Preliminary investigation of Sasan Gir earthquake - 2011, Junagadh district, Gujarat

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Abstract

Seismic activity in the Sasan Gir area is reported to be continuing for last 10 years and in the entire Saurashtra region for more than 200 years. The present seismic activity commenced with the occurrence of an earthquake of magnitude 5.3 on 20th October, 2011. Since then activity is continuing in the area with subsequent lower magnitude earthquakes. About 200 aftershocks have recorded and the magnitude of earthquakes is fluctuating between 1 & 2. Among 200 aftershocks 2-3 aftershocks are ranging from 3-4. Location of the epicenter of earthquake as per ISR differs from USGS. ISR has reported epicenter of the earthquake at 21.114° N; 70.54° E whereas the USGS has fixed at 21.18°N; 70.48°E. The depth of focus is also differently mentioned by ISR and USGS at 8.5 km and 15.5 km, respectively.

Geologically the major part of the area is covered by the Deccan Volcanics. The volcanic rocks are overlain at places by miliolitic limestone. The rocks are covered by thin veneer of soil. Different sets of lineaments / dykes trending N-S, NNW-SSE, NW-SE, NE-SW and E-W is present in the area. The affected area is bounded by two major faults aligned in NW-SE direction and NNE-SSW direction in western and eastern margin of Saurashtra Region, respectively. Near epicenter mainly miliolitic limestone and alluviums are highly affected during the earthquake. Mostly single storey small houses are located in and around the Sasan Gir area without proper designing. Most affected villages in the area are Ladudi, Haripur, Sandhbeda Nes, Jepur, Dhravawad, Devgam, Jalandhar, Khatrasa, Chitravad and Hiranvel. At all these places some of the poorly constructed houses developed fractures in the walls, roofs and some of the supporting pillars were also dislocated. Nowhere ground surface rupture has been observed.

On the basis of macro seismic survey, isoseismal map is prepared and meizoseismal area is demarcated. The meizoseismal area is of ellipsoidal in shape stretching about 17 km along a- axis and 13 km about b-axis. The a-axis is aligned in NE-SW direction. On the basis of field observation an isoseismal of Intensity VII is prepared and the epicenter is lying near Chitravad village.

1. Introduction:

On the basis of geomorphology and seismotectonics, the entire Gujarat has been divided into three regions namely, Saurashtra, Mainland Gujarat and Kachchh (Yadav et al., 2008). Saurashtra region is bounded by N–S trending Cambay rift in the east, the extension of Narmada fracture/lineament in the south, Kachchh rift to the north and the major WNW–ESE fault which is an extension of the west coast fault system in the Arabian Sea, in the west (figure 1). The Saurashtra region is considered as a horst surrounded by rift graben (Kaila et al., 1980; Biswas, 1987). Volcanic vis-à-vis tectonic characteristics of Saurashtra peninsula exhibited in the central, southern and northern part of Saurashtra (Biswas and Deshpande, 1983). Saurashtra region forms a part of the western continental margin of India, and falls in the seismic zone-III of the Zoning Map of Bureau of Indian Standards.

Saurashtra region has several earthquakes of magnitude ranging between 5 and 6.9 in the past centuries (Lele, 1973). The region as a whole and the area around Junagadh and Bhavnagar has been tectonically unstable, as revealed by the earthquakes that have taken place in the region in the recent and past centuries (table1). Earlier Junagadh was jolted by moderate earthquake of magnitude Mw = 5.0 that occurred near Talala along the Girnar Mountains on November 6, 2007 (figure 1). Geochronological data indicate Neotectonic activity in parts of Saurashtra particularly in coastal regions (Juyal et al., 1995).

