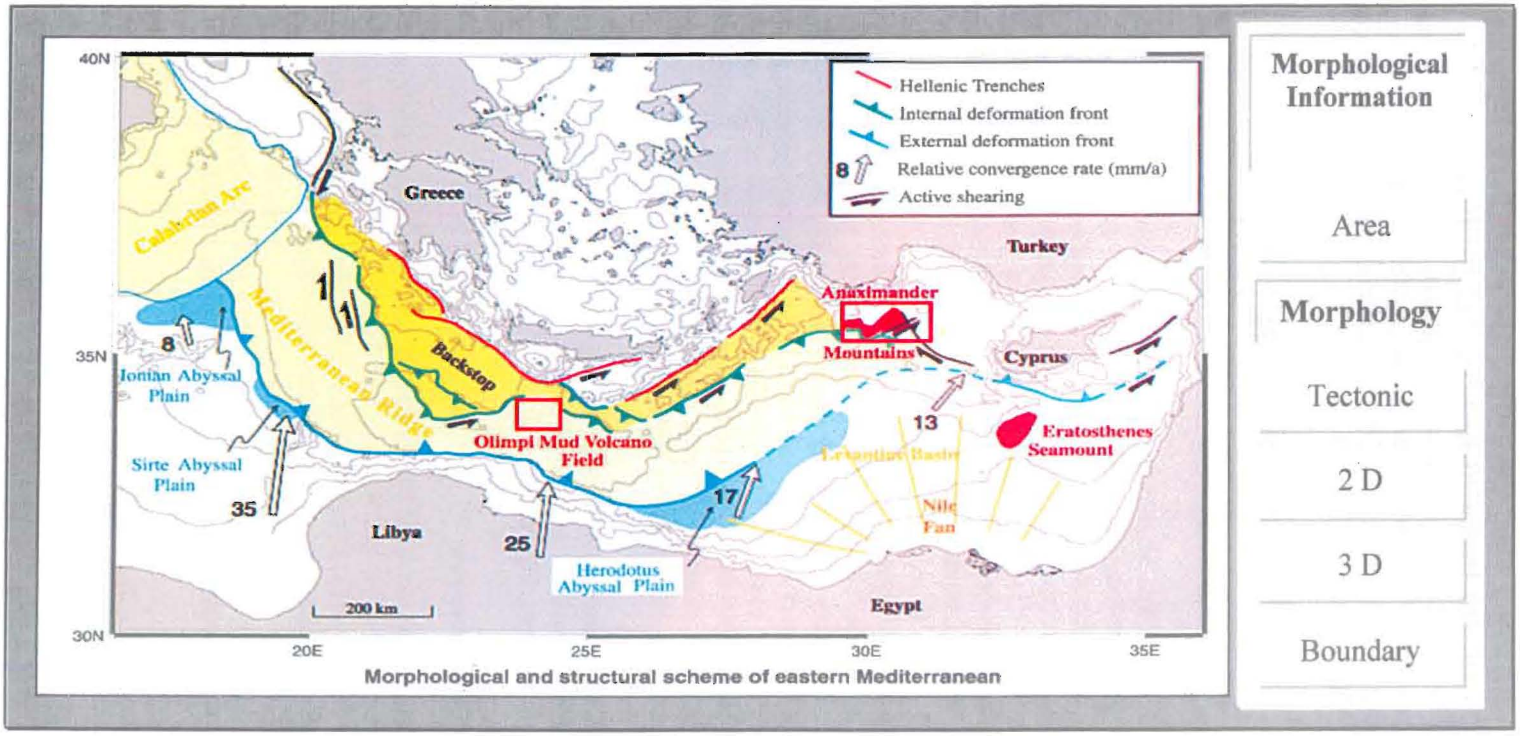

Fig. 1: It is an example of the screen output provided by the EMTDB graphic shell. It shows the morphological and structure scheme of eastern Mediterranean. On the right is the submenu of the second level operating, Loubrieu et al., 2000. The button Morphology is activated and initiates the program of selection of a morphological area for data retrieval and visualization.

