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عضویت در خبرنامه
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سازمان بنادر و دریانوردی به عنوان تنها مرجع حاکمیتی کشور در امور بندری، دریایی و کشتی‌رانی بازرگانی به منظور ایفای نقش مرجعیت دانشی خود و در راستای تحقق راهبردهای کلان نقشه جامع علمی کشور مبنی بر "حمایت از توسعه شبکه‌های تحقیقاتی و تسهیل انتقال و انتشار دانش و سامان‌دهی علمی" از طریق "استانداردسازی و اصلاح فرایندهای تولید، ثبت، داوری و سنجش و ایجاد بانک‌های اطلاعاتی یکپارچه برای نشریات، اختراعات و اکتشافات پژوهشگران"، اقدام به ارایه این اثر در سایت SID می‌نماید.

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TSUNAMI ATTACKS ON IRANIAN COASTLINES; HISTORY AND PREDICTION

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Even though tsunami events are rare along Iranian coastlines, they should not be completely ignored because of the destructive forces of tsunamis that are able to cause a major loss of life and injury as well as the property damages. In this study, a historical survey of tsunami attacks on Iranian coastlines is presented and the possibility of the occurrence of tsunamis along the coasts of the Caspian Sea, the Persian Gulf and the Sea of Oman is investigated. It is shown that Oman Sea coastline is the most vulnerable part of the Iranian coasts for both tsunamis and tropical storms. Considering the economical and social importance of Chabahar Bay, the probable water level rise in the bay due to an probable sever earthquake resulting from Mekran fault is investigated. The predicted results can be utilized for the development of possible countermeasures.

1. Introduction

Tsunami, or "harbor wave" in Japanese language, is a long sea wave that can be generated by a rapidly occurring change in seafloor topography because of undersea landslides, volcanic eruptions or tectonic displacements such as earthquakes. It is believed that the substantial vertical offset caused by a dip-slip earthquake mechanism is necessary to generate large tsunamis and strike-slip earthquakes are less likely to cause tsunamis. Strike-slip earthquakes with movement of a big body of land slides may generate tsunami, but its probability is less than that of dip-slip ones.

In this study, a historical survey of tsunami attacks on Iranian coastlines is presented. The possibility of tsunami occurrence along the coasts of Iran; i.e. the Caspian Sea, the Persian Gulf and the Sea of Oman, is separately investigated.

A numerical model for predicting tsunami attack on land is also presented to simulate tsunami generation and also its propagation toward shoreline.

2. History and Possibility of Tsunami Attacks

It is observed that all the coastlines of the country are seismically active. Figure 1 shows the Seismicity of Iran.

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2.1. *The Persian Gulf*

Persian Gulf is seismically active since some parts of the boundary of Arabian plate and Eurasian plate lie in it. However, due to shallow water depth and also the small width of the Strait of Hormoz, i.e. not an open sea, the tsunami risk is small and it can be neglected. There is no record of historical tsunami in the Persian Gulf.

2.2. *The Caspian Sea*

Table 1 presents the historical records of tsunami in the Caspian Sea. In spite of the occurrence of tsunami in Caspian Sea, the possibility of tsunami attack on the Iranian border is not high due to the lack of the open sea conditions.