Recent seismic activities in the Jamnagar and Junagadh districts of Saurashtra have drawn the attention of earth scientists to know the ongoing tectonic activity in vicinity of Sasan Gir and Talala and how the tectonic structures are responsible for the past and present earthquakes in this region. It poses a question as to whether it has a potential to produce earthquakes of large magnitude in near future (?). Present study was carried out to study the Sasan Gir earthquake have been large enough (M=5.3) to cause concern as far as damage to life and property is concerned. The aim of this paper is to document the preliminary investigation of the earthquake affected area and tries to correlate the major and minor fractures and lineaments with the regional tectonic structures which can provide useful information about tectonic activity and help to understand the orientations of stresses.

2. Geological Set-up:

The area is dominantly occupied by extrusive basalt associated with intrusives belonging to Deccan Volcanics with Miliolite formation belonging to Porbandar Group and Quaternary sediments. The basalts have been intruded by acidic and basic dykes and plugs. Basic dykes trending N-S, NW-SE and NE-SW directions are basaltic, doleritic and micro-gabbroic in composition (figure 2.1: geological map). Circular plugs have intruded the basalt flows in the southern part of the area. It is coarse grained, dark grey, massive and doleritic in composition. They occur as humps or circular like bodies in flat terrain as well as in basaltic rocks. Limestone of miliolitic Formation occurs as blanket over the Deccan Volcanics at different levels varying thickness. A number of flows of Deccan Trap have been delineated in the area. The miliolitic limestone has a patchy occurrence and occurs mainly along valleys or other low lying area.

Major and minor lineaments of the study area are prepared from the LISS-III imagery thematic maps obtained from BISAG on 1:25000 scales. Five sets of lineaments trending N-S, NNW-SSE, NW -SE, NESW and E-W have been noticed. Majority of the lineaments are concentrated in northern part of the area while the central and southern parts having relatively less number of lineaments. These lineaments are intersected with each other. Most of these trends NE- SW are prominent. Three and Two sets of joints are recorded which are generally vertical to sub- vertical. These lineaments are parallel to the tectonic structures of the Saurashtra region. A fault has demarcated at the north-western part of the Sasan Gir area (figure 2.2).

3. Present Status of Junagadh Earthquake:

The present activity commenced with the occurrence of an earthquake of magnitude 5.3 on 20th October, 2011. The epicenter was 20 km south-east of Sasan Gir near Chitavad town in Junagadh district. The tremor of this earthquake was felt across the Saurashtra region. The activity resurfaced with the occurrence of another main shock of magnitude 4.1 on 21st October, 2011 was followed by several aftershocks of magnitude more than 3 and even several aftershocks were also continuing of magnitude ranging between 2 and 1 (figure 3.1). Sasan Gir (Junagadh) earthquake event created a lot of panic amongst the local population/people. The number of earthquakes has recorded from 20th October, 2011 to 21st October, 2011. The aftershocks were reduced by the end of 22nd October, 2011 (figure 3.2). More than hundred aftershocks occurred in the forenoon of 22nd October 2011 (ISR). Various agencies, National and International i.e., Institute of Seismological Research (ISR), Indian Meteorological Department (IMD), India and United States of Geological Survey (USGS) recorded epicenter, focal depth and magnitude differing with each other as detailed below:

Table 2
Magnitude with depth of Sasan Gir earthquake, Junagadh.

Date	Time (IST)	Lat. (N)	Long.(E)	(on Richter Scale)	Depth (km)	Location	Agency
20.10.2011	10:48 pm	21.114°	70.54°	5.3	8.5	13 km SE of Sasan Gir, Junagadh.	ISR, Gandhinagar, Gujarat, India.
20.10.2011	10:48 pm	21.18°	70.48°	5.0	15.5	Junagadh, Gujarat.	USGS

4. Macro seismic / Damage Survey:

Geological Survey of India deputed a team of Geologists to visit affected villages to assess the damage near the epicenter zone from 21st-25th October, 2011. Some of the photographs showing damage in the affected area are shown in figure 4.1 (a-f). Based on the observation of damage pattern and standard Questionnaires has been recorded in data sheet. Isoseismal map of the most affected areas was prepared on the basis of the damage pattern. Information was collected from the people of the affected area in the prescribed format. Detail of the observations is listed below:

