Neotectonic and paleoseismicity data in seismic hazard analysis of the Bam earthquake

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Abstract: The town of Bam with geographical coordinates of about 59° in eastern length and 29° latitude lies in southeast Iran. The devastating Bam earthquake, with the magnitude of 6.5 on the Richter scale, occurred on December 26, 2003, killing about 28,000 people and injuring 25,000 people. It made 90% of residents in the town and its suburbs homeless, collapsing and devastating 85% of urban buildings and structures. Bam is located between the Lut and Jazmourian tectonic depressions. The Lut block, with Bam on its western edge, is surrounded by unstable faults that are often the source of seismic activity. Its western border is the Nayband fault. It is observed that this is a suite of strike-slip faults, and the fault series of 1978-2004 is one of the most obvious, which is observable on the ground. All segments of have been activated at some time, and this activity has developed from north to south, i.e. from Tabas city towards Nayband, then towards Shahdad and from there towards Bam.

Résumé: La ville de Bam avec des coordonnées géographiques environ de 59° dans le sud est oriental de mensonges de longueur et de latitude 29° de l'Iran. Le tremblement de terre dévastateur de Bm avec le magnitude de 6,5 sur l'échelle de Richter qui s'est produite décembre 26 2003 a causé le massacre d'environ 28000 personnes, enrouler de 25000 personnes. Il a fait au repos 90% des résidants dans la ville et ses banlieues sans foyer, s'effondrant et dévastant 85% de bâtiments et de structures urbains. Bam est située entre la grande Lut dépression tectonique et la dépression de Jazmourian au sud. Le bloc de Lut que la ville de Bam réside en son bord occidental a son frontière occidentale exécutée par le défaut de Nyband. Si nous étudions le mouvement et l'action du défaut de Nyband, on l'observe qu'il a éprouvé la segmentation de la grève - glissez le défaut, et censurer la série de 1978-2004 est un du type le plus évident de segmentation qui est observable sur la terre et n'importe quel segment de lui a été activé en même temps. Cette activité a été accomplie du nord au sud, c.-à-d. de ville de Tabas vers le pays de Nayband, et vers Shahdad et de là vers Bam.

Keywords: Bam, data analysis, earthquake, geological hazard, risk analysis, seismic risk.

INTRODUCTION

Earthquakes occur in narrow belt, where major earthquakes resulting from slip along a fault plane Iran is situated within the Alpine-Himalayan seismic belt and is characterized by high level of seismic activity (Fig. 1) The central part of Iran, particularly Kerman province and south of Khorasan, is characterized by a moderate to high level of seismicity and several complex seismotectionic environments. Movement of the African Plate towards the Touran Plate, pushes the Arabian Plate and southwest Asia, leading to the creation of faults and ruptures in the zone including Iran. Central Iran, especially the region of Tabas and Bam has a high density of Neogene and Quaternary faults, and frequent destructive earthquakes occur on reactivation of some existing faults at the surface.

Bam is located between two large tectonic depressions - Lut in the north and Jazmourian in the south. The two main tectonic elements, the Lut block and the zone of flysch, extend away from Lut and include part of the eastern state of Iran. The Lut block, on which Bam town lies at the western edge, is an extension with its northern zone surrounded with various unstable faults that create seismic activity. The Lut block extends more than 800 km from the Jazmourian depression northward towards Gonabad in Khorasan. Its average width is about 200 km. Its western border is an extended fault zone called the Nayband-Bam fault. Studies of the movement and action of the Nayband-Bam fault, show that it has experienced segmentation of a strike-slip fault. The fault series of 1978-2004 is one of the most obvious results, which is observable on the ground. All segments of the fault have been active at some time, and this activity has been developed in a sequence from north to south, i.e. from Tabas city, towards the Nayband area, and then towards Shahdad and onwards to Bam town.

