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Tsunami in Makran Region and Its Effect on the Persian Gulf

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1. Introduction

The Makran Subduction Zone characterizes by the subduction of the oceanic part of the Arabian plate beneath the Eurasian plate. The offshore Makran region located in the Oman Gulf shows relatively low seismicity in comparison with the surrounding regions (Figure 1). In spite of low seismicity, 3 tsunamis in the Makran region has been reported. 2 of them had known seismic source, and the other one has unknown origin. The most recent tsunamigenic event was on November 1945 associated with an earthquake of magnitude 8.1, affecting along the Makran coastlines of Iran, Pakistan, Oman and United Arab Emirates; with the loss of life of around 4000. Since then a long silence poses a potential threat of major tsunamigenic disaster for the coastal region.

Makran Subduction Zone is unique region in the world due to its geological and seismological characteristics. High sediment input of 7 km, shallow angle of dip and rate of subduction are interesting and distinctive features of this zone.

The Makran subduction zone appears to be divided into at least two segments - the west and the east, separated by a sinistral fault known as the Sonne Fault. This has been supported by Kukowski et al., (2000) where they introduce a new boundary coinciding very well with the Sonne strike-slip fault. In contrast to east, the western segment characterizes by absence of inter-plate events. The lack of major earthquakes in the western segment either means the segment has been locked and accumulating strain energy for hundreds of years or it is creeping aseismically. This movement supported by the regional GPS study that indicates a convergence of about 2 cm/year (Bayer et al., 2006). In addition, the existence of Holocene (10,000 years) marine terraces (Page et al., 1979) indicates that this segment is active, although the recurrence period of earthquakes (> 8.0) may be much longer (i.e. thousands of years). In this context, it is important to mention that the western segment of the Makran subduction zone may have experienced a large offshore earthquake in 1483 (Ambraseys and Melville, 1982). Although recent work suggests this may have been a moderate event near the Qeshm Island, Strait of Hormuz in association with the Zagros seismically active region (Musson, 2008).

Based on the 2D offshore seismic reflection data the main structural provinces and elements in the Gulf of Oman are (i) the structural elements on the northeastern part of the Arabian Plate and (ii) the Offshore Makran Accretionary Complex Elements. On the northeastern part of the Arabian Plate, five structural provinces and elements being defined: the

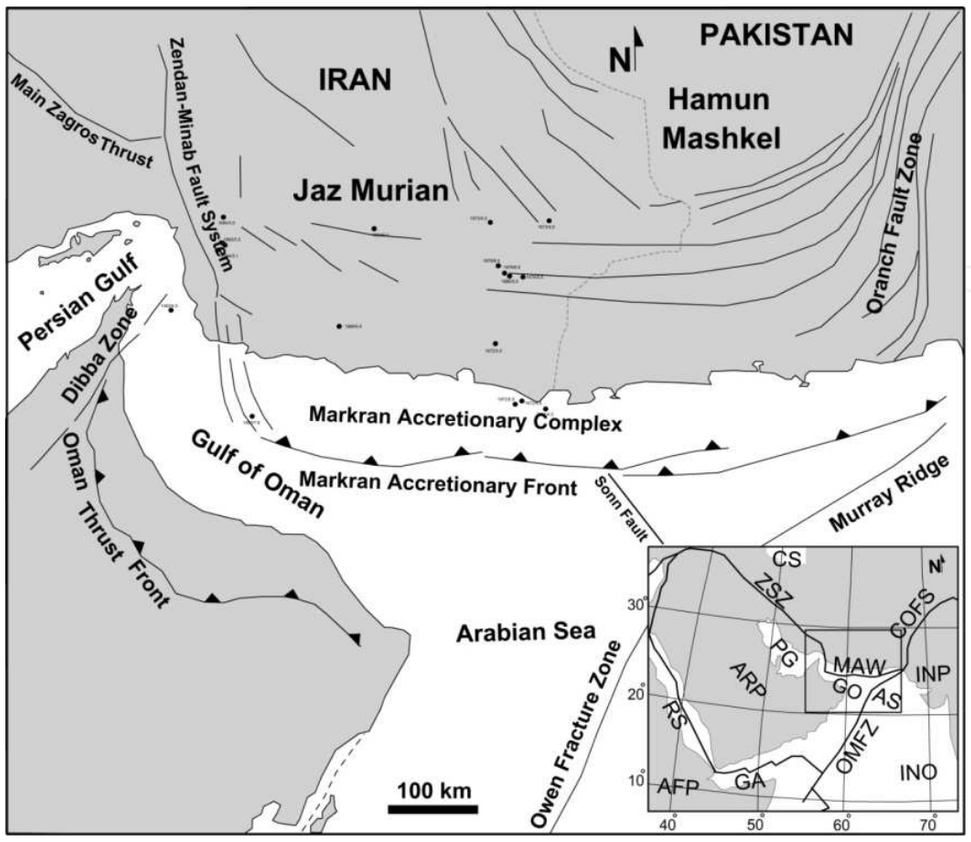


Fig. 1. Plate tectonic setting of the Oman Sea and the main structural elements, the plate boundaries in the north of the Indian Ocean and some major earthquakes locations are also shown. AFP; African Plate, ARP; Arabian Plate, AS; Arabian Sea, COFS; Chaman Oranch Fault System, CS; Caspian Sea, GA; Gulf of Aden, GO; Gulf of Oman, INO; Indian Ocean, INP; Indian Plate, MAW; Makran Accretionary Wedge, OMFZ; Owen Murray Fault Zone, PG; Persian Gulf, RS; Red Sea, ZSZ; Zagros Suture Zone (modified after Mokhtari et al. 2008)

Musendam High, the Musendam Peneplain, the Musendam Slope, the Dibba Zone, and the Abyssal Plain (Mokhtari et al. 2008). The Zendan-Minab Fault System and the Accretionary front define the western and southern boundary of the Makran Accretionary Complex, respectively. The Oranch Fault Zone is located in the eastern side of this complex and being considered as the western boundary of the Indian Plate, while the Murray ridge system defines the offshore boundary of the Arabian and Indian plates. These seismic reflection data (covers both Persian Gulf and eastern part of Oman Gulf, (PC2000) acquired by National Iranian Oil Company) has been further analyzed for refinement and better understanding of the structural elements and their tectonic significance. Kopp et al. 2000 has applied wide-angle and seismic reflection data and achieved the similar result on the western side of the Oman Gulf.