1. It was observed that the mainshock as well as the aftershocks were accompanied with bang sound in the villages near the epicenter.
2. Most of the people of the area were frightened and ran out from their houses. Furniture was over turned and people lost balance and fell down from beds and from in-house swings in Haripur and Laduli.
3. The general feeling of the people of the Sandhbeda Nes village, which is near the epicenter (USGS), is that the movement was vertical followed by horizontal shaking during the main shock.

4. It was observed that the water in the streams turned turbid due to stirring of the mud. Due to intense shaking minute sand boils developed in the east of Abudi Nes village on the banks of the nala.
5. In many buildings of Type B (ordinary brick buildings), Grade 2 damage (small cracks in wall, fall of plaster) are observed in the villages from Sandhbeda Nes in the north- east to Dhrabawad in the south-west.
6. Most of the Type A (rural structures, clay houses) have suffered Grade 3 (heavy damage, large and deep cracks in walls) and many Grade 4 damage (collapse of walls) in the villages from Sandhbeda Nes to Dhrabawad villages.
7. Conjugate cracks and step like cracks are very common in the Type B buildings, which follows the blocks of miliolitic limestone or bricks as the case may be.
8. No ground cracks are recorded except a few near the houses which suffered most. No cracks were reported from the nala or river beds of the area.
9. Recurring aftershocks are creating panic to the villagers and they are staying outside the houses during night times, even being very close to the Gir forest, known for Asiatic lions.
10. A cave in limestone horizon, to the east of Haripura, collapsed partially due to the mainshock of the 20th October and blocked its path underway.

On the basis of the above observations an isoseismal of Intensity VII is prepared (figure 4.2) covering the Haripura, Hiranvel, Chitravad, Sandhbeda Nes, Devaliya Nes, Jalandhar, Devgam, Abudi Nes, Ladudi, Dhrabawad, Jangar, Jepur and Khirdhar villages of Talala and Mendarda talukas of the Jamnagar district.

5. Discussion:

Saurashtra region were affected by numbers of earthquakes of magnitude in the last two hundred years (Lele, 1973). Junagadh experienced swarm earthquake activity in 2001, 2004 and 2005 with maximum magnitude of 3.1. The maximum activities of tremors / shocks were recorded during October-November by IMD (Bhattacharya and Dattarayam 2003).

Other parts of Saurashtra such as Bhavnagar and Jamnagar have witnessed similar swarm type of seismic activity. All the tremors in Saurashtra are accompanied by blast sound which suggest the depth level of shocks i.e., shallow level (Rastogi et al., 2011). Based on the dykes pattern and lineaments, three trends have been demarcated and related with the trend of Narmada lineament as well as Cambay rift (Karanth and Sant, 1995). These lineaments are parallel to the tectonic structures of the Saurashtra region. The major part of the lineament is showing an NE- SW trend which is the horizontal maximum compressive stress (Gowd et al., 1992). Apart from this there are other trend in the study area that varies from N-S, E-W, NNW-SSE and NW-SE. This indicates/suggests a complex stress pattern in this part which plays a vital role in recent tectonic / seismic activity in the Saurashtra region.

6. Conclusion:

The Junagadh area is prone to moderate earthquake activity. Seismic activity in the Junagadh area is reported to be continuing from last 20 years and in the entire Saurashtra region for more than 200 years. Seismic activity is continuing in the area with subsequent lower magnitude earthquakes. In and around the Sasan Gir area mostly single story small houses are located without proper designing. At places some of the poorly constructed houses developed fractures in the walls, roofs and some of the supporting pillars were also dislocated. Nowhere ground surface rupture has been observed.

