Seismic Hazard in Iran

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EARTH-390

NATURAL HAZARD POLICY

1 INTRODUCTION

Located in the Alpine-Himalayan orogenic belt, Iran is a seismic country. Seismic hazard in Iran, consequently, has been the subject of many debates both among scientific communities and societies. With a more than 75 million population in 2011 (Fig. 1), most which live in cities close to seismic zones (Fig. 2 and Fig. 3), careful study of Iranian seismic hazard is of utmost importance.

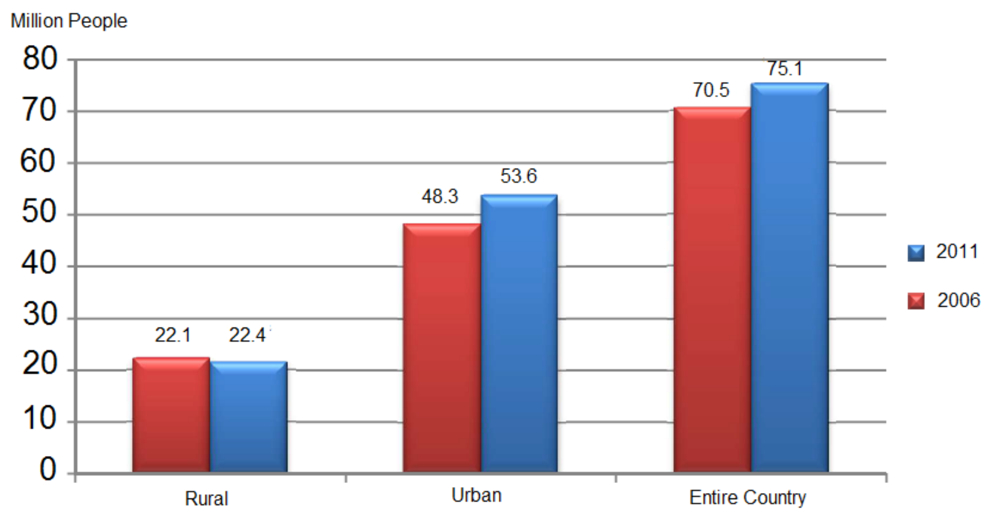


Figure 1. Population distribution of Iran in 2006 and 2011. Results from the Iranian national census. (Statistical Centre of Iran, 2011)

According to official and unofficial records, over the past 35 years, more than 100,000 people have lost their lives as a result of earthquakes in Iran. A comparison between this number and other loss figures in Iran, along with responsible, scientific considerations on the seismic hazard in the country can lead to a valuable, realistic insight about the level of seriousness of the issue.

In this study, we are going to address the above question on an introductory level.

Figure 2. Position of Iran in the Middle East and distribution of some of its major cities.

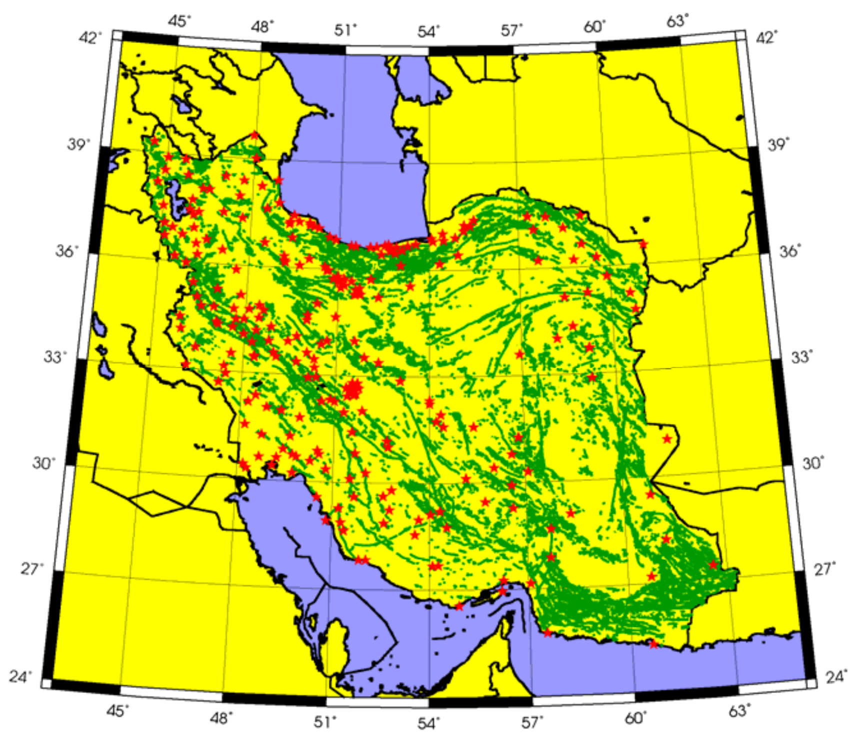


Figure 3. Iranian Quaternary fault systems (data from Geological Survey of Iran [GSI]) shown with green lines. Major cities are shown with red stars.

2 IRAN: A SEISMIC COUNTRY – GENERAL PERSPECTIVE

Position of Iran in the Alpine-Himalayan seismic belt (Fig. 4), puts the country in a reasonably explained framework. This level of seismicity (Fig. 5) is a result of the present convergence of the Arabian plate and Iran (now a part of Eurasia) in a continental collision (resulting in the Zagros mountain range). The Iranian old micro-plate which is sandwiched between Arabia and the main Eurasian continent, giving rise of several bands of seismicity, including the Alborz Mountains at the southern coasts of the Caspian Sea.