It is believed that the smaller fault system can act as superimposing (secondary) elements in strengthening the tsunami effect. Thus, in this respect a better understanding of the main structural elements and their tectonic behavior can be important. This information could be implemented in future for more detail hazard assessment.

The tsunami threat faced by Indian Ocean countries in general and Makran in particular consists of a tsunami from local, regional and distant sources, whose effects at any location are highly dependent on variations in bathymetry between the source and the affected area. These factors if not being implemented accurately will make the design of an effective tsunami early warning system problematic.
In this chapter after discussing the tectonic setting of Makran Subduction Zone, its effect on tsunami generation has been elaborated and tsunami hazard assessment as key element for the early warning system has been introduced. Although the Persian Gulf due to its seismotectonic setting and shallow water depth could not be classified as tsunamigenic zone, but effect of tsunami generated in the Makran region on this area will be specially emphasized due its major recent inhabitant growth and industrial developments.

2. Tectonic setting

The latest major plate tectonic event causing most changes in the structural evolution in the Oman Sea is related to the evolution of the Sheba Ridge, accompanied by opening of the Gulf of Aden and rifting/opening of the Red Rea (Figure 2). This event has been dated to 23 Ma-Oligocene-Early Miocene (Edwards et al., 2000). The change in the plate configuration also resulted in compression in the Owen Fracture Zone. It might even be that the transform

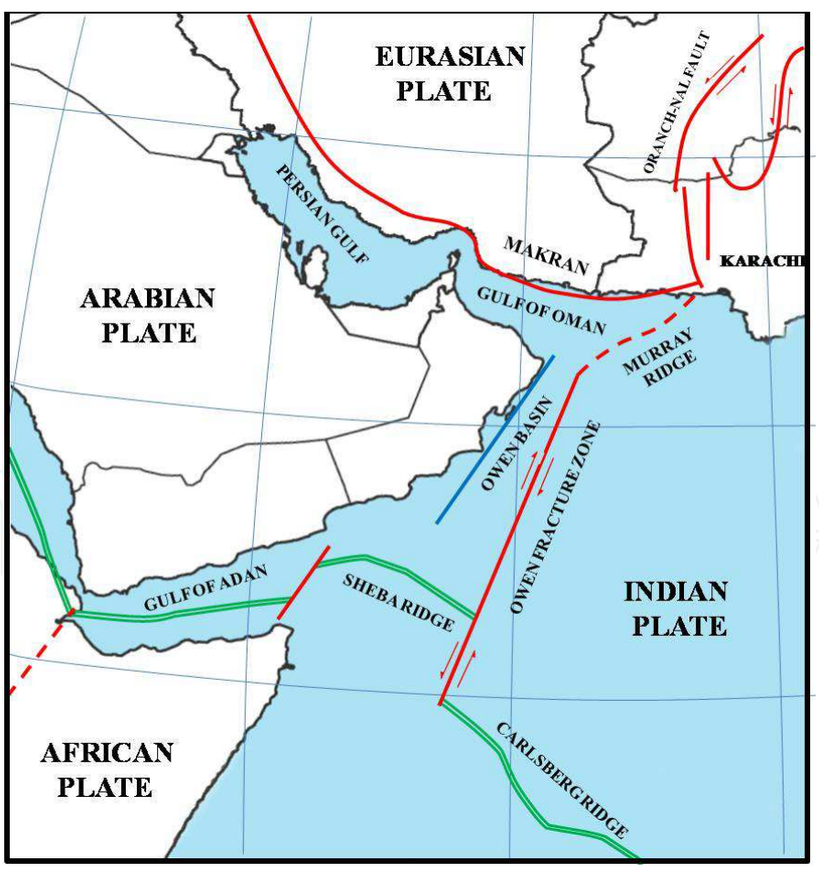


Fig. 2. Major structural elements and the plate boundaries in the study region. The blue line indicates "the initial location of plate boundary?".

defining the eastern boundary of the Indian Plate prior to this event was located further west (Figure 2), jumping to its present location at the Owen Fracture Zone when the Sheba Ridge was formed (Barton et al., 1990).
The breaking of the Arabian Plate from the African Plate probably resulted in an increase in subduction rate. At this stage the evolution of the mountain chains along the Himalayan continent-continent collision zone was uplifted and eroded, resulting in a major increase in sediment input into the Indian Ocean and the Oman Sea.