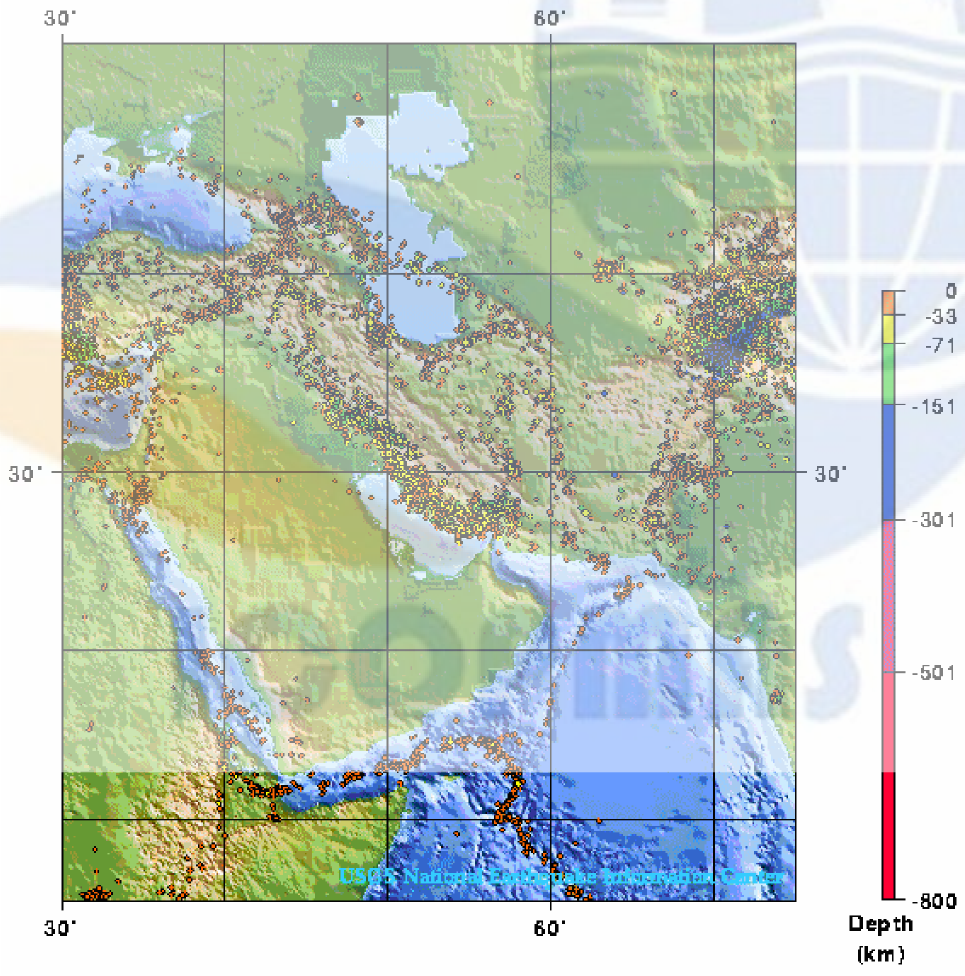

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Figure 1. Seismicity of Iran Coasts (1969-1989)

Numerical simulations of tsunami also indicate that although a maximum water level increase of about 1.0 m on some of the Caspian Sea coastlines, i.e. those close to the epicenters of the earthquakes such as Azerbaijan Coastlines, is probable, the increase of the water level on the Iranian coasts is negligible.

Table 1. Historical Tsunami Records in the Caspian Sea [4]

Date	Location
743	Darband
918	Darband
957	Darband
1668	Turk
1867	Baku
1876	Ablionoy
1895	Krasnodesk
1902	Baku

2.3. *Oman Sea*

The historical records of tsunami in the Oman Sea and the Indian Ocean are presented in Tables 2 and 3, respectively (Murty, 1999). The possibility of tsunami attack in this coastline is very high. Table 3 indicates a direct tsunami attack on Iranian coastline in 1008 AD.

Southeast part of Iran slightly felt the waves of Sumatra Tsunami. The tide gage of Iranian Survey Company at Chahbahar Bay recorded an increase of water level of about 20 cm. The elderly people living in Chahbahar also remember the significant damages due to high water waves about 60 years ago. This should be related to the tsunami occurred in November 1945.

Table 2. Historical Tsunami Records in the Oman Sea

Date	Location
326 BC	The Indus delta/Kutch region
1524	Off Dabhol coast, Maharashtra
27 Nov. 1945	Off the Makran coast, Pakistan

Table 3. Historical Tsunami Records in the Indian Ocean

Date	Remarks
326 B.C.	Alexander the Great
Between 1st April and 9th May 1008	Tsunami on the Iranian coast from a local earthquake

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August 27th 1883	Krakatoa 1.5 m tsunami at Madras, 0.6 m at Nagapattinam, 0.2 m at Arden
1884	Earthquake in the western part of the Bay of Bengal. Tsunamis at Port Blair, Dublet (mouth of Hooghly River)
26th June 1941	8.1 quake in the Andaman Sea at 12.9^0N, 92.5^0E. Tsunamis on the east coast of India with amplitudes from 0.75 to 1.25 m
27th November 1945	8.25 quake 70 km south of Karachi at 24.5^0N, $63.O^0$E Tsunami amplitude at Kutch was 11 .0 to 11.5 m.

Tsunamis generated in Indian Ocean can get access to the southeast part of Iran. In spite of the tsunamis coming from Indian Ocean, a very active fault called Mekran lies in the vicinity of Oman Sea coastline (Fig. 2). It is the most important seismically active faults in south Asia, Oman Sea and Indian Ocean. This dip-slip fault is the most dangerous fault of the Iranian coastlines and it is capable to generate a significant tsunami. Any earthquake caused by this fault can directly attack the Iranian coasts of Oman Sea.