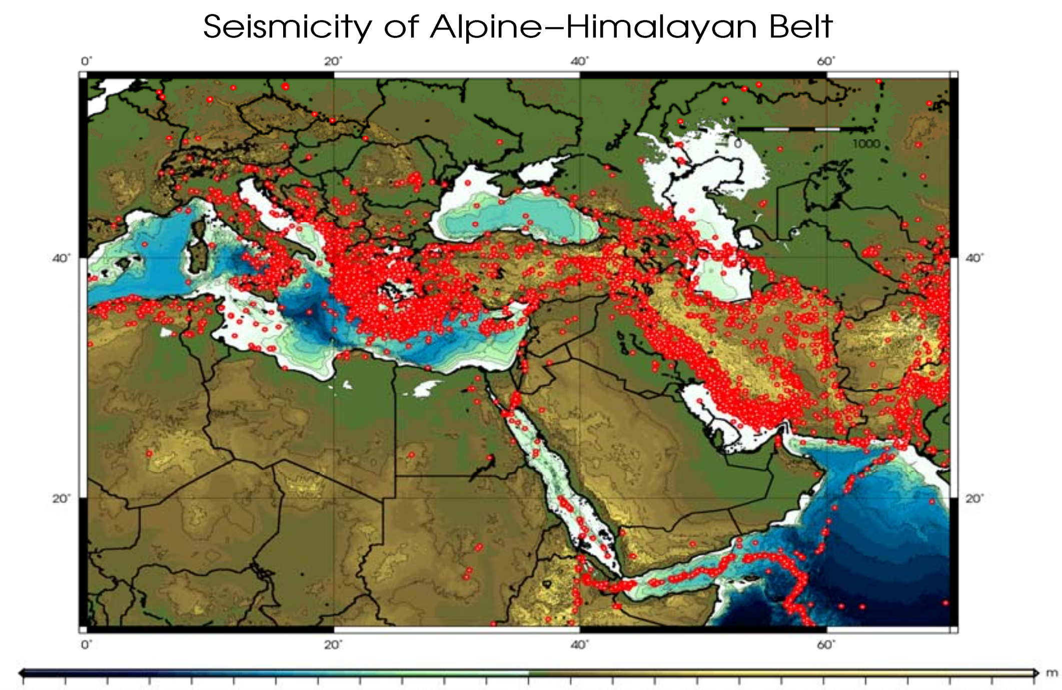


Figure 4. Seismicity of the Alpine-Himalayan belt. Topography data are from ETOPT2 (Amante and Eakins, 2009) and the seismicity data is from EHB (2008) for the period of 1900-2008.

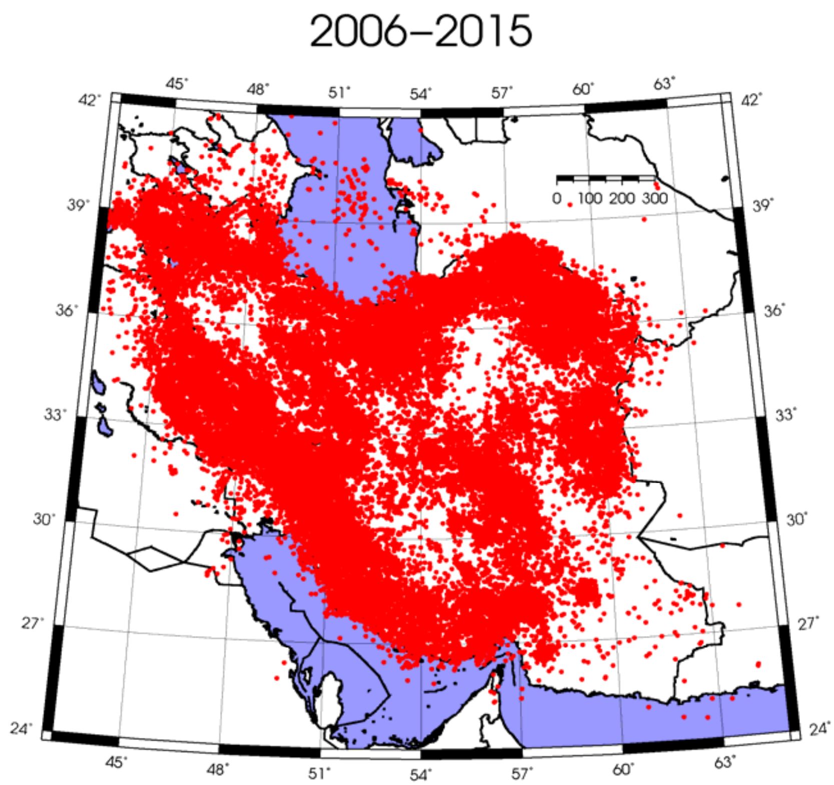


Figure 5. Seismicity of Iran. Data from Iranian Seismological Center (IRSC) for the period of 2006-2015.

3 EXPOSURE TO (NATURAL) HAZARDS

In order to acquire a better understanding of the level of seriousness of seismic hazards in Iran, it is useful to take a brief look at the exposure of the country to other types of natural hazards. A comparison of casualty figures helps us get a realistic feeling for designing hazard policies. A number of disastrous such hazards are listed Table 1. This endeavor is a bit smeared by the fact that there is not an official agency or institution in Iran responsible to gather and process or publish such information.

Table 1. Fatalities or damage caused by different hazards in Iran.