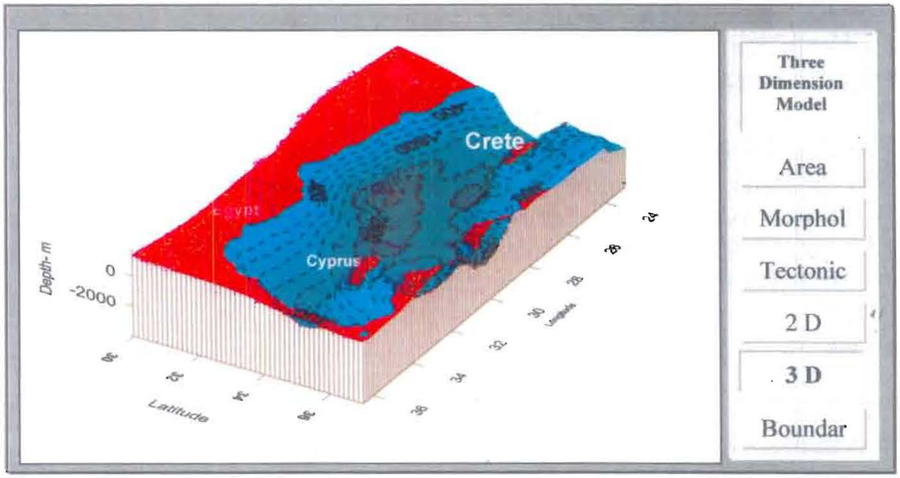

Fig. 2. The 3D Model for the Eastern Mediterranean

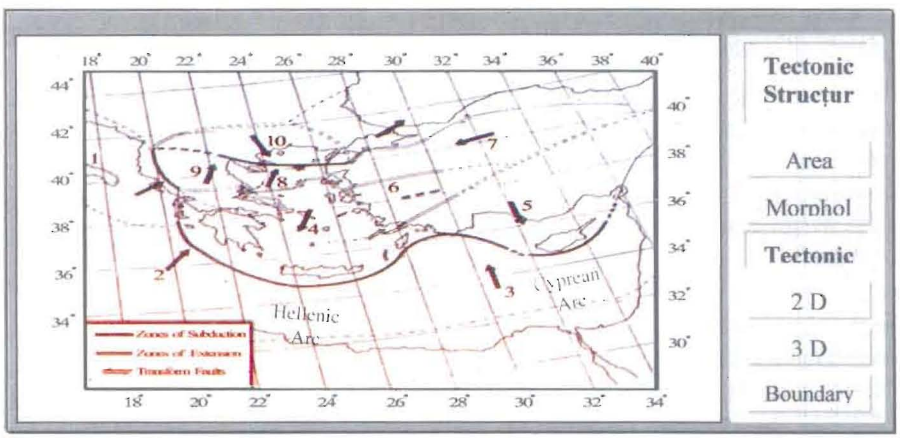

Fig. 3: Tectonics structure with the lithospheric blocks in the Eastern Mediterranean area. 1- Adriatic. 2- Ionian. 3- Levantine. 4- Aegean. 5- Taurus. 6- Western Turkey. 7. Northern Anatolian. 8-Saros. 9- Olympus. 10-Rhodopean.

Tectonically it was though that the Eastern Mediterranean is dominated by the relative North-wards motion of the African Plate, with subsequent sinking below the European Plate, and by the motion of two microplates: the Agean one (SE-wards) and the Anatolian one (SW-wards). The first motion should be connected with the Calabrian and Hellenic arcs subduction (Benioff) zones and have originated the so-called Mediterranean Ridge (Embryonal phase of a mountain chain) and the Hellenic Trench; the second ones are the very strong seismic and volcanic activity of Greece, of the Aegean Sea and Anatolia.

The modern theory of tectonic movement explains the generation mechanism of earthquake in terms of accumulated strain between plates and its release due to breaking. It is a common rule that the tsunami magnitude is proportional to the earthquake magnitude. The tsunamizoning can provide more reliable bases for the statistical evaluation of tsunami risk for particular parts of the coast.

3. Tsunamis

The EMTDB is concerned with all information and data about seismic, Landslide and volcanic tsunamis. Preliminary results show how it is difficult to get a clear definition of those tsunamis, because of a lack in the historical sources, in spit of the large amount of seismological data concerning earthquakes related to the analyzed tsunamis.

3.1. Seismic tsunami

The term "seismic" tsunami generation refers to the tsunami generation because of seismic fault displacement at the sea floor. Any other mechanism of tsunami generation is characterized as "nonseismic". The cause of a tsunami is the displacement of sea bottom which is frequently accompanied by an earthquake of great magnitude. Oscillation of ground caused by a Tsunamigenic earthquake is generally strong and continues long.

Tsunami earthquakes are different from "Tsunamigenic Earthquakes" which are simply earthquakes that generate tsunamis. Then slow earthquakes which excite large tsunamis are called tsunami earthquake. Most studies have concluded that slow faulting causes tsunami earthquakes. Among all the tsunami earthquakes, the 1896 Sanriku, Japan, and the 1946 Unimak earthquakes are most anomalous (Kanamori, (1972). The Sanriku earthquake was felt only moderately along the Sanriku coast, but very large tsunamis attacked the coast about 30 min later and drowned more than 22,000 people who apparently did not expect tsunamis because of the lack of strong shaking. The magnitude of the 1896 Sanriku earthquake is estimated to be only 6.8 to 7.5. These magnitude normally observed in the Eastern Mediterranean. Preliminary results of the EMTDB show the seismic tsunami but cannot identify its kind (Tsunami earthquakes and Tsunamigenic Earthquakes) because of very lack of information in the historical sources Data, Fig. 4.