Although the southeast part of Iran is among the most undeveloped parts of the country, Chabahar Bay is a major economical and trade zone which is currently under increased attention and rapid development. Here, a probable tsunami attack on the Oman Sea coastline and the resulting water level rise at Chabahar Bay is numerically simulated.

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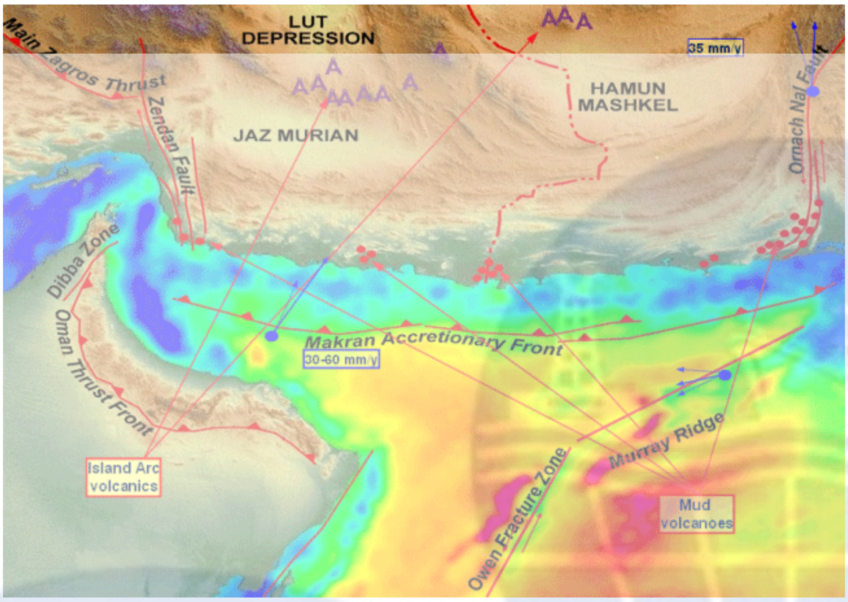

Figure 2. Mekran Fault

Mekran dip-slip fault locates along the coastlines of Iran and Pakistan with an average distance of about 100 km and it has been very active in the past decades (Murty, 1999). November 28th, 1945 earthquake with a magnitude of Mw 8.0 and Ms 7.8 and its resultant tsunami attack on the coasts on Baluchistan of Pakistan was caused by the displacement of this fault. The fault has caused over 60 recorded mild to sever strong motions. It is also believed that the tsunami attack on Iranian coast in 1008 AD was due to the activity of Mekran fault.

3. Tsunami Numerical Model

A numerical model is set up to study one cycle of tsunami, starting from the earthquake and its resultant displacement in the sea floor, off-shore tsunami propagation and inland simulation (Naksuksakul, 2006). Earthquake data is needed for the initial condition of simulation. The world-wide used displacement model of Mansinha and Smylie's model, derived from analytical expressions of Volterra's formula, is adopted in the model. Mass conservation equation and momentum conservation equations in two directions are the governing equations for the off-shore tsunami simulation and the inland simulation. Leap-frog scheme is also applied in both parts. No reflection is considered when flood propagates to the side boundaries of interested areas.

4. Model Results

November 28th, 1945 earthquake is selected as a probable earthquake caused by Mekran fault and the resultant tsunami attack to Chabahar Bay is simulated. Fig.3 shows the water level rise in the bay. It is observed that the level rise outside the bay

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is higher, as expected. Tsunami travel time from the assumed earthquake epicenter to Chabahar bay is also estimated about 30 minutes.

Although the water level rise is not high, this small travel time highlights the difficulties of evacuation operations.

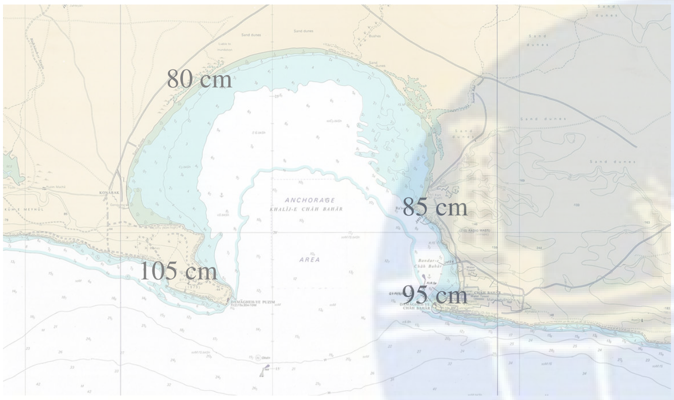

Fig. 3 Water level rise in Chabahar Bay

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