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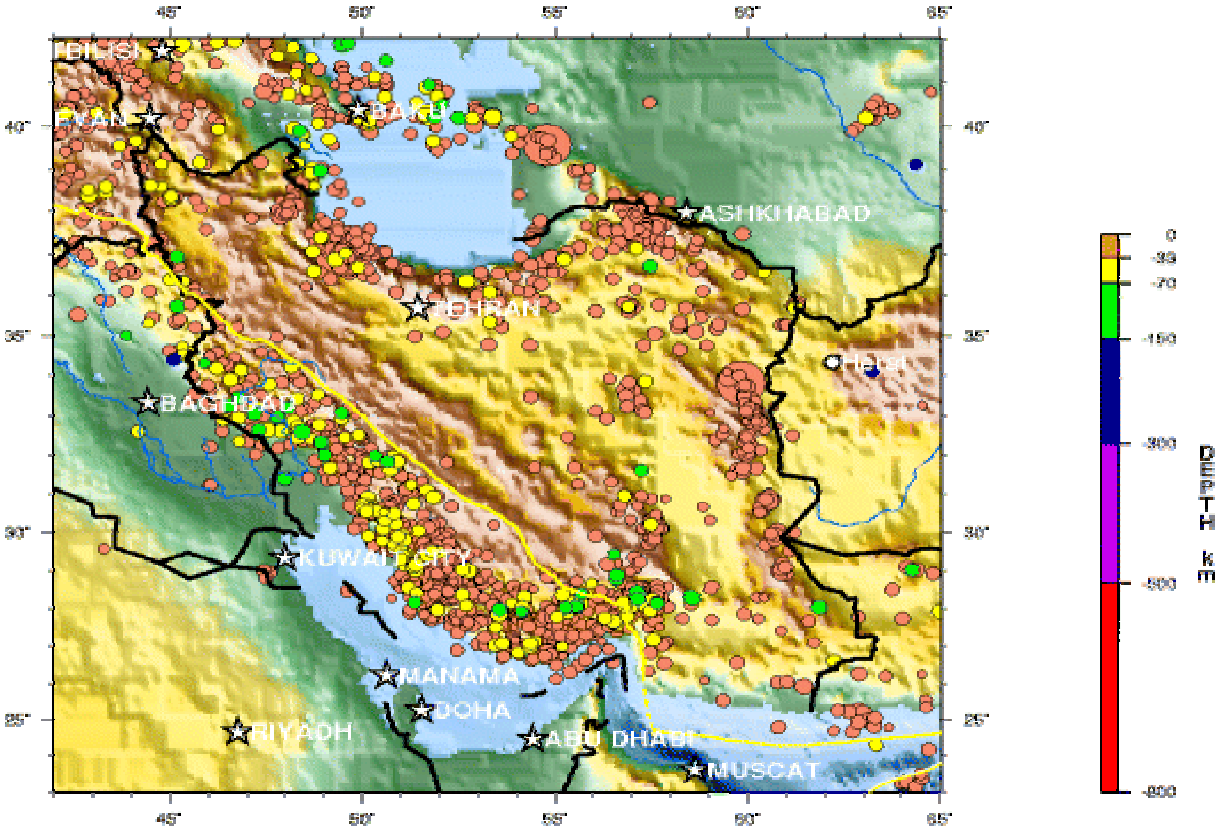

Figure 1. Distribution of large and moderate sized earthquakes that occurred between 1900 and 2000 in Iran.

Seismicity and paleoseismicity in southeast Iran

Unit the last few years, seismicity in Iran was mainly characterized through historical data, and instrumental data. For the last three decades, in such areas with strong and moderate seismicity and present-day deformation, this period of observation is certainly representative of long-term activity. It has therefore been necessary to implement new studies in order to define and analysis seismic events older than the historical period, i.e. paleoearthquakes. Paleoseismicity is the study of these ancient earthquakes using the traces they have left in the geological terrain - surface ruptures or paleoliquefaction (this paper refers only to surface ruptures).