3. Characteristics of the Makran Accretionary Complex

Based on the seismic reflection, wide-angle reflection data and mapping, both east and west Makran and the plate tectonic setting of the area several structural provinces and elements have been defined (Mokhtari et al. 2008 and Kopp et al. 2000).
It is important to mention that the evolution and deformational history of an accretionary complex is the result of a continuous process, not series of separate events. Therefore, some of the provinces defined do not represent different tectonic/structural settings or events, but as different stages in the evolution of an accretionary complex. Also, what has been observed and defined offshore is an integrated part and continuation in time of the onshore areas, only younger in age and to some extent less deformed. Therefore, understanding the onshore is important, for both the offshore tectonic/structural evolution and the depositional history.
The following gives a summary of some of the characteristics of the Makran Accretionary Complex. Two-thirds of the accretionary complex is located onshore and bounded to the east and west by large transform faults defining plate boundaries. It is oriented in the east-west direction with a total length of more than 900 km long. The distance from the accretionary front to island arc volcanic (the Bazman, Taftan and Sultan) is about 500-600 km. The island arc volcanics are located where the subducting plate is at approximately 100 km depth. But there are no indications of active volcanism or intrusions in the accretionary complex. The subducting plate has a northward dip of >20 till 270N, then bending down to an angle of approximately 300. Oligocene-Present ocean ward coastline regression is ~250 km; i.e. 6-10 km/my (Ahmed 1969). The accretionary complex is being cut by north-south, northwest-southeast and northeast-southwest oriented wrench faults. The thrust faults are oriented nearly perpendicular to the direction of convergence as shown in Figures 3 and 4.
There is no obvious topographic trench associated with the present accretionary front. This could be related to a thick sedimentary cover of terrigenous sediments as mentioned above. In addition, there are no obvious magnetic anomalies related to ocean floor spreading in the Oman Sea. The earthquake activity is low and majority of the small and moderate earthquakes appear to be associated with the above-mentioned wrench faults. Earthquake fault plane resolutions show predominantly shallow northward dipping thrusts, with dips increasing northward, away from the accretionary front.

3.1 Seismic expression

Seismic expression of main structural elements based on seismic reflection data has been shown on Figures 3 and 4 for east and west Makran, respectively. The lengths of the seismic profiles are different. In addition the Figure 3 is depth migrated seismic section so the dips shown are more closely resemble the actual values, while the Figure 4 is time migrated and the dipping geometry is apparent. As it can be seen from the figures, the main structural

elements are similar on both east and west side of the Makran region, despite their different seismological behaviors. In these figures, for example northward dipping thrust pack is easily detectable within the accretionary prism. Also, the southward converging reflectors beneath the abyssal plain representing north side dipping geometry of the underlying oceanic crust.

4. Seismicity

In Makran, the oceanic crust of the Oman sea subducts with a very low angle beneath the Eurasian plate. This subduction zone exhibits different seismic behavior from the west to the east. The eastern Makran experienced large earthquakes and currently shows very low seismic activity (Ambraseys and Melville, 1982).

The most recent instrumentally recorded earthquake occurred in eastern Makran in 1945, which generated a tsunami that affected the coasts of Iran, Pakistan, Oman, United Arab Emirates and India (Pendse, 1946; Ambraseys and Melville, 1982; Byrne et al., 1992). Due to a difference between the origin time of the earthquake and the arrival of the tsunami, the latter being delayed by about 30 minutes at locations within the rupture zone (Bilham et al., 2007), so there is speculation that a submarine landslide may have been an important contributor to the tsunami excitation.

The western segment lack any significant event, but it may have witnessed the occurrence of a large onshore earthquake in 1483 (Ambraseys and Melville, 1982), although recent work suggests that a moderate event has occurred in the vicinity of Qeshm Island near strait of Hormuz. This event may have been incorrectly associated with a separate event in the

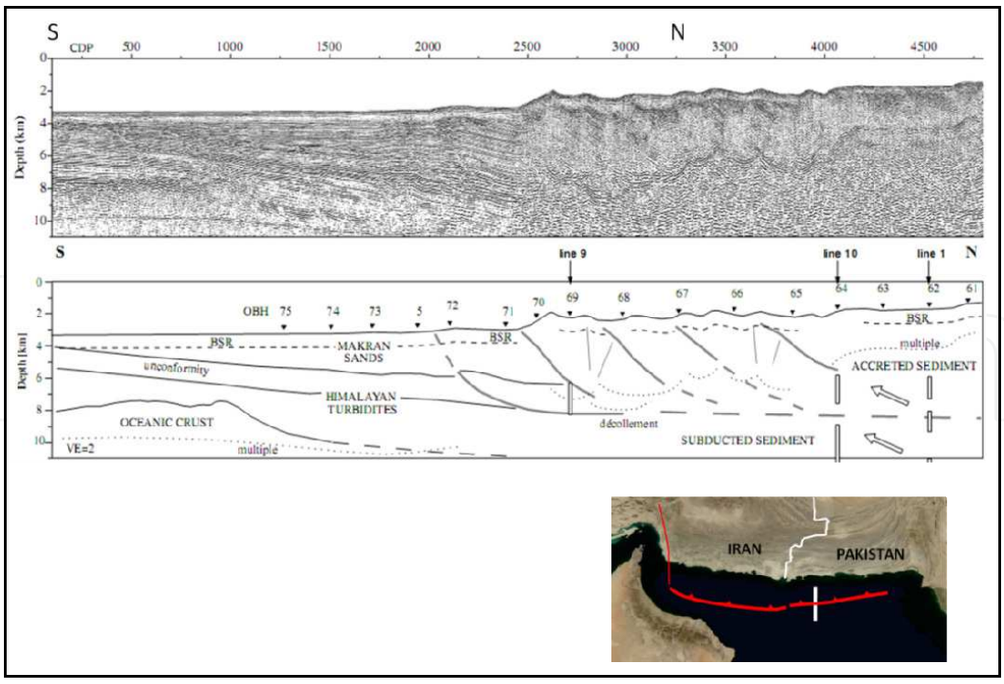


Fig. 3. The offshore seismic reflection profile in the Pakistani side of the Makran and it interpretation as line drawing below. The seismic section is depth migrated. The location of the seismic profile shown on the index map at the right corner (from Kopp et al. 2000).