The meizoseismal area is demarcated on the basis of damage patterns and ground survey. The meizoseismal is of ellipsoidal in shape stretching about 17 km along a-axis and 13 km about b-axis. The a-axis is aligned in NE-SW direction (figure 4b). The interrelationship of the local and major faults and lineaments with the ongoing seismic activity of the area can be established by carrying out detailed seismotectonic investigations in the region. The Junagadh district falls in seismic zone-III as per BIS therefore civil engineering structures in the area are to be constructed considering seismic zoning, local geology and ongoing seismic activity.

References:

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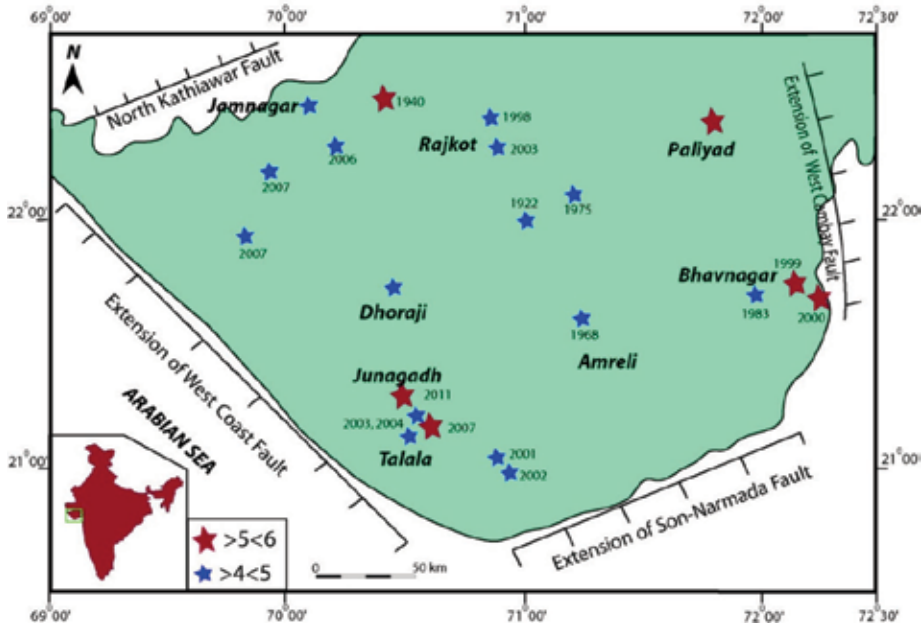

Figure 1 Tectonic map of Saurashtra and distribution of past and recent earthquakes.