Large parts of Iran are seismically very active. In highly seismic zones, paleoseismicity has been used for many years to fill in the gaps in our knowledge of active structures (Vittori et al. 1991; Weldon 1991; Berberian, 1976). Such studies have been carried out in various areas in Iran following major earthquakes, in order to determine whether similar events had already occurred. In the past few years, numerous trenches have been excavated across the faults, and prehistoric earthquakes have therefore been identified. Under these conditions, the parallel study of recent seismic events and of paleoseismic data revealed in the trenches have enabled an attempt to quantify the past events. Studies of surface ruptures observed during recent earthquakes have revealed very rapid variations of the amounts of displacement along the active faults during the Bam earthquake. The Bam fault has created a major topographic dislocation in the eastern Bam plain towards Baravat (Figure 2). This fault scarp, shows vertical displacement of 10 to 20 m in different places (Zare and Hamzehloo 2004).

More than eight destructive earthquakes have been reported during a 50-year period in the history of this region of southeast Iran (Table 1). The main trends of main faults (including the Bam fault) in the Bam region are around N-S and NW-SE. The NW-SE faults (Kuhbanan and Ravar faults) and the N-S faults (Nayband, Chahar-Farsakh, Anduhjerd, Gowk, Sarvestan and Bam faults) define the borders of north-south structures in the Lut area. The Gowk fault system is recognizable for its surface ruptures during the 1981, 1989 and 1998 earthquakes, and is also distinguished by a hot spring system.

Table 1. Earthquakes greater than 6.25 Richter (Magnitude) occurred in Iran (area) between 1900-2004

Date	East	North	Magnitude (Mb)	Focal depth (km)	Location	Losses
23 Jan 1909	49 E	33 N	7.4	25	Dorud (Silakhor, Zagros)	5000-6000 killed
12 Feb 1953	54 E	35 N	6.25	12 - 18	Torud (Kavir)	920 killed
16 Feb 1941	58 E	33 N	6.25	12 -18	East Central Iran	600 killed, 2500 houses destroyed
01 Sep 1962	50 E	35 N	7.25	20	Buyin-Zahra (Tehran)	12,225 killed, 21,310 houses destroyed
31 Aug 1968	59 E	34 N	7.2	15	Dasht-e-Bayaz (Khorasan)	>10,000 killed, 12,000 houses damaged
April 1972	53 E	28 N	6.9	15 - 18	Qir (Zagros)	5000 killed, 5000 houses destroyed
06 May 1930	44 E	38 N	7.4	20 - 25	Salmas (Azerbaijan)	2514 killed, 60 villages destroyed
01 Jul 1995	-	-	7.3	20 - 25	Sangchal.	-
12 Dec 1995	-	-	7.2	20 - 25	Farsinaj	1130 killed, 200 villages destroyed
15 Aug 1956	-	-	6.7	20	Nahavand (Firouzabad)	191 killed, 110 villages destroyed
20 Mar 1967	-	-	7.0		Bandar Abbass (Khorgo)	128 killed
15 Sep 1978	-	-	7.7	15 - 20	Tabas (Khorasan)	19,600 killed, 16 villages destroyed
13 Nov 1979	-	-	6.6	15 - 20	Qainat	250 killed
26 Nov 1979	-	-	7.1	15 - 20	Qainat (Kowli)	130 killed, 150 villages destroyed
10 Jun 1981	-	-	6.7	15 - 20	Golbaf (Kerman)	128 killed
27 Jul 1981	-	-	7.3	15 - 20	Sirj (Kerman)	1300 killed
20 Jun 1990	-	-	7.4	20 - 25	Manjil-Roudbar (Zanjan)	35,000-40,000 killed
26 Dec 2003	58 E	29 N	6.5	10 - 12	Bam (Kerman)	28,000-30,000 killed