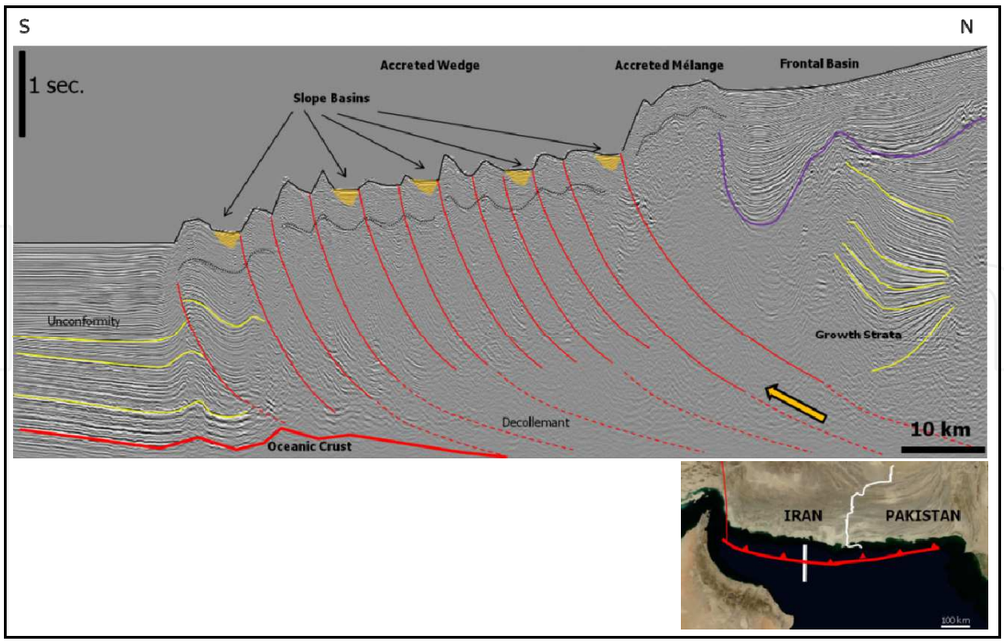


Fig. 4. The offshore seismic reflection profile in the Iranian side of the Makran and the interpretation is superimposed as line drawing on the seismic section. The seismic section is time migrated. The location of the seismic profile shown on the index map at the right corner. The yellow arrow indicates the displacement direction (modified after Mokhtari et al. 2008).

Zagros region (Musson, 2008). Despite the above fact, the lack of major earthquakes in the western segment means either the segment has been locked for hundreds of years or this segment is creeping aseismically. However, the regional GPS measurements indicate a convergence rate of about 2 cm/year (Bayer et al., 2006). In addition, the existence of Holocene (10000 years) marine terraces (Page et al., 1979) indicates that this segment is active, although the recurrence period of megathrust earthquakes events may be much longer (i.e. thousands of years).

4.1 The Persian Gulf seismicity

The Persian Gulf with a maximum depth of only 60m and not being in the subduction zon, has little chance of being a tsumanigenic zone. Nevertheless, there is a non-conclusive record of 1008 A.D. in the Siraf area within the Persian Gulf where inundation has been reported. This may have caused generation of waves, as a result a number of ships were sunk, with the loss of life. In addition, many people were killed when "the sea inundated the land" McEvilly and Razani (1973). Although, Ambraseys and Melville (1982) concur on the loss of several ships, they state that there is no evidence of waves inundating the land. Other records show that high winds affected the region during the same time period, thus the reported flooding and destruction of ships could have been caused by storm surge.

It is important to mention a similar more destructive 978 A.D. earthquake occurred in the same location shows no record of wave generation (McEvilly and Razini, 1973;Ambraseys and Melville, 1982). It is therefore, possible that the reported waves may have been generated by an earthquake triggered coastal landslide. Although the historical records do

not indicate that one occurred in conjunction with this particular event, or any other earthquake in the Persian Gulf region. Given the fact that wave activity was only reported in the earthquake's epicentral region, the implication is that this event was localized and if a tsunami was indeed generated, its energy was quickly attenuated, given the shallowness of the Gulf.

4.2 The Oman Sea seismicity

The following historical and instrumental tsunamigenic events have been reported in the Oman Sea. The first historical even occurred in 325 B.C. in the Port of Alexander (Near present day Karachi, Pakistan). A large wave believed to be a tsunami, damaged the Macedonian fleet of Alexander the Great while at anchor east of the present day Karachi. The damaging waves probably originated in the same source region (east) as the destructive 1945 Makran tsunami. Its effects on the Makran region would likely have been similar to those in 1945 event.

In 1851 a large event occurred in the eastern Makran, Pakistan. The event has occurred west of 1945 tsunamigenic earthquake but with no details as to whether a tsunami was generated (Okal et al. 2006). However, given the proximity of this event to the 1945 tsunami source, it is possible that a tsunami was generated.

The most recent tsunamigenic event occurred in western Makran, Pakistan at 03:26 IST (Indian Standard Time) on 28 November 1945 with a magnitude of 8.1 (Berninghausen, 1966; Quittmeyer and Jacob, 1979; Ambraseys and Melville, 1982). It is the only large earthquake that recorded instrumentally, which allows to be used as validation in modeling and simulation. The earthquake was felt in Karachi, Pakistan, where ground motions lasted approximately 30 seconds, stopping the clock in the Karachi Municipality Building and interrupting the communication cable link between Karachi and Muscat, Oman (Omar, 2005). Ground motions were felt as far away as Calcutta, on the eastern side of the Indian subcontinent (Ambraseys and Melville, 1982; Byrne et al., 1992; Pacheco and Sykes, 1992; Pararas-Carayannis, 2006; Omar, 2005). The damage from the earthquake was great, but the greatest destruction to the region was caused by the tsunami that was generated. Tsunami waves "swept the whole of the Oman Sea coast" (Berninghausen, 1966). It is estimated that 4,000 people were killed.