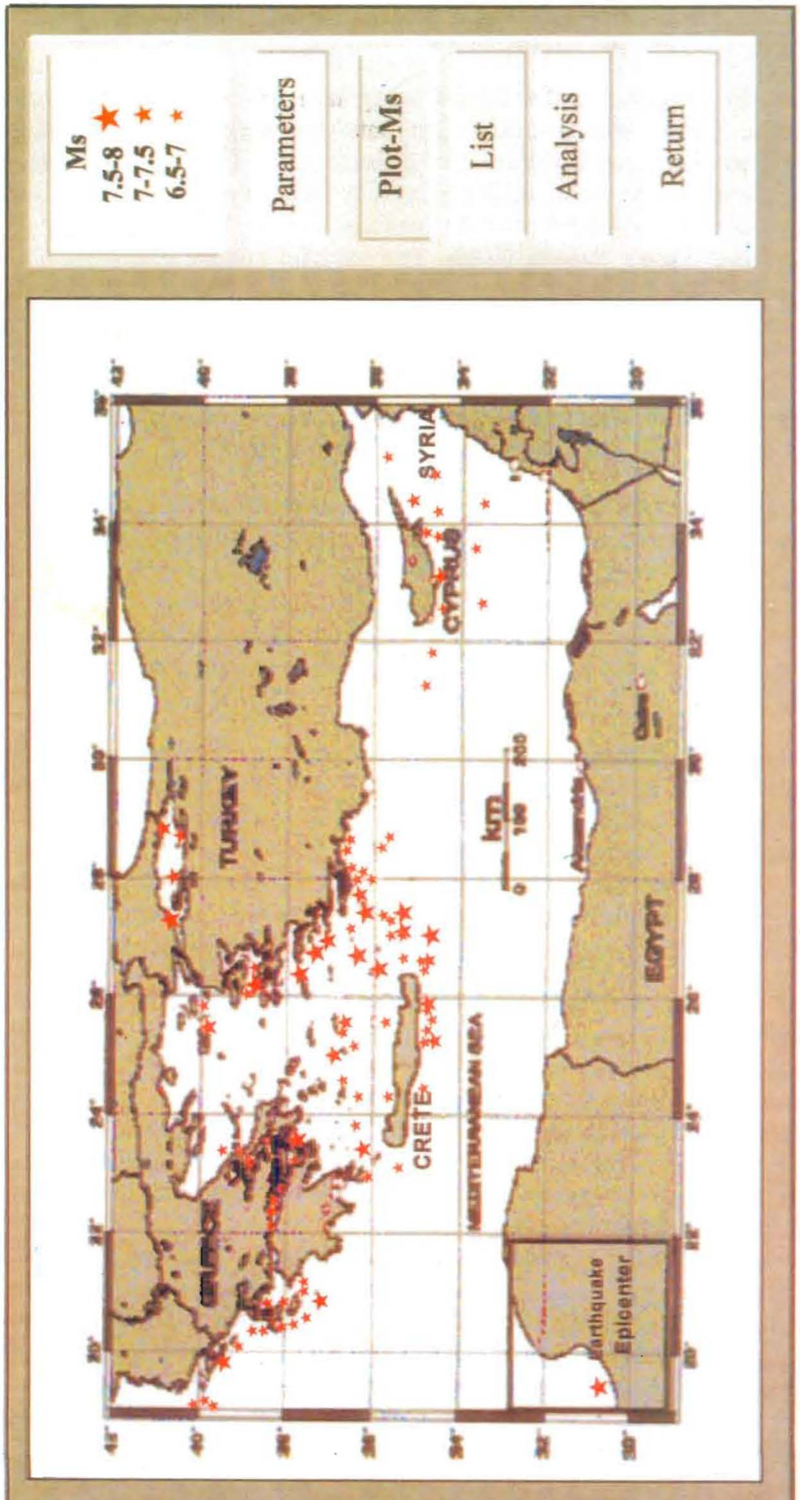

Fig. 4: Map of historical epicenters seismic tsunamis within the Eastern Mediterranean. The size of the stars represents the events magnitude. On the right- the submenu of the second level in the seismic tsunami database, is being initiated, buttons Parameters, List and Analysis.