Hazard	Approx. Damage or Number of Fatalities
Traffic Accidents	20,000 people per year
Disease and Epidemics	50,000 people per year
Air Pollution	100,000 people per year
Floods	$60 million per year
Landslides	NA
Earthquakes	3,000 people per year

3.1 TRAFFIC ACCIDENTS

In the absence of official figures, the media have estimated the fatalities of driving accidents to be about 20,000 people each year (e.g. Alef News, 2012; Fig. 6).

3.2 AIR POLLUTION

Air pollution is a major cause of deaths in major cities in Iran. Tehran, in particular, is a polluted city (City of Tehran Publications, 2013). The reason for the bad quality of air in Iran could be sought in the geographic location of the city. Tehran is huge city, built on the southern slopes of the Alborz Mountains and extending far south to the central plains of the Iranian Plateau (Fig. 7). This results in the entrapment of CO, CO2, SO2, aerosols and other pollutants in the low-lying are (Fig. 7). Measurements of air pollution factors shows that, the concentrations of major pollutants is way above the standard threshold (Figs. 8a and 8b).

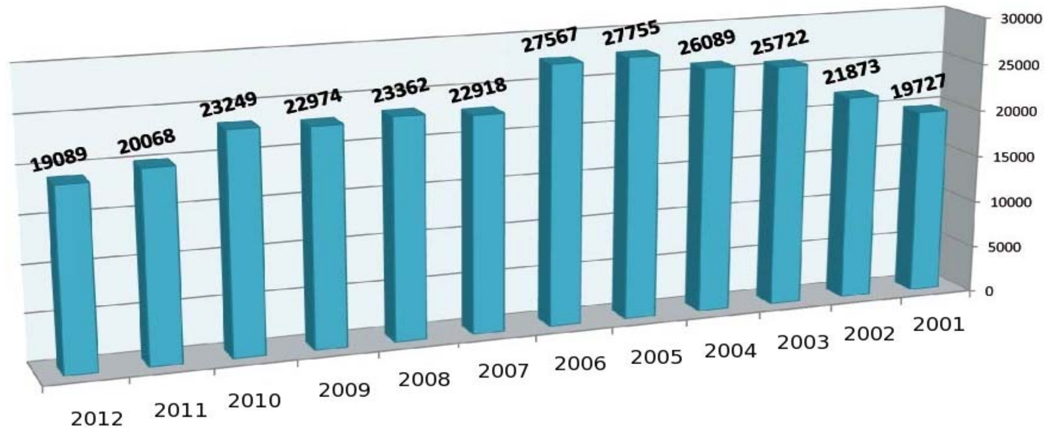


Figure 6. Number of fatalities due to driving accidents from 2001 to 2012 (Alef News, 2012)

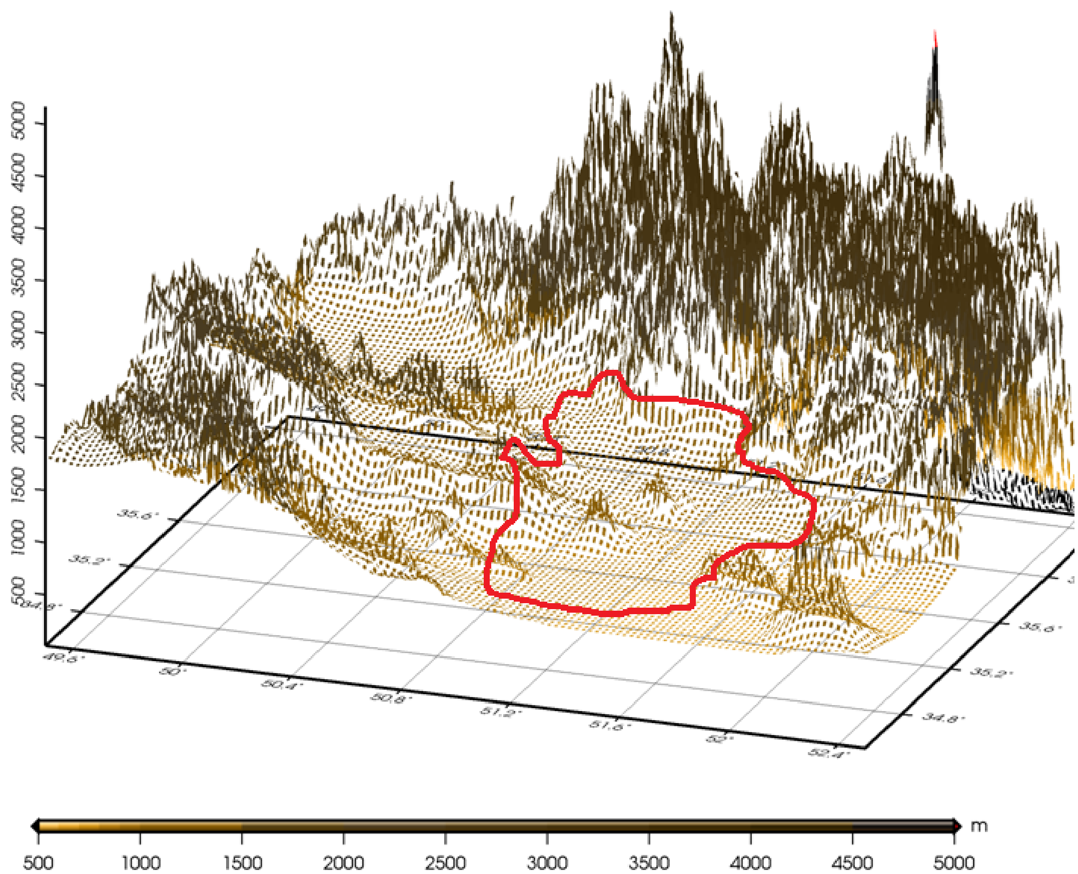
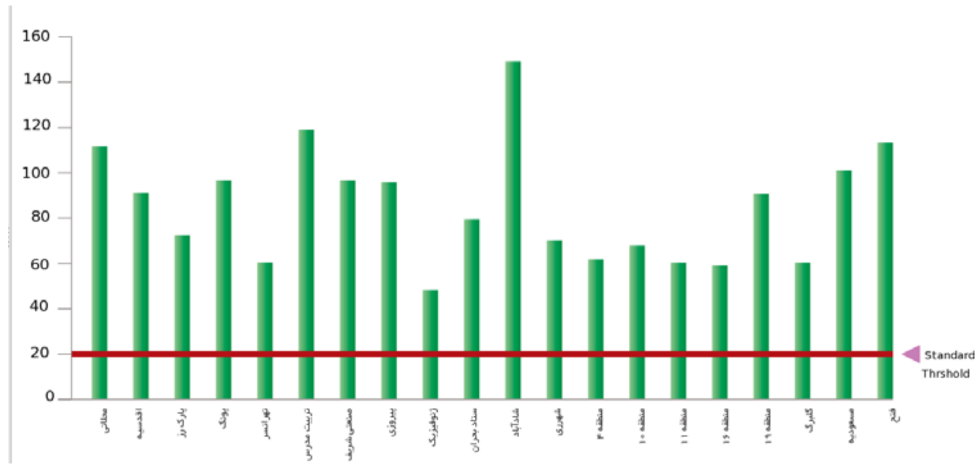
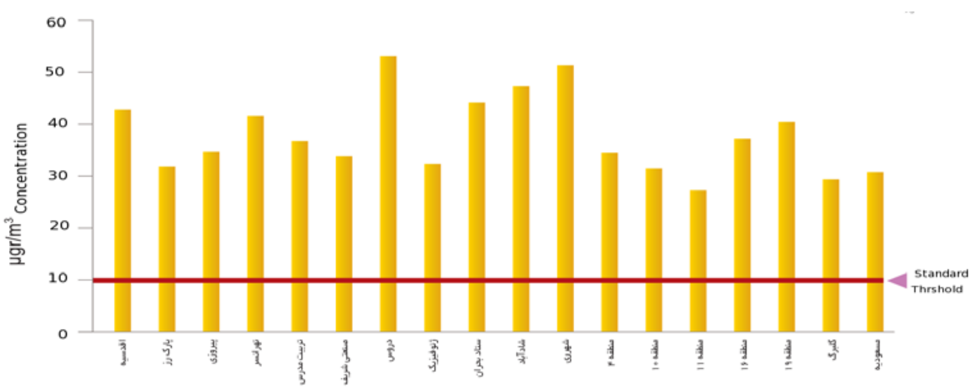