5. Tsunami risk assessment

The term tsunami risk refers to the potential risk of coastal community due to the occurrence of tsunami, including the physical, human and economic losses. The assessment of that risk depends on the: 1) vulnerability of the exposed buildings and infrastructures; and 2) the level of the community's preparedness which has high impact on the human and economic losses due to tsunami, as it has been formulated by the following convulsion relation:

$$\text{Tsunami Risk} = \text{Tsunami Hazard} * \text{Vulnerability} * \text{Exposed assets} / \text{Preparedness}$$

5.1 Tsunami hazard

Tsunami hazard in Oman Sea is mainly due to the occurrence of the near-field earthquake in Makran region; as well as far-field earthquake such as 2004 Sumatra earthquake that had caused tsunami in the region, recorded on the tidal gauges (personal communication) in Chabehar coast, with no report of any major damage.

A tsunami generated in the region could reach the Iranian and Pakistani coast under 15-20 minutes and Arabian Peninsula within an hour (Figure 5). In this calculation, a tsunami assumed to occur in the close vicinity of the 1945 tsunamigeneic earthquake and with the same parameters. Such a tsunami can propagate in any direction and thus, dependent on the location of the source, path of propagation and near-shore morphology form a risk to any vulnerable coastline surrounding the area.

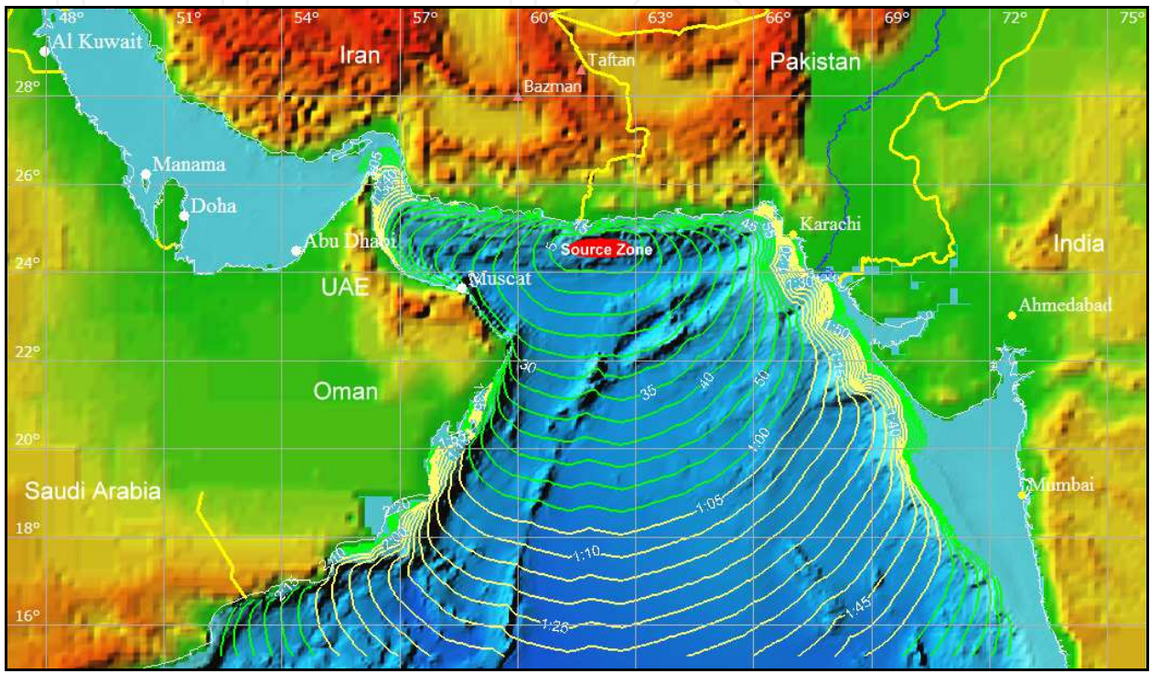


Fig. 5. Shows the tsunami travel time in the North West of Indian Ocean, the isoclines intervals are 5 minutes (based on modeling program winITDB/PAC package).

In this context tsunami risk maps in the region in a rather regional sense has been prepared and will be discussed in the following section.

5.1.1 The Oman Sea

Several tsunami hazard assessment has been done for the Makran region such as Mleczko et al. 2009, Heidarzadeh, et al. 2010, Rafi, et al. 2010. Here the result of Mleczko et al. 2009 has been presented due to its comprehensiveness and taking into account maximum feasible cases. Their approach consisted of the following steps: 1) Determination of the earthquake source zones; 2) identification of the probability of occurrence of earthquake; 3) Simulation of the tsunami based on synthetic earthquake and estimation of the maximum tsunami amplitudes that result from each case at selected locations; and 4) calculation of the probability of occurrence of a given maximum tsunami amplitudes. The result are being plotted as "low" and "high" hazard in an integrated manner to cover the Makran region.

The main differences between the two cases are the size of the maximum earthquake that is possible to occur in the region. In the case of the low hazard, the Wells and Coppersmith (1994) empirical relationship assuming full length and half width of eastern

Makran and for the high hazard the maximum earthquake with magnitude of 9.2 to occur using the full length and width of the entire subduction zone have been used. The 1945 tsunamigenic earthquake has been used as validation of the result for the low case. Meanwhile, as there is no certain and reliable record in the western side of the Makran region, the low hazard has been eliminated by Mleczko et al. 2009. Probabilities were assigned to each of the synthetic events (low and high) using the historical record and the available geophysical information. The most important factors controlling the earthquake probability are the rate of convergence across each segment, the overall global rate of earthquake occurrence at subduction zones observed historically and the maximum magnitude assumed for this zone.