Fig. (4) shows the epicenter locations and magnitude of the historical seismic tsunami events in the Eastern Mediterranean. Epicenters and magnitudes before about 1900 are usually based on the maximum intensity of earthquake. The EMTDB contains 108 seismic tsunami events. The main activity of seismic tsunami events located around the Hellenic Arc. The zone of islands area in between Greece, Crete and Turkey is highly affected by these seismic tsunami events. The recorded seismic events are 63 in Greece area, 22 around Crete area and 12 around Turkey. This implies that about 71 seismic tsunamis waves were observed in the Aegean Sea. No more than 17 seismic tsunami events around the Cyprean Arc in the Levantine Sea. The biggest seismic tsunami wave in the Eastern Mediterranean was triggered in the west cost of Patmos-Greece in September 29,1650. The Maximum triggered earthquake magnitude about 8 is observed in 365 AC in Crete, 1303 in Lybian Sea, 1304 northern Crete.

Being included in the data set, they can represent the tsunami impact for those parts of the coast where lack of actual observations is noticeable. One can hope that this approach to the tsunamizoning can provide more reliable bases for the statistical evaluation of tsunami risk for particular parts of the coast. An example of application of the built-in analyzing software-tsunami occurrence is depending on a time domains (year). This kind of diagram can be used for the evaluation of completeness of catalogs, Fig. 5 & 6.

The spatial distribution of historical seismic tsunami (AC) in Eastern Mediterranean is depicted in figure 5. It is represent the seismic tsunami events in two different zones. The first zone (Z1) is Cyprean Arc and second zone (Z2) is Hellenic Arc. The main source activity of seismic tsunami events in the Eastern Mediterranean is the zone of Hellenic arc (Z2). Also, when the seismic tsunami is will be active in the Cyprean arc (Z1), it is exposed to low seismic tsunami activity in the Hellenic arc zone (Z2). The two zones are different in the rate and the time occurrences of seismic tsunami activity.

Figure 6 shows the cumulative number of the historical (AC) seismic tsunami events in the Hellenic and Cyprean Arcs. It is shown that, when the seismic tsunami was active around the Hellenic Arc during the period 200-600 AC and period 1500- 2000 AC, the Cyprean Arc shows slightly very low ac activity in the same period. On the other side, the seismic tsunamis in the Cyprean Arc was active in the period 700-1300 AC and was exposed to very low seismic tsunami activity in the Hellenic Arc. This may indicate that the seismic tsunami activity is mainly depending on the accumulation rate of strain energy in the Eastern Mediterranean between the Hellenic and Cyprean Arcs. The earthquake generation process is related to the elastic strain rebound characteristic of rock structures. So, the elastic strain rebound characteristics that represent the strain release of that volume is function of time and is controlled by the Tectonics activity of the strain region between Hellénic and Cyprean Arcs of the Eastern Mediterranean. According to the slope of cumulative historical seismic tsunami activity, the Hellenic Arc is more active than the Cyprean Arc. So, it indicates that most historical seismic tsunami was clearly felt in the area between Turkey, Crete and Greece.

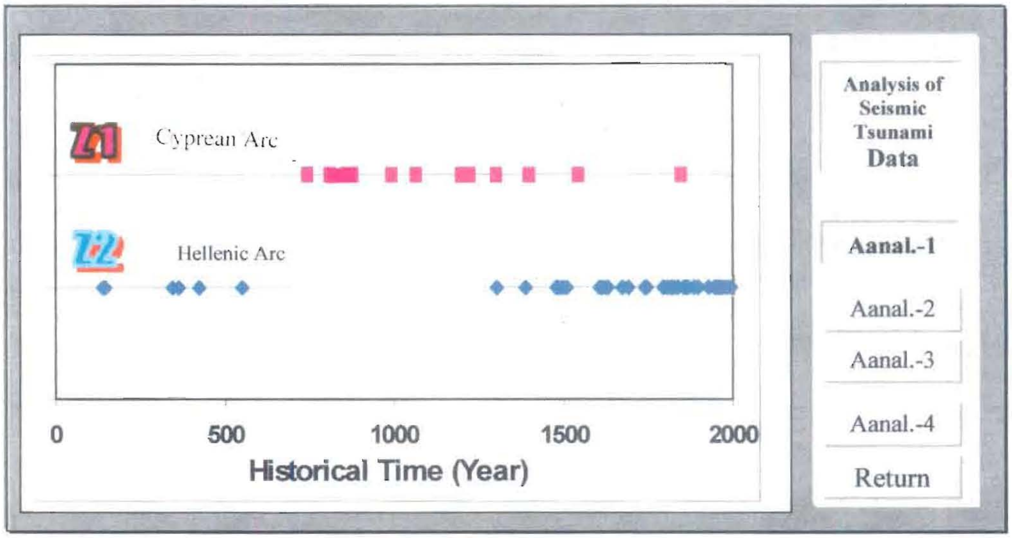

Fig. 5: An example of application of the built-in analyzing software-seismic tsunami occurrence is depending on a year. This kind of diagram can be used for the evaluation of completeness of catalogs.