Figure 6. Topography of Tehran region. The red contour represents the boundaries of the main city (topography data from GEBCO, 2008).



(a)



(b)

Figure 8. Concentration of (a) carbon monoxide and (b) aerosols in 18 station in Tehran (Tehran Air Quality Control Center, 2013)

3.3 FLOODS

Unfortunately, there is no official data about the number of casualties caused by flooding in Iran. However, the annual damage due to floods seems to be increasing over years with an average of ~$62 Million every year (see Fig. 9).

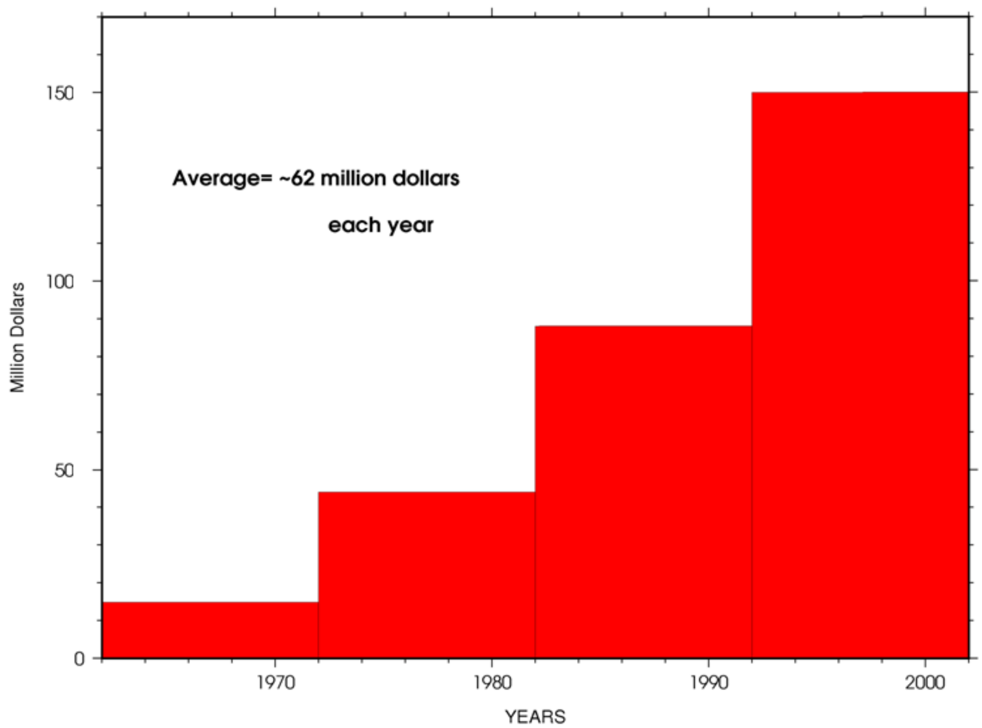
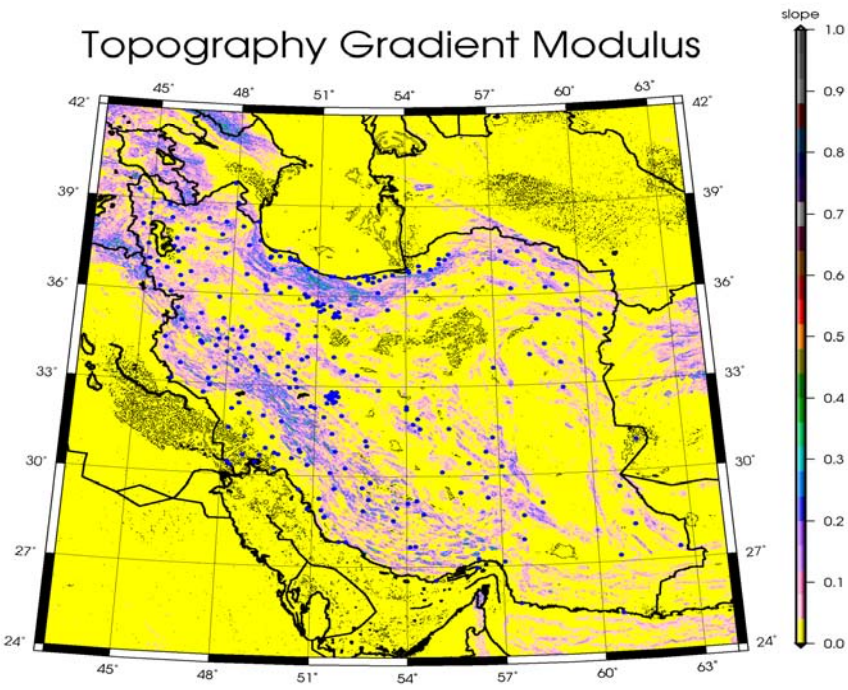