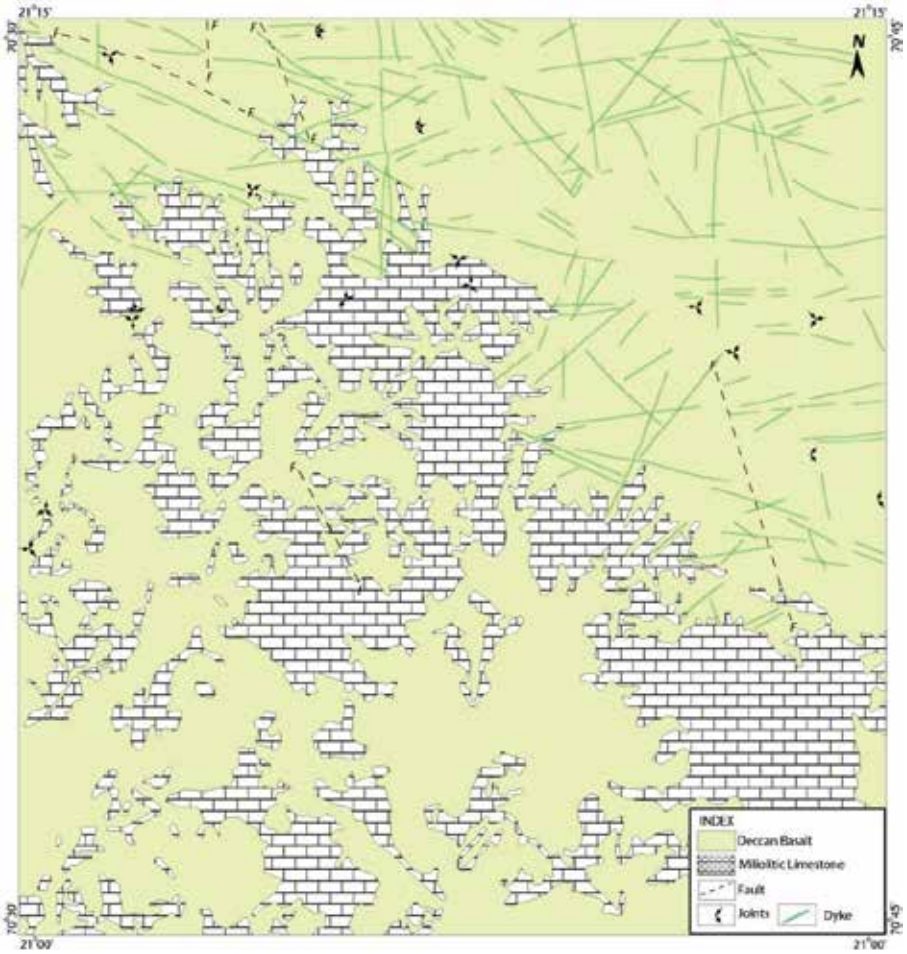

Figure 2.1 Geological map of Study (Sasan Gir) area.