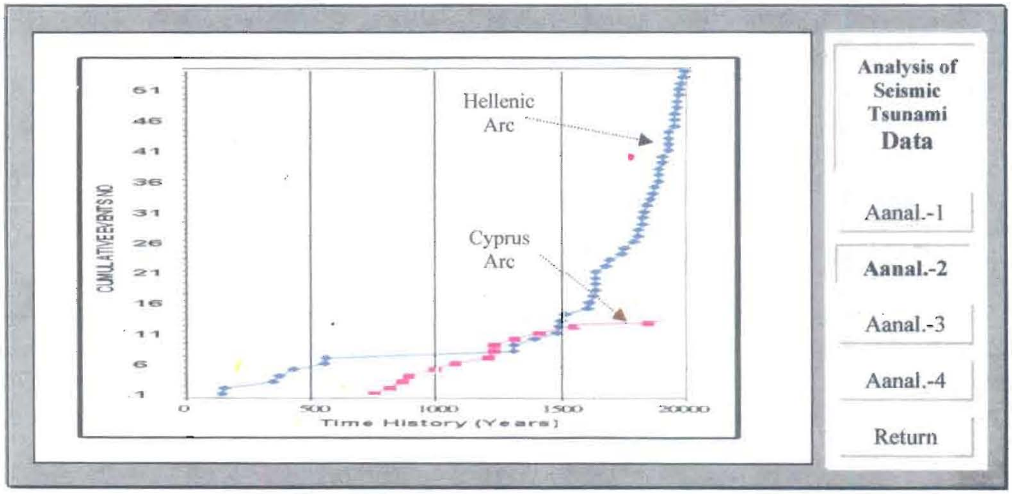

Fig. 6: Other application of the built-in analyzing software-seismic tsunami occurrence depending on the cumulative number of events activity per year.

3.2. Landslide and Volcanic Tsunamis

The other alternative accounts for a purely "aseismic" mechanism and the tsunami is by no means associated with a seismic events. For example, volcanic subsidence or gravitational submarine slide could be factors of aseismic tsunami generation.

Tsunamis of volcanic and Landslide origin are rarely observed but known to be commonly violent and destructive. Figure (7) shows the location of tsunami events related to the Landslide and volcano in the Eastern Mediterranean. In Eastern Mediterranean, at least 5 Tsunami disasters by the eruptions of the coastal volcanoes have been recorded. They are mainly located around Crete and south coast of Peloponnesus, Fig. 7. The available recorded tsunami events related to the landslide in the EMTDB are three events (1861, 1963 and 1995) located in the Corinth Gulf.

4. Intensity of tsunami

There are two measures to express features of tsunamis magnitude and intensity. A magnitude corresponds to the total energy of a tsunami, and intensity gives the local strength of the tsunami at a given location. The EMTDB shows the Tsunami intensity according to the Soloviev tsunami intensity (i). It is defined in terms of the tsunami height H. The degree of the tsunami damages, consequently the estimated intensity varies widely with construction and engineering quality of the structures. Figure (8) shows the historical Maximum tsunamis intensity within the region of the Eastern Mediterranean. Maximum intensity of about 5 is recorded along the west cost of Patmos-Greece in September 29, 1650.

The maximum tsunami intensity in Cyprean zone is about 2.5, recorded in South Cyprean, Lebanon, Syria costs. The Tsunami intensity in Alexandria (Egypt) is related to the effect of seismic tsunami of the Hellenic Arc.

5. Maximum run up height

Figure 9 shows the list in the EMTDB of observed tsunami wave heights for the selected event of August 17, 1999, Izmit Bay- Turkey. It contains the names of areas where tsunami waves were observed and measured, its geographical coordinates and the maximum run-up height.

The coastal observations of tsunami, which consist mainly of tsunami run-up heights, were taken from existing tsunami catalogs, various reports and publications. They all were provided by the EMTDB with the shoreline maps of the Eastern Mediterranean. The recorded Data in EMTDB of disaster locations affected by the tsunami waves are 162 localities observed in Greece, 23 locations in Turkey and about 3 localities in different other countries such as Cyprus, Egypt, Syria and Palestine.

