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Numerical computations of 1303 tsunamigenic propagation towards Alexandria, Egyptian Coast

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Abstract

A numerical model is presented to assess the probable tsunami impact of future earthquakes occurring along the Eastern Mediterranean Ridge, and their effect on Alexandria, Egypt. On the 8th of August 1303 a major earthquake of magnitude about eight caused a large tsunami that killed many people around Alexandria, where ships were carried over buildings and settled on land.

Calculations were done with an initial condition of continuous water flow normal to the shore line. This tsunamigenic event was examined to study the effect of location, direction, travel time and height towards the Egyptian Coast. Computed tsunami features such as travel times and run-up height distribution are given; which are useful in the evaluation of the tsunami hazard.

Keywords: Tsunami; 1303 Earthquake; Hazard; Alexandria; Subduction zone; Nile Delta

1. Introduction

At least two big tsunami disasters affecting the Nile Delta and Alexandria have been reported since ancient times. These disasters happened on 21 July 365 and 8 August 1303, respectively (with magnitude about 8). These two earthquakes had similar effects on Alexandria, the Delta of Egypt and the surrounding area in the eastern Mediterranean. The data for the present analysis are mostly collected from the world wide tsunami dataset in the US Natural Geophysical Data Center (NGDC) and from Ambraseys et al. (1994).

The present paper aims to evaluate the tsunami mechanism of the 8 August 1303 event of magnitude about 8. Also, computed tsunami features such as travel times and height distribution will be considered, to evaluate the future tsunami hazard.

2. The 1303 tsunamigenic event

Old documents describing the disaster of the 1303 tsunami event, concentrate on the frightening effects of that exceptional seismic tidal wave (tsunami) which struck many localities in the Mediterranean basin. It has been suggested that this extensive sea wave was caused by an earthquake having its epicenter near the island of Crete. According to Papazachos (1990), Ambraseys et al. (1994) and Riad et al. (2003) several kinds of disasters were caused: houses were destroyed, and human lives lost, destruction on water surge being due to buoyancy, drag force, impacts of water and floating materials.

In Alexandria, preceded by heavy thunder and lightning, the whole stability of the earth was shaken. Huge masses of water surged onto the land when least expected, and overwhelmed and killed many thousands of people. Some ships were seen to have been destroyed by the rapid whirlpools created by the retreating waters, and the dead bodies from the wrecked ships floated face up or down. Some large ships were hurled by the fury of the waves onto roof tops, and others were thrown up to two miles from the shore

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(Papazachos, 1990; Ambraseys et al., 1994; Riad et al., 2003).

3. Tectonics

The Eastern Mediterranean is characterized by two main seismic regions: the Hellenic and Cyprean Arcs. The main, large-scale geodynamic feature that controls the seismicity in the Hellenic Arc and trench system is the active subduction of the Mediterranean lithosphere beneath the South Aegean Sea. The Hellenic Arc is generated by the active subduction of the oceanic lithosphere in the east Mediterranean with NE–SW direction. It is a very small and bent arc with a slab subducting at a low angle (about 30°), which can be inferred from the fact that the seismicity prevails at intermediate depths rather than deep. The arc separates the southern Mediterranean, about 3 km deep and which is undeformed, from the Aegean Sea that has a notably complex structure (Mantovani et al., 2002).

Papazachos (1990) noted that the Hellenic Arc has a large number of earthquake foci lying close to it. Also, the existence of extensive fault zones close to zones of thrusting in the Eastern Mediterranean area shows its tectonic complexity (Fig. 1). The seismicity in the subduction zone present beneath Crete is characterized by earthquakes of large magnitude that have a history of affecting Egypt (Maamoun et al., 1984).

The geophysical data confirm the structure, and give clues to the possibility of obtaining useful information, such as the mean dip and the length of the descending lithospheric plate (Makris and Wang, 1994). The dip angle of the seismic zone is clear, but foci of considerable depth are found under the Hellenic trench, as if part of the lithosphere is steeply dipping under the trench (Fig. 2).

4. Bathymetry

Fig. 3 represents the bathymetric contour map of the Eastern Mediterranean, modified from available data of the bathymetric contour map of Krasheninnikov and Hall (1994), and from digital bathymetric data of the US National Geophysical Data Center.

The Eastern Mediterranean Sea is dominated by an elongated NE–SW trending depression known as the Herodotus Abyssal Plain. South of the Hellenic Arc (shown in Fig. 3), an "external trench" forming a discontinuous series of small submerged plains up to (3800–4000 m deep), are included in basins of complicated topography. The Nile cone is characterized by a very gentle slope, but the western side has a slightly steeper slope.

5. Method

In recent years, numerical simulations have been developed and used to compute the behavior of tsunamis in shallow water and on land. The results of these numerical computations are often referred to in practical designs of coastal defense works against tsunamis. There have been many numerical studies of tsunamis e.g. Aida (1974, 1984), Iwasaki and Mano (1979), Abe et al. (1990) and Shuto et al. (1990). Most of them aimed to simulate historical tsunamis, for which data such as run-up heights, inundated areas and fault models are of poor reliability. Aida (1975, 1984) made such modeled the 1792 Unzen and the 1741 Oshima tsunamis and compared the run-up height distributions with those estimated from old documents. Abe et al. (1990) carried out field investigations of the height of the Sanriku earthquake tsunami (A.D.869), on the basis of archaeological findings and sedimentological examination.

In the present work, the simulation based on a set of equations of motion and continuity for linear long-waves was solved by a leap-frog method in a finite-difference scheme. The present computation uses the linear long-wave theory, which does not include the physical dispersion term. The linear long-wave assumption is valid when the source size is much larger than water depths. The linear long-wave theory is applied to a marine study area of 200 km long and 250 km wide along the northern coast of Egypt (Fig. 4). Upon entering shallow water and

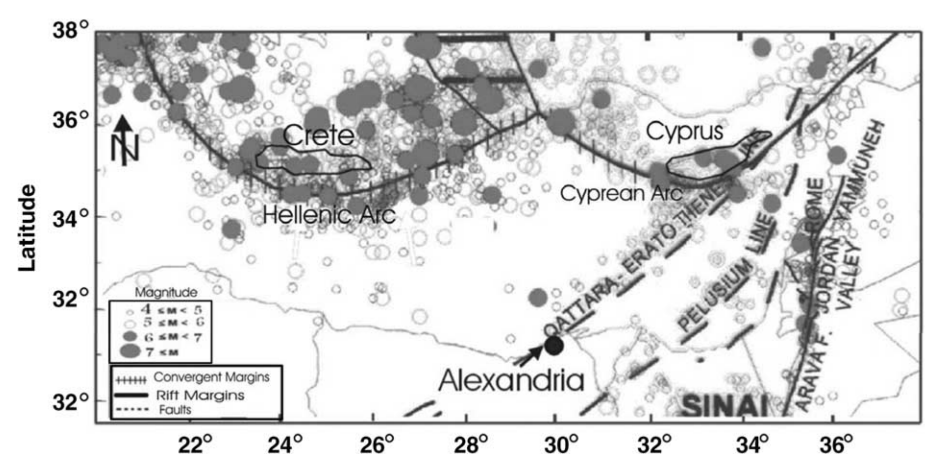

Fig. 1. Recent and historical seismicity (2200 BC–1996) with the neotectonics elements in the Eastern Mediterranean, after Riad et al. (1996).