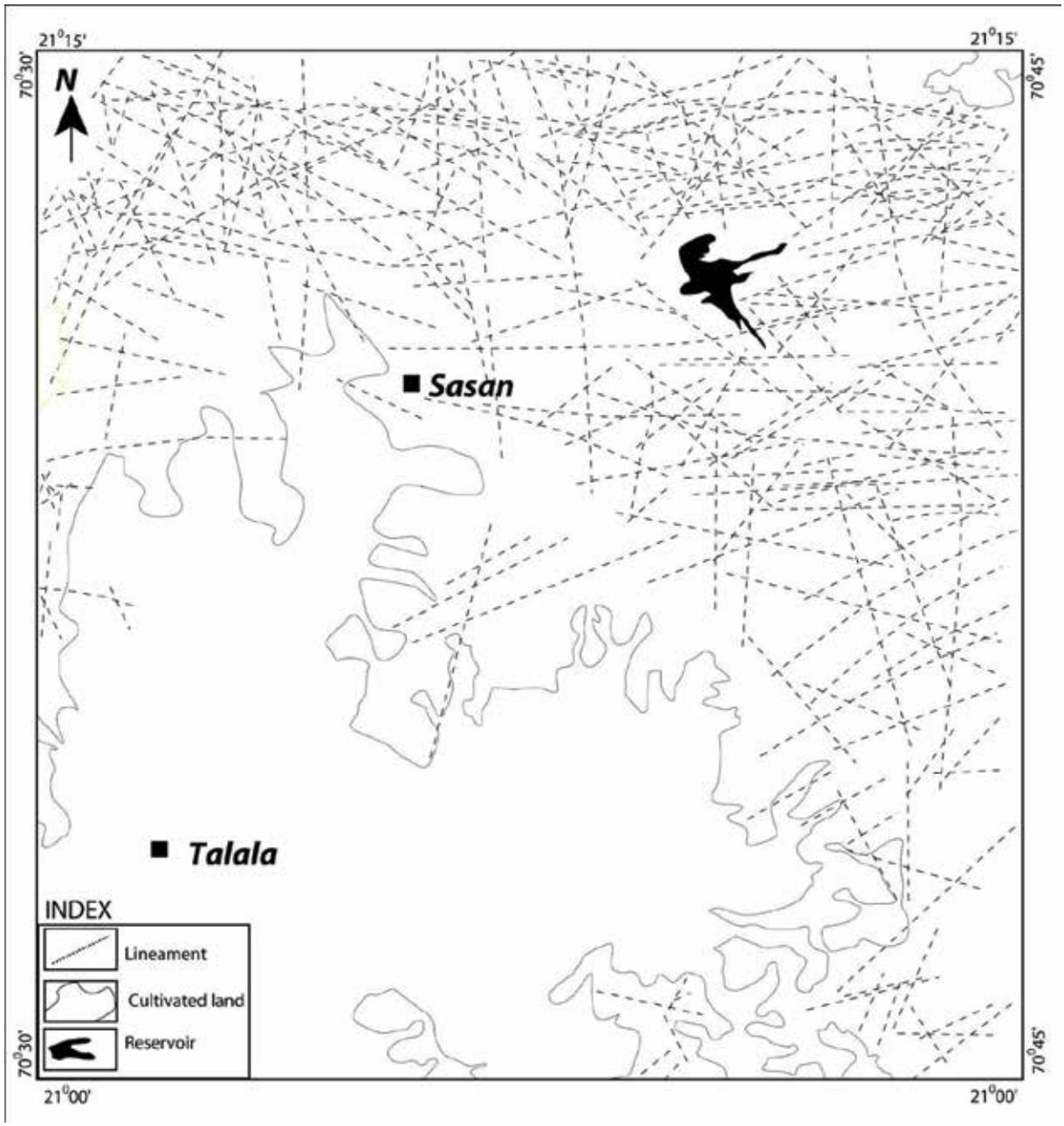

Figure 2.2. Lineament map of Study area.