Numerical computations had been performed to simulate the propagation of tsunami waves from the earthquake source zones to the model output points (Mleczko et al. 2009). The results of these simulations were used to estimate the maximum tsunami amplitude at each model output point due to each synthetic earthquake.

Table 1 shows the expected maximum tsunami amplitude with probability of exceedance of 1 in 2000 (return period of 2000 years) for any point in the affected area.

Impacted coast	Low Hazard (m)	High Hazard (m)
Iran	0.15-0.50	0.9-3.0
Oman	0.15-1.0	0.6-3.0
Pakistan	1.0-2.0	0.5-3.0
UAE	0.15	1.00

Table 1. Expected maximum tsunami amplitude for the probability of exceedance of 1 in 2000 (return period of 2000 years) for Makran subduction zone.

The assumed source zone in the Makran region for low hazard case and the maximum expected tsunami amplitude for each nation facing the source zone are shown in Figure 6. Whereas, Figure 7 shows the source zone in the Makran region for high hazard and the maximum tsunami amplitude expected to impact the coastal region. Summary of hazard assessment for Iran, Pakistan, Oman and United Arab Emirates coastal area has been discussed.

The 2000 year maximum amplitudes offshore Iran are quite uniform, but is slightly higher in the west than in the east as shown in Figure 6. For the high hazard case the maximum amplitude is around 3.0 m (Figure 7).

The hazard in the offshore Pakistan has a great deal of variability in the low hazard map (Figure 6 and Table 1). In the case of high hazard, the maximum exceedence amplitude for western Pakistan is much higher than that for eastern Pakistan (Figure 7). The offshore Oman the maximum amplitudes increase from south to north (Figure 6). In the high hazard assessment the hazard off northeast Oman which directly faces the western Makran is significantly larger than any other part of the Omani coast (Figure 7 and Table 1).

The offshore United Arab Emirates the hazard low case everywhere quite low (Figure 6), while the hazard from the high hazard assessment was noticeably higher (Figure 7 and Table 1).

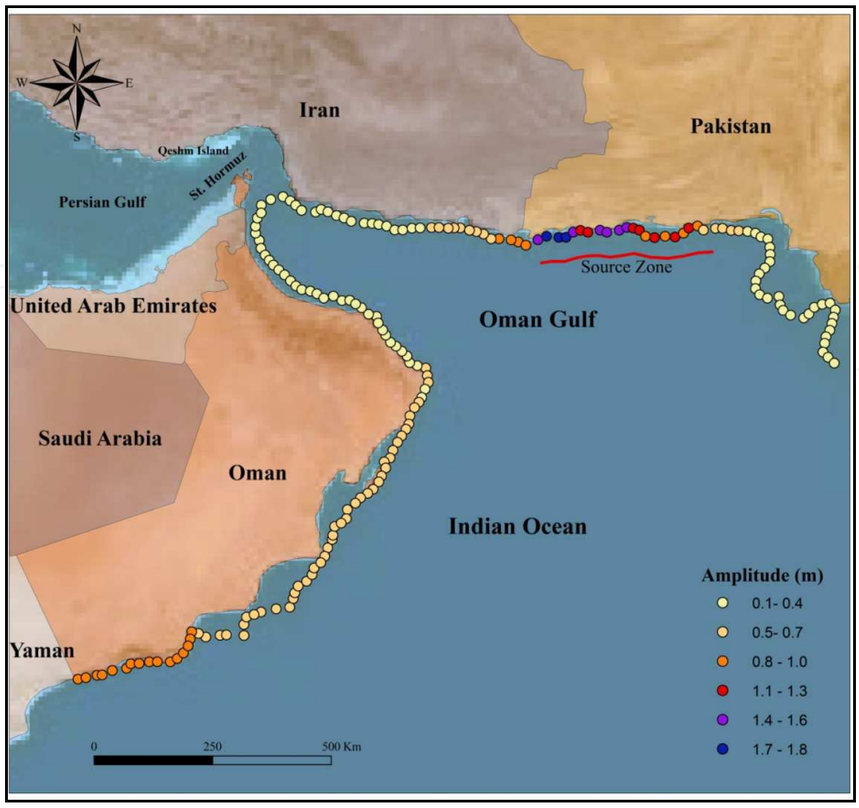


Fig. 6. Integrated "low" hazard map for the Makran region, also the source location has been shown. The dots show the 2000-year maximum amplitudes (modified after Mleczko et al. 2009).

It is important to note that due to quality and resolution of the bathymetric dataset (two arc minutes) used, the result on the modeled tsunami amplitude in the vicinity of shoreline must be interpreted with caution. It is also important to emphasize that the results presented here should not be directly used on onshore inundation, run-ups or damage assessment. Such phenomena are strongly dependent not only on the offshore tsunami height, but also on factors such as shallow bathymetry and onshore topography. A study of inundation therefore requires detailed bathymetric and topographic data and involves even more intensive numerical computations than those discussed here.

5.1.2 The Persian Gulf

Although the onshore of the Persian Gulf is a tectonically active region, most of the earthquakes take place inland, away from the coasts. With the exception of the 1008 A.D event, which is not conclusive (as it may have been the result of storm surge)?

There is no direct record of 1945 tsunami in the Persian Gulf, but at the Ras al-Khaimah, United Arab Emirates, there was a large sandbar that ships use to transport goods over. It was noted that sometime before 1964 this bar was breached by a "tidal wave", which formed a direct channel from the open sea to the harbor (Jordan, 2008). Ambraseys and Melville (1982) have suggested that this wave was associated with the 1945 Makran tsunami. It is important to note that, it seems that Musandam Peninsula in the Strait of Hormuz can play as a buffer in protecting the Persian Gulf from Tsunami effect even from Makran region.