Figure 9. Approximate annual loss due to floods in Iran (Vatanfada, 2003).

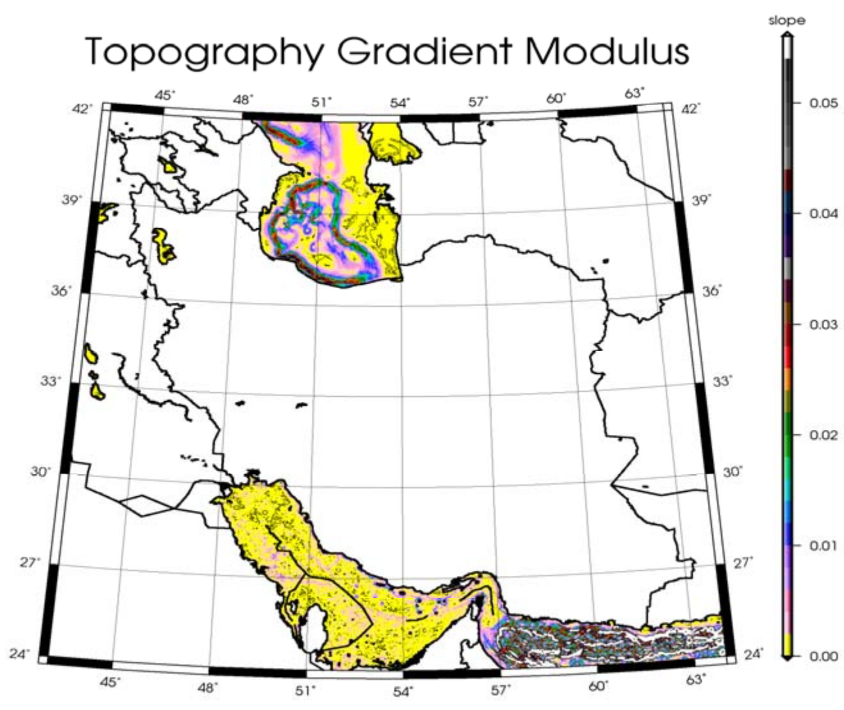
3.4 LANDSLIDES

Landslides are very common geological hazards in Iran, but unfortunately we could not find any official or semi-official figures for the fatalities or financial loss caused by landslides in the country.

Iran is a mountainous country and many of the major Iranian cities are built on mountain slopes (Figs. 4 and 10a). Submarine landslides (which usually happen at slopes of 3 to 6 percent (e.g. Skempton, 1953) can also happen in the proximity of Iranian coastlines (see Fig. 10b) and have caused local tsunamis (e.g. Salaree and Okal, 2015).



(a)



(b)

Figure 10. Slope distribution in the Iranian plateau. (a) Slope distribution on land with major cities (same cities as in Fig. 3). (b) Submarine slopes with a focus on 0 to 6 percent.

3.5 EARTHQUAKES

Unofficial figures show a total of ~100,000 casualties due to earthquakes in Iran over the past 35 years which translates to ~3,000 people each year. About ~80,000 of this number is due to the two major earthquakes over the same time period, i.e., Rudbar (20 June 1990) and Bam (26 December 2003) which leads us to believe that the annual average cannot be trusted and the annual average is closet to about 500.

4 SEISMIC HAZARD

A quick analysis on the data from Fig. 3 and Fig. 5 may lead us to believe that the seismicity pattern in Iran is more or less in agreement with the positions of active faults in Iran (Fig. 11).