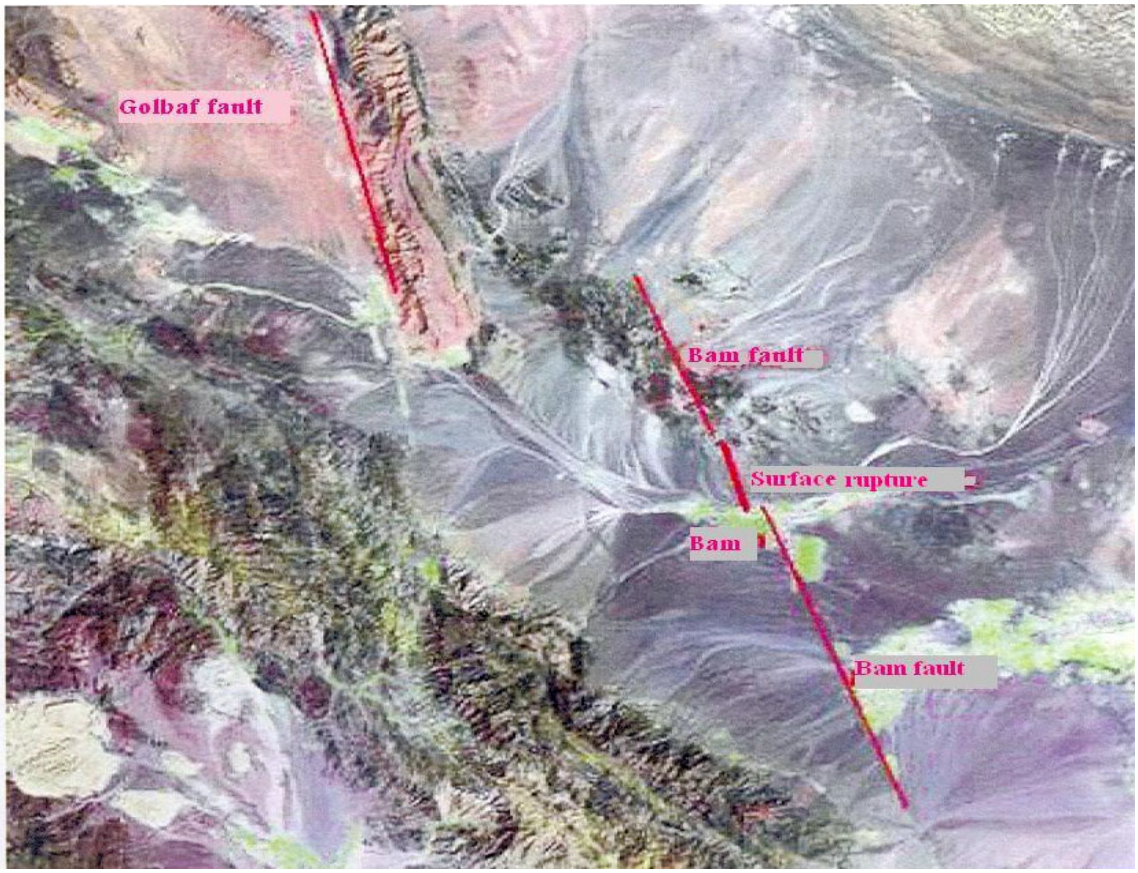

Figure 2. Satellite map of the Bam area, with the Bam and Golbaf faults indicated.

Active faults and seismic hazard assessment in southeastern Iran

Over the last three decades methods for assessing seismic hazards in engineering and other practical applications have continuously evolved. Because of the uncertain nature of the supporting seismic data and the changing needs of the community, such as the use of probabilistic risk analysis and risk-based regulations, the predominantly deterministic approach of the early days is slowly being replaced by probabilistic techniques. These are highly data-intensive, and call for integrated multidisciplinary approaches to make maximum use of the available data.

This presentation describes some of the limitations and identifies the issues of importance in the assessment of seismic hazards in the south eastern and central Iran. Extensive investigations of Plio-Quaternary geology resulted in a better understanding of the potential occurrence of large earthquakes in the Tabas, Shahdad and Bam depression.