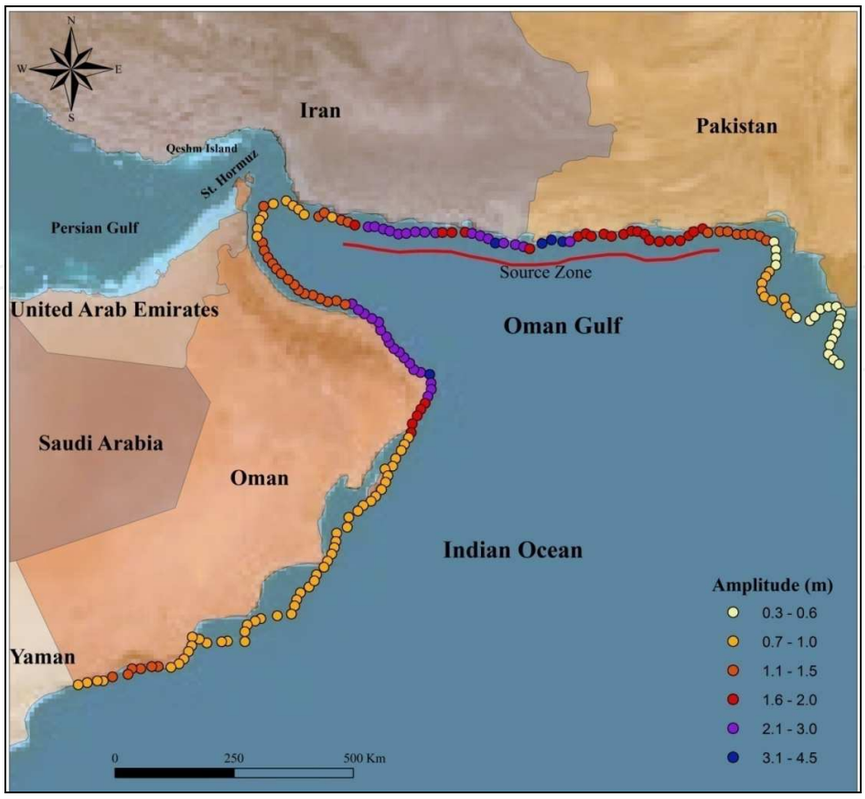


Fig. 7. Integrated "high" hazard map for the Makran region, also the source location has been shown. The dots show the 2000-year maximum amplitudes (modified after Mleczko et al. 2009).

6. Prevention and recommendation

Risk posed by tsunami in addition to its destruction could also cause flooding, contamination of drinking water in the coastal region, fires from ruptured tanks or gas lines and loss of vital community infrastructures, etc. In this regard one should not forget that a local tsunami generally produces run-up significantly higher than that of a distant generated tsunami, provided that the source earthquakes were of similar magnitude. Therefore, the tsunami waves produced in Makran may be more destructive along its coasts. For such cases, one should think of natural preventive measure. In this respect, the effect of tsunami can be minimized on flat coastal plains area by planting tree belts and mangrove plant between shorelines and areas needing protection. In addition, manmade marine structures, such as barrier wall could be considered if economically and practically is feasible.

A monitoring system for acquisition of seismic signal and water level displacement simultaneously (Tidal Gauge) must be installed in the region of the selected area. Figure 8 shows the seismic stations distribution in the region. But the key elements in this regard is the integration of data gathering, analysis and local and regional distribution of analyzed result in timely manner to be able to reach the potentially effected nations. In addition at least two tsunami-meters should be installed in the region for prevention of false alarm and tsunami generation and identification.

In addition, implementation of national education and training programs about tsunami hazard is vital especially in the case of near field tsunami such as Makran. In this way, the damaging effect of a disaster could be minimized.

The role of governments of the region is of utmost importance for proper implementation and application of above-mentioned information. In addition, the modeling and tsunami simulation should be conducted using regional and local bathymetric information to be used for the early warning purposes by trying many different possible scenarios.

The effectiveness of an Early warning system also depends on the timely communication of warnings to communities, businesses and households at risk. If information on impending hazard events, risk scenarios and disaster preparedness strategies fails to reach those at risk on time, then an early warning system will have failed *a priori*. The development of national and local capabilities for early warning system must therefore include the design and implementation of communication strategies, taking into account both the content and form of warning information and the media used to communicate with those at risk.