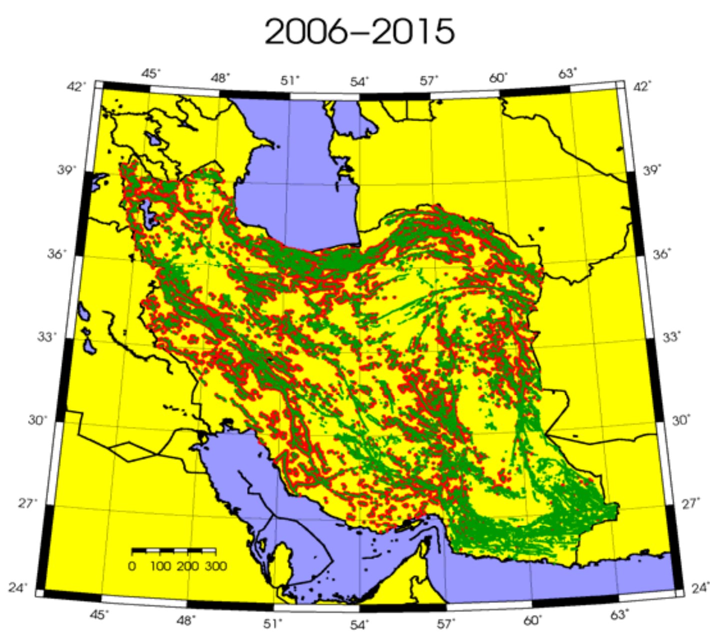


Figure 11. Epicenters of the Iranian earthquakes (2006-2015) which are within a 10km distance from faults (fault data and seismicity data are from GSI and IRSC, respectively).

Nevertheless, another look at Fig. 5 will reveal that, although the seismicity in the Iranian plateau follows a certain pattern, the geographic distribution of earthquakes is more or less sporadic and thus, such analyses cannot be useful in determining seismic hazard in Iran. Some studies (e.g. IIEES) have tried to make detailed seismic hazard maps for the country, however, they are more or less based on the same method (plus some other adjustments using shaking/acceleration data).

Another critical aspect of the failure of these models (as will be briefly discussed in 4.1-4.2) is the degree at which the earthquake locating process in Iran can be trusted. Iranian Seismological Center (IRSC) has currently 124 seismic stations in the country, 19 of which are not operational. These stations are divided into 18 subnetworks which are more or less positioned around major population centers. This has led many of other seismically important regions unattended to (Fig. 12) and therefore, the calculated distribution is to some extent an artifact of positioning of stations.

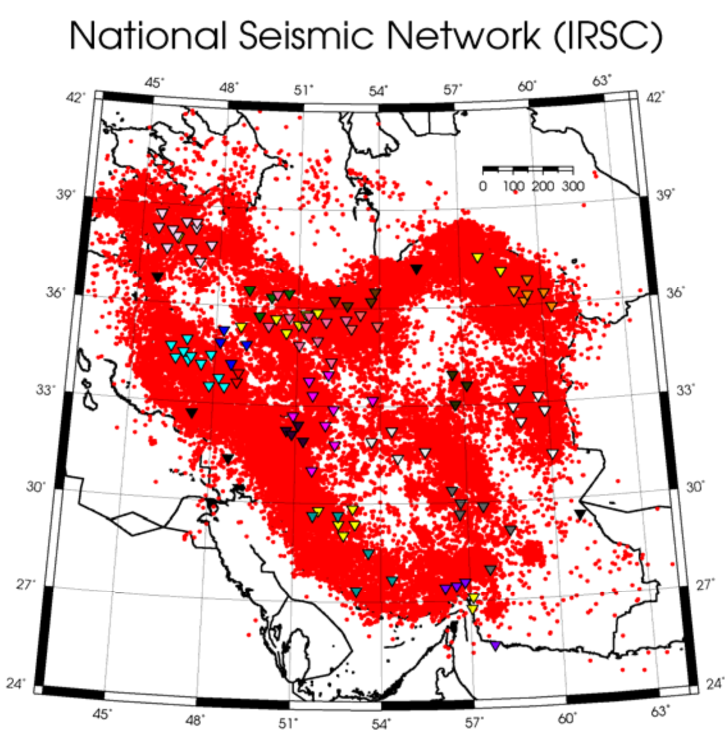


Figure 12. IRSC stations which are superimposed on a map of calculated seismicity of Iran.

This brings about the question of catalog completeness, which to some extent can be remedied using historical data (Fig. 13). Ambraseys and Mellvile (1982) in their monumental compilation of the major historical earthquakes of Iran, have identified over 400 earthquakes with considerable amount of details which can be used in obtaining a more realistic view of seismic hazard in the country.