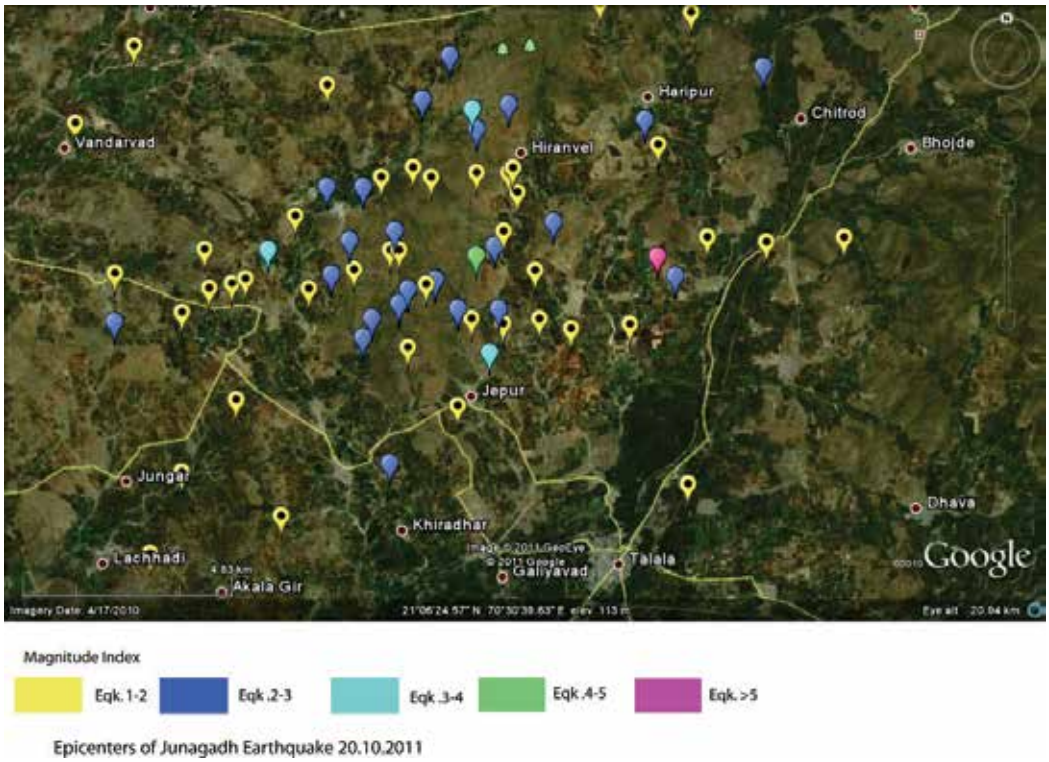

Figure 3.1 Location of Sasan Gir earthquake and distribution of aftershocks of lower magnitude of earthquake on Google Image.

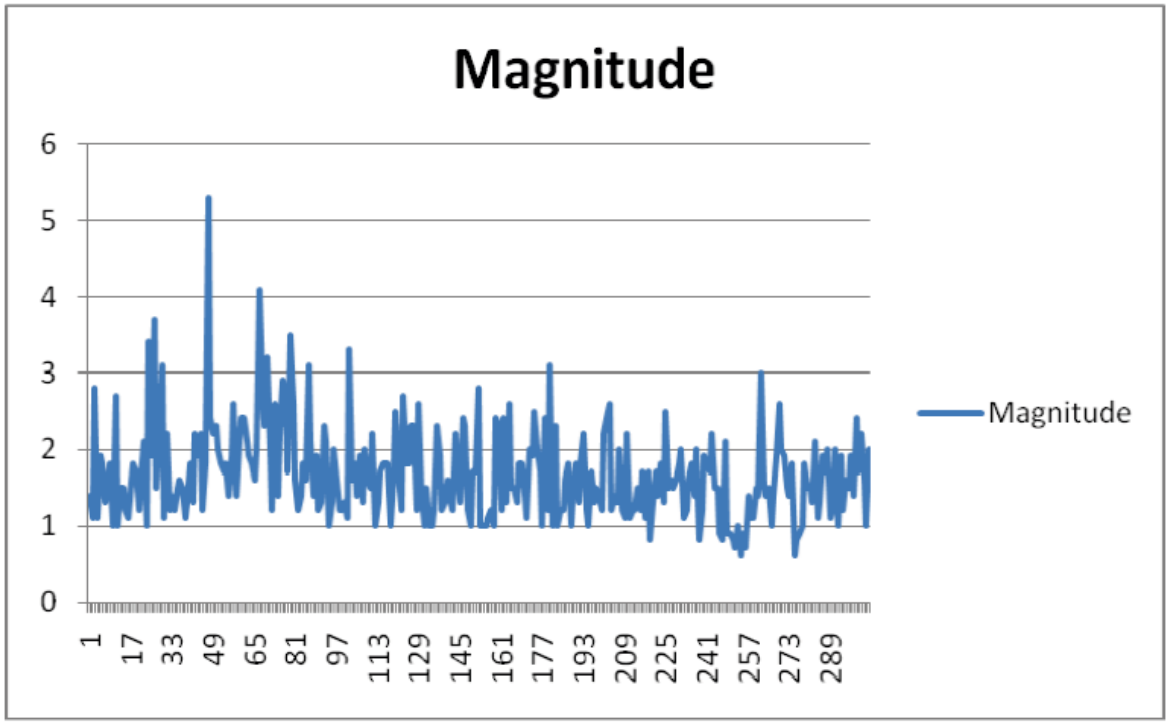

Figure 3.2 Graph plotted between magnitude verses no. of earthquakes.

Figure 4.1 (a) Total collapse of Kachchha house, Chitravad. (b) Prominent cracks in walls, Hiranvel (c) Wide open cracks in the wall and floor, Sandhbeda Nes (d) Peeling of roof plaster, Forest Quarter, Devaliya (e) Conjugate fractures in a wall, Devgam (f) Ladudi Wall and roof collapse at Ladudi.