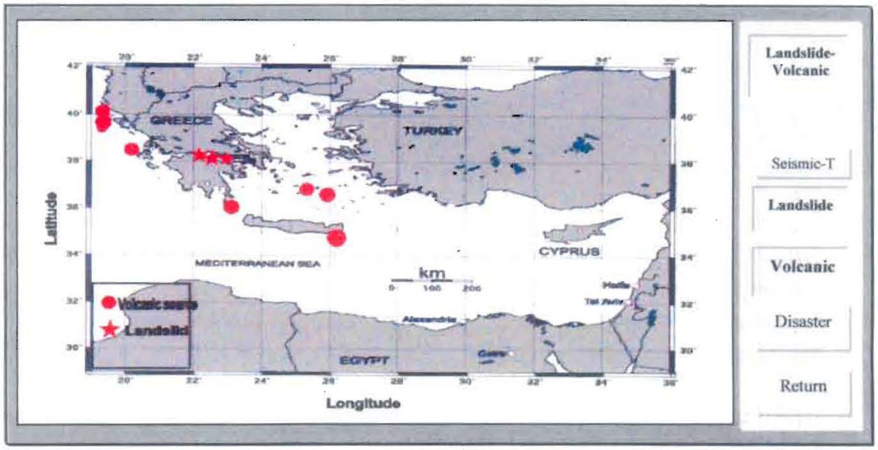

Fig. 7: Map of historical epicenters of Landslide and volcanic tsunamis within the Eastern Mediterranean. The circles represent the volcanic events and the stars represent the landslide events.

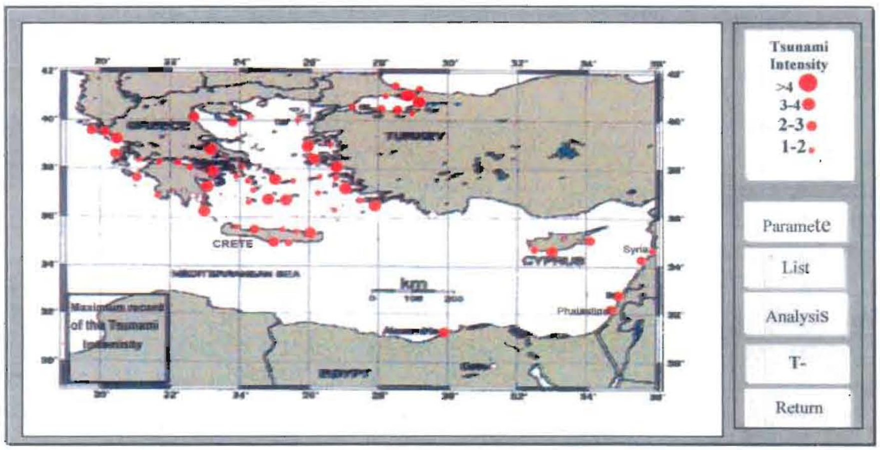

Fig. 8: Map of the maximum tsunami intensity observed in the Eastern Mediterranean coast. The size of circles represents intensity values.

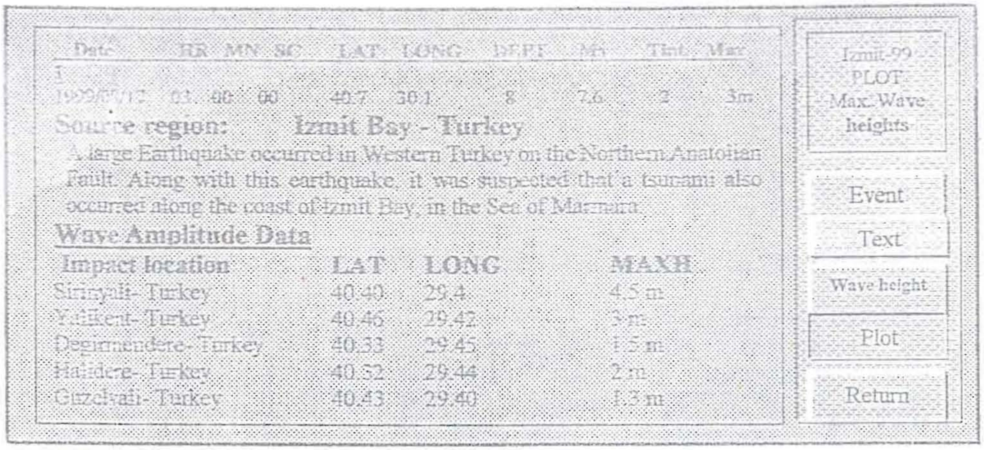

Fig. 9: List of the observed tsunami wave heights for the selected event (Izmit Bay – Turkey) of August 17, 1999. It contains the names of areas where tsunami waves were observed, its geographical coordinates and the maximum run-up heights. On the right-the submenu of the third level in the Tsunami database.

Fig. (10) represents the maximum run up height (>3 m) of the tsunamis recorded above sea level in meters and the Date of occurrence along the Coast of the Eastern Mediterranean. The Up normal maximum recorded run up height located in the west cost of Patmos-Greece in September 29, 1650. The mean rate of the maximum run up height in the eastern Mediterranean is about 3 m. The mean rate of the maximum run up height around the Hellenic arc is about 6 m, and around the Cyprean Arc is about 2 m.