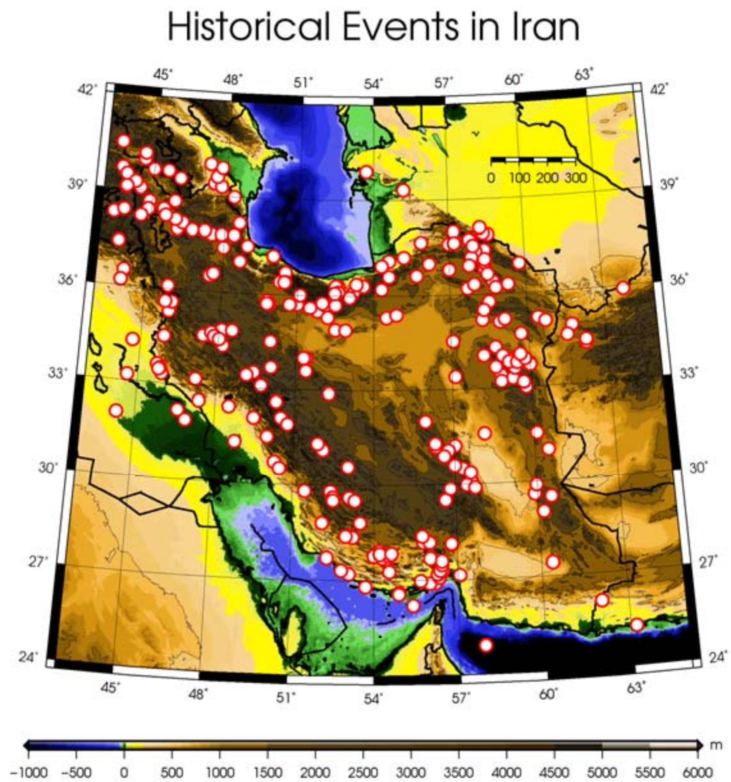
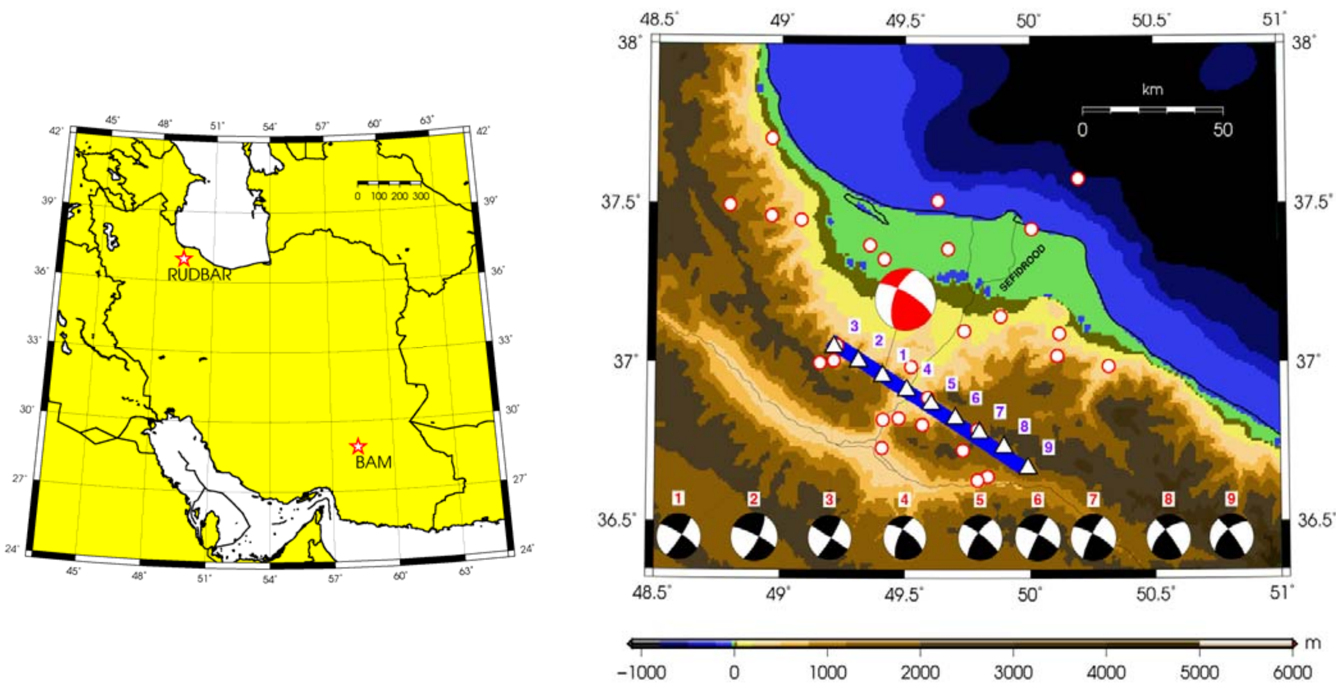


Figure 13. Approximate epicenters of historical earthquakes as inferred by Ambrayseys and Mellvile (1982).

With this level of knowledge about the seismicity pattern in Iran, we are, from time to time, surprised by major unforeseen earthquakes which result in great damage and huge number of casualties. Below we will briefly discuss three case studies which to some extent demonstrate this fact.

4.1 CASE STUDY 1: RUDBAR EARTHQUAKE (1990)

Rudbar earthquake, the greatest recorded seismic event in NW (Figs. 14a and 14b) of Iran (M_w=7.4) happened at midnight (local time) of 20 June 1990 and resulted in about 40,000 casualties and leaving a total of $7.2 billion of economic loss, mainly caused by earth structure (liquefaction) (Fig. 15a) and lack of construction codes (Fig. 15b)



(a)

(b)

Figure 14. (a) Epicenters for Rudbar and Bam earthquakes. (b) Map of the 1990 Rudbar earthquake with CMT mechanism (red beachball) and its aftershocks during the first 24 hr (red circles; from USGS). Also shown are the nine subevents (triangles) of Campos et al.'s (1994) model with respective focal mechanisms (indices referring to Table 3). The dark blue bar represents the length of faulting as used in the single event dislocation model (Salaree and Okal, 2015).

(a) (b)

Figure 15. (a) Liquefaction effect due to the 1990 Rudbar earthquake. (b) Poor construction resulting in great damage.

4.2 CASE STUDY 2: BAM EARTHQUAKE (2003)

Bam earthquake (M_w=6.6) happened at midnight of 26 December 2003 in SE Iran (Figs. 14a and 16). It resulted in the overall 40,000 fatalities mainly due to poor construction and unknown position of the fault (Figs. 17a and 17b).

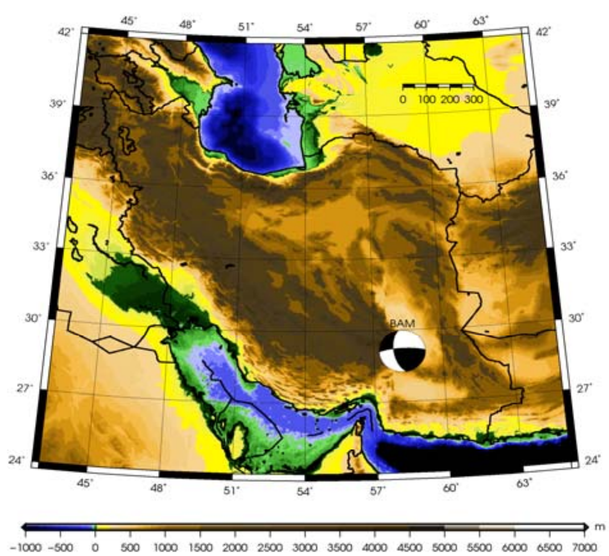


Figure 16. Epicenter and focal mechanism of the 2003 Bam earthquake.

(a)

(b)

Figure 17. Massive damage due to poor construction. (b) Bam citadel before (left) and after (right) the 2003 earthquake. The 2000 years old, mainly adobe complex is a good evidence that there has not been a major earthquake in this part of the country and that the fault responsible for this event was unknown.

4.3 CASE STUDY 3: THE CASE OF TEHRAN (????)

Tehran is the capital of Iran with a population of ~14 million people during daytime and is located within a belt of folds and thrusts (Fig. 18). It has been completely destroyed by major earthquakes (reaching M~8) at least twice during recorded history (Ambraseys and Mallvile, 1982).

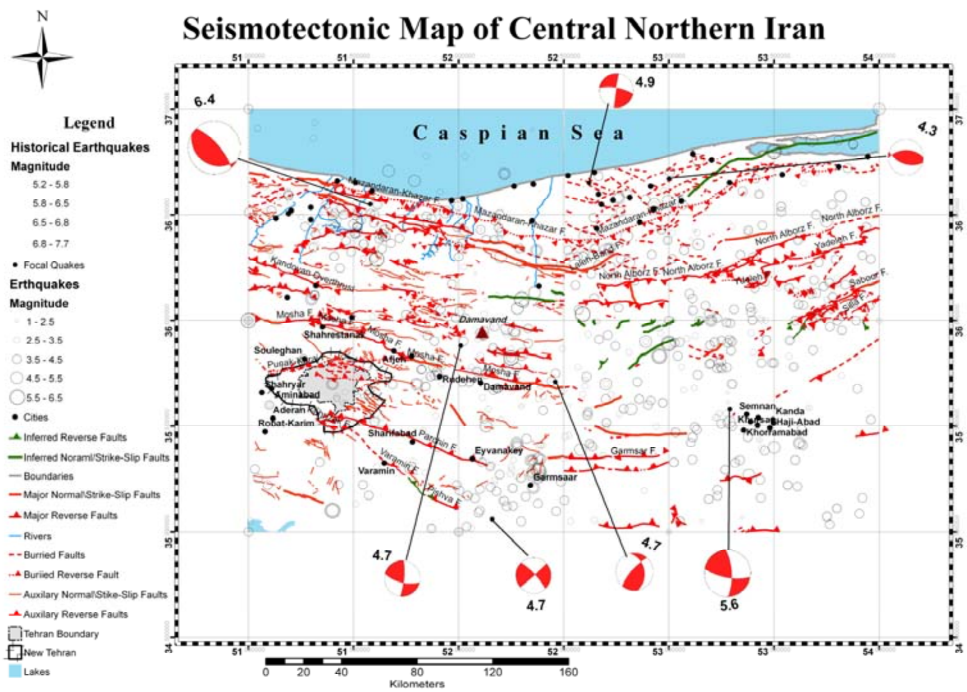


Figure 18. Seismotectonic map of central northern Iran. Tehran is depicted by the closed contours on the left (Fault System Data from GSI; Centroid Data from CMT (Ekström, et al. 2012) ; Epicenter Data from IRIS).

The controversy of a 150-year recurrence time for major earthquakes mainly results from a not-so-credible interpretation of historical events, basically extracted from the work of Ambraseys and Mellvile (1982). This stems from the a 150 year interval between the two major events on the same segment of the Mosha fault (see Fig. 18) in the NE of Tehran (Table 2).

Table 2. Destructive earthquakes in proximity of Tehran (Ambraseys and Mellvile, 1982)

Year	Approx. Magnitude	Years from the previous event
400 BC	7.6	0
743	7.2	1143
855	7.1	112
958	7.7	94
1177	7.2	219
1665	6.5	488
1815	? (great enough!)	150
1830	7.1	15

5 FINAL REMARKS

Iran is a very seismic country and seismic hazard must be considered seriously. Although the main portion of loss from earthquakes in Iran is due to poor construction techniques, it seems that our current state of knowledge about destructive earthquakes in Iran is also limited. Besides, since the number of fatalities due to earthquakes in Iran, as compared to those of other hazards, is small we can argue that instead of investment in major retrofitting the current structures, it is advisable to build new buildings following better codes (see Stein and Stein, 2014).

On the other hand, in the absence of a credible, reasonably complete dataset, we can treat *almost* everywhere in the country in the same way, and it seems reasonable to follow the same "good" guidelines everywhere.

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