A series of faulting events has occurred in the period 1854-2003 (Table 1). The 27 May 1897 earthquake with magnitude M5.7 affected a large area and caused damage in Kerman city. In 17 January 1864, the Chatrood earthquake (M6.0) occurred in the region. In April 1854 the Horjand earthquake (M5.8, I=VIII) occurred northeast of Kerman on the same trend as the Lakarkuh fault. The Sirch earthquake is the largest event recorded instrumentally in the Kerman province. The large earthquakes in 1981 were associated with a total of 64 km of fresh movements along the northern end of the Golbaf (Gowk) fault and 10 km on the segment of the Lakarkuh fault. A maximum vertical displacement of 10 cm was observed east of Golbaf, whereas, after a second shock, displacement of 14 cm vertically and 20 cm horizontally (dextral) were measured near Chahar-Farsang and Poshteh along the Lakarkuh fault system.

Finally there was the last earthquake in Bam city 26 Dec 2003 which occurred on the Bam fault. Many earthquakes have been recorded in the Bam region, but the city of Bam had no reports of great historical earthquakes before the 2003 event. Figure 3 shows the historical and instrumental seismicity of the region, with most of the major earthquakes occurred northwest of Bam.

The average recurrence interval of large earthquakes in this region is estimated to be between 50-60 years. More than 50 destructive earthquakes have been described in the last 1200 years in southeastern and central Iran.

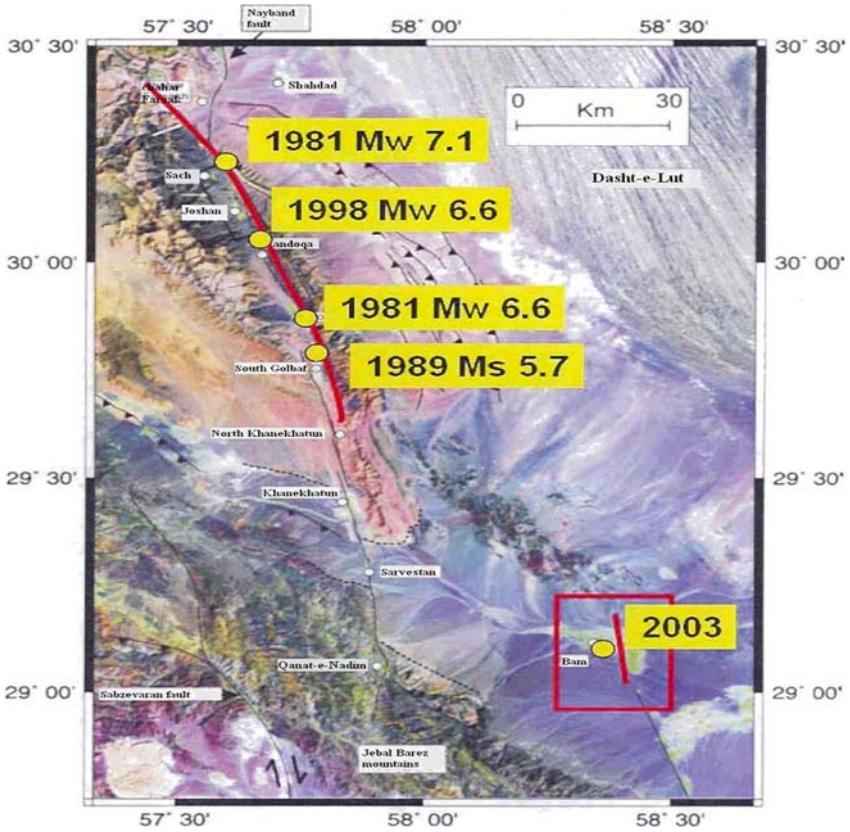

Figure 3. Recent major earthquakes in the region of Bam.

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