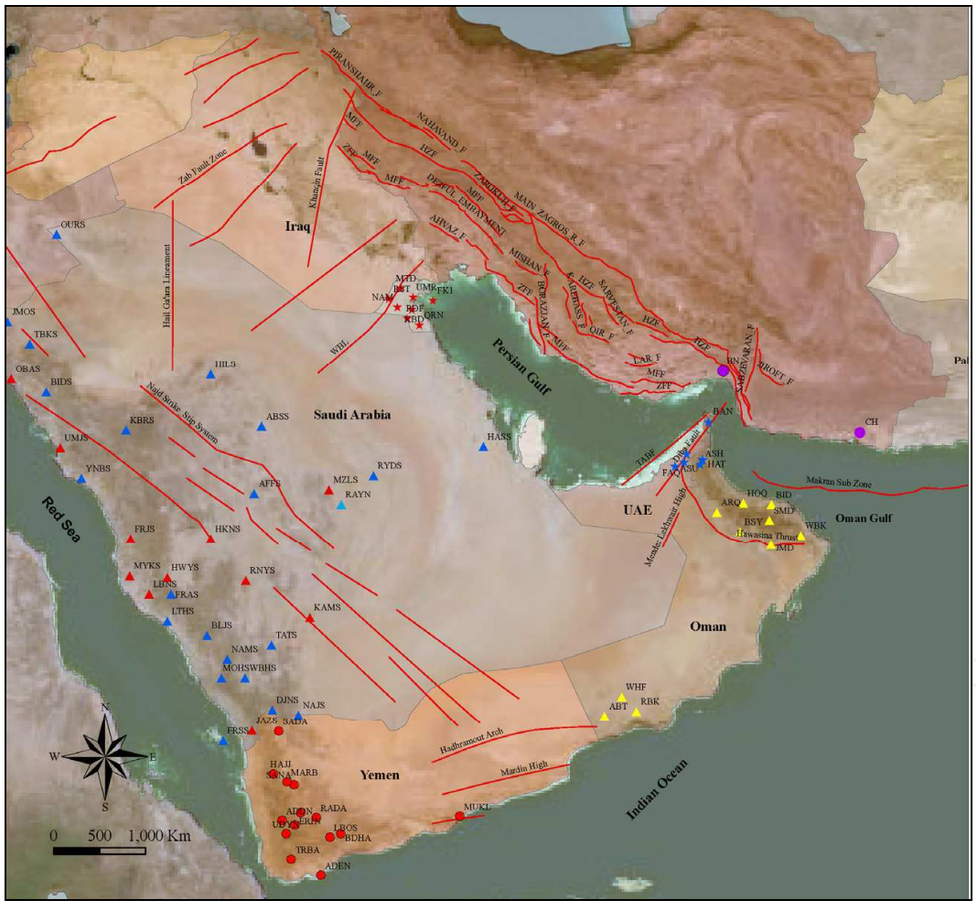


Fig. 8. Seismic station distribution in the region complied from seismic networks of, Iran, Oman, UAE, Saudi Arabia and Yemen (websites and personal communications)

Effective tsunami early warning system also requires the existence of institutional capacity for warning, risk analysis, disaster preparedness and communication at the local level. As mentioned above, given the need to generate high resolution risk scenarios and to develop appropriate preparedness and communication strategies, targeted at specific vulnerable

sectors and groups and given the need to involve these sectors and groups in early warning system design and implementation, the local dimension is fundamental to the overall early warning system goal of transforming hazard warnings into risk reduction.

7. Conclusions

There are only a few recorded tsunami events that have affected the Makran region. The most recent and destructive one is the 1945 event that has affected the region and caused both human and property losses in Iran, Pakistan, Oman and United Arab Emirates. It is important to note this conclusion is based on the historical events, if a paleotsunami investigation being conducted in the region, this conclusion might be revised.

There is an uncertain tsunami event in the Persian Gulf that was small and localized. Given the shallow nature of the Persian Gulf and the lack of confirmable tsunami events in the past, it can be concluded that the risk of tsunamis (although active, due to its proximity to Zagros) in the Persian Gulf is very small. On the other hand, the effect of Makran tsunami on the Persian Gulf due to recent population and industrial growth should not be ignored.

Over the past 15 years, there has been enormous progress in the understanding of tsunami generation, propagation and inundation. While the timing and source of a tsunami are not predictable, modeling technology now exists to effectively predict tsunami propagation, and to a lesser extent inundation, given a known source mechanism. The tsunami modeling in the Makran showed the expected tsunami amplitude in the coastline of the northwestern Indian Ocean in the case of "high" hazard model could reach up to 3.5 meters.

This progress should be translated into sound approaches to prepare communities (from coastal planners and emergency responders to the general population) for the event of a tsunami. Preparation should be focused on the priority of saving human lives. The detail maps (locally suitable) of predicted inundation, for a range of source scenarios, should be produced for courtiers in the vicinity of the Makran subduction zone, namely, Iran, Pakistan, Oman and United Arab Emirates to be a basis for coastal zoning, future coastal construction and also for planning of evacuation routes.

The public education especially in case of near-field hazard such as Makran is vital in risk and vulnerability reduction. People who live in coastal settings should be provided with timely and reliable information on the risks of that environment.

Although there is small chance for tsunami generation in the Persian Gulf and in addition the Musandam Peninsula in the Strait of Hormuz can play as a buffer in protecting this area but the effect of large tsunami in the Makran region should always be considered as serious threat to this region.

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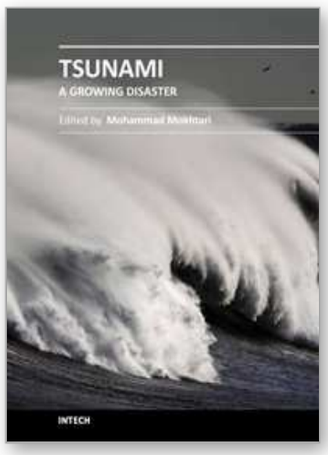
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The objective of this multi-disciplinary book is to provide a collection of expert writing on different aspects of pre- and post- tsunami developments and management techniques. It is intended to be distributed within the scientific community and among the decision makers for tsunami risk reduction. The presented chapters have been thoroughly reviewed and accepted for publication. It presents advanced methods for tsunami measurement using Ocean-bottom pressure sensor, kinematic GPS buoy, satellite altimetry, Paleotsunami, Ionospheric sounding, early warning system, and scenario based numerical modeling. It continues to present case studies from the Northern Caribbean, Makran region and Tamil Nadu coast in India. Furthermore, classifying tsunamis into local, regional and global, their possible impact on the region and its immediate vicinity is highlighted. It also includes the effects of tsunami hazard on the coastal environment and infrastructure (structures, lifelines, water resources, bridges, dykes, etc.); and finally the need for emergency medical response preparedness and the prevention of psychological consequences of the affected survivors has been discussed.

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