6. Disaster location of tsunami

When tsunami disaster is discussed, a primary concern is usually the loss of human lives and the damage to houses. This EMTDB missed the real data about the number of loss of human lives and damages except some of the recent tsunami events as in August, 1999 in Turkey where the maximum run up height was about 4-5 m. Generally, fishing boats are snapped in pieces along the promenade, thrown 45 m from where they were moored. Tons of fish were washed ashore at the Izmit and Istanbul. The official Quake death toll passes more than 7,000 with 33, 022 injured related to August, 1999 earthquake. This is very important to analyses the data for determination of the damage percent R_{DB} according to Shuto, 1993 & 1997. The EMTDB data base records contain all the available Photos (about 40 photos) of the tsunami in the Eastern Mediterranean, Fig.11. The study of the disaster data is very important for a disaster prevention plan. A disaster prevention plan is usually made after a disaster occurred, by taking the results of the disaster into consideration. For developing a costal area, social and economical changes may introduce a new type of disaster, which the area has never experienced before. It is now necessary for a planner to learn experiences in the past and foresee possible disasters in the future. So, the risk evaluation against tsunamis is important for any population living along coastal region of the Eastern Mediterranean.

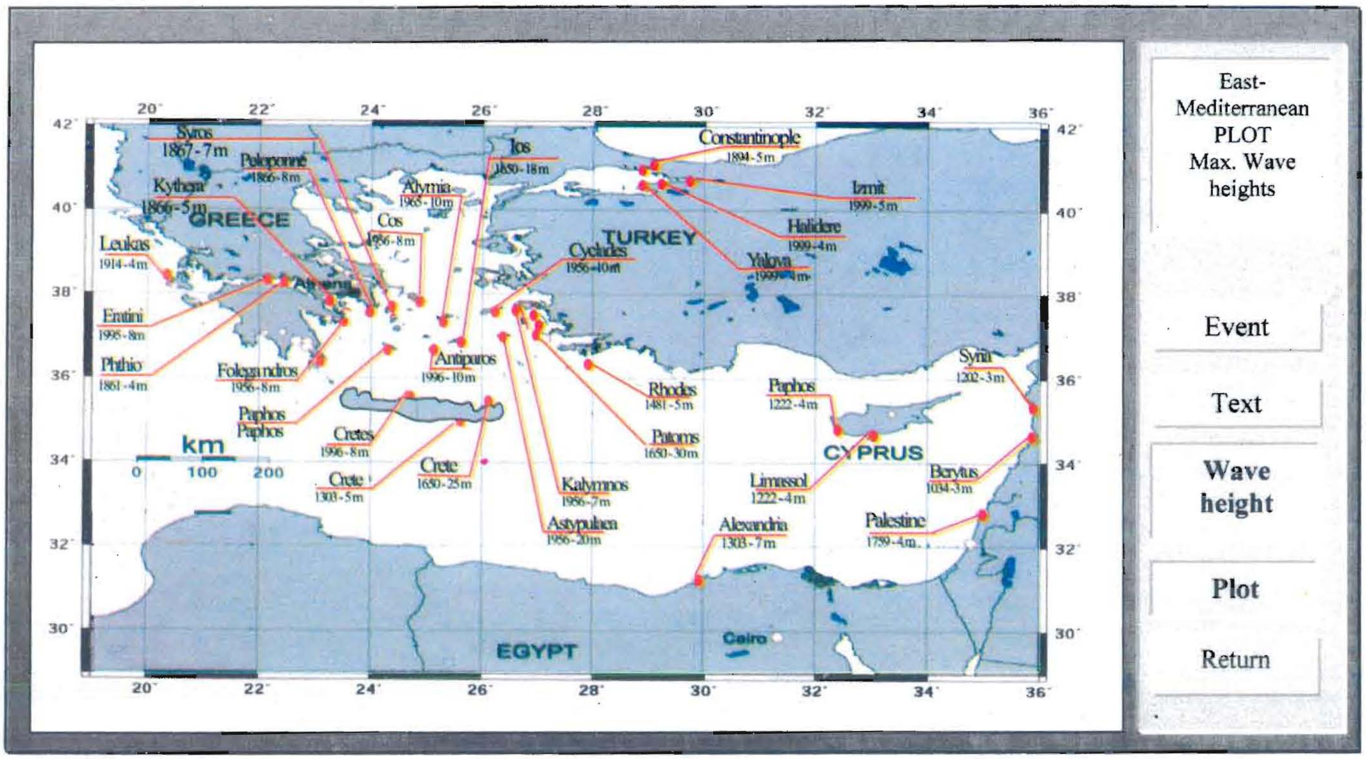

Fig. 10: Map represents the location and values of the Maximum run up height (> 3m) of the historical tsunamis in the Eastern Mediterranean.

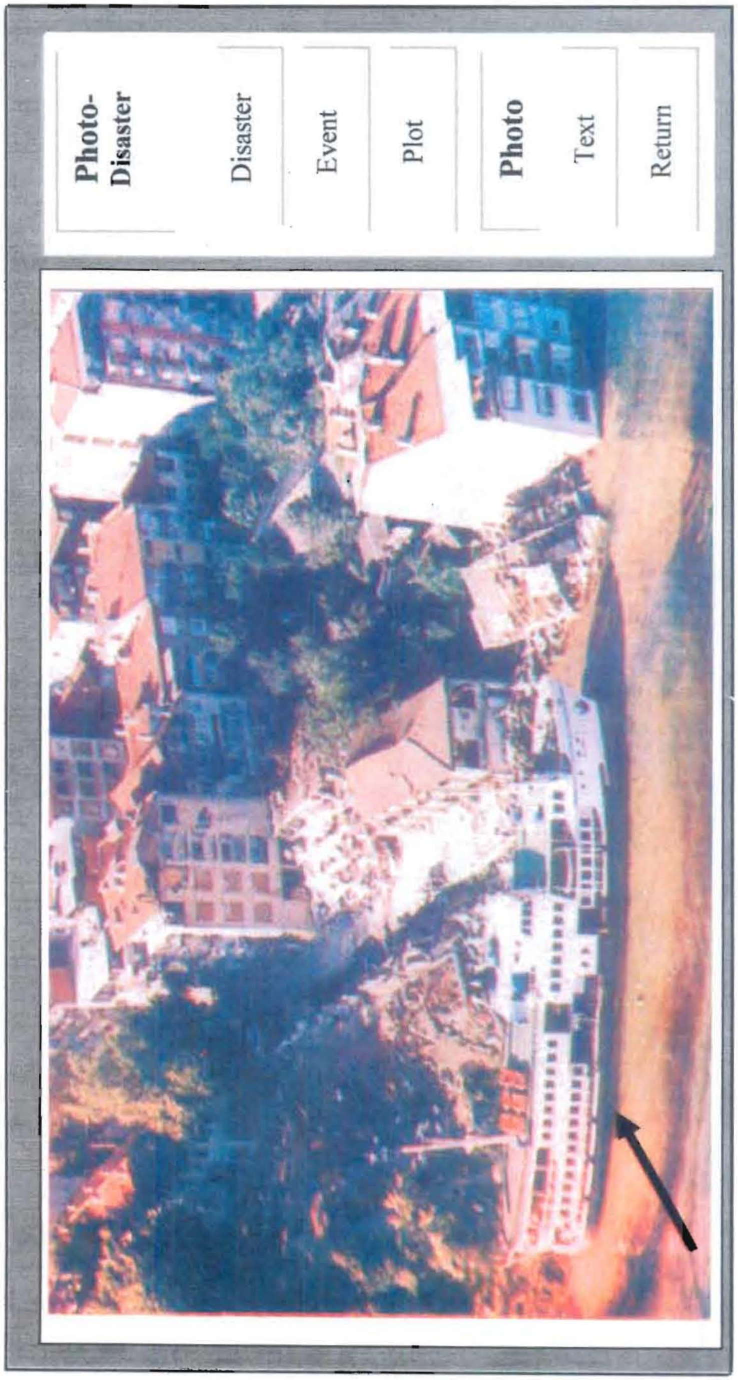

Fig.11: The photo of the August 17, 1999 Izmit-Turkey tsunami hazards recorded in the EMTDB.

CONCLUSIONS

As a result of this feasibility study, a concept and prototype of Tsunami data Base is important. Additionally, this paper (EMTDB) includes some software blocks for tsunami simulation (e.g. run up height and some standardized tools for data processing, plotting and obtaining their statistics). It helps for the producing New Eastern Mediterranean Tsunamis Catalogue which should be completed for the whole surrounded area, to define in a more objective way the real features of the tsunami-hazard and at last, to provide a reliable data set.

The revision of tsunamis in EMTDB has pointed out the inconsistency of some of them and confirmed others. About other events there is still a doubt that we are concerned with anomalous phenomena whose association with an earthquake is not clear, but we can ignore their occurrence. Infact we know that if the threshold magnitude to trigger a tsunami is about 7, to propagate a deformation for tens of kilometers would need an earthquake of comparable energies. Those conditions are not verified for the studied events.

The seismic tsunami activity is mainly depending on the accumulation rate of strain energy in the Eastern Mediterranean between the Hellenic and Cyprus Arcs. The reliability and heterogeneity of historical tsunami information are important factors in determining its future recurrence. The distribution of population causes bad control of epicenter earthquake location, but the location of disaster area (related to the effect of tsunami) is reported more clearly.

The latter application is very important for providing the existing tsunami warning system with more quantitative information than is now available, especially around the Hellenic Arc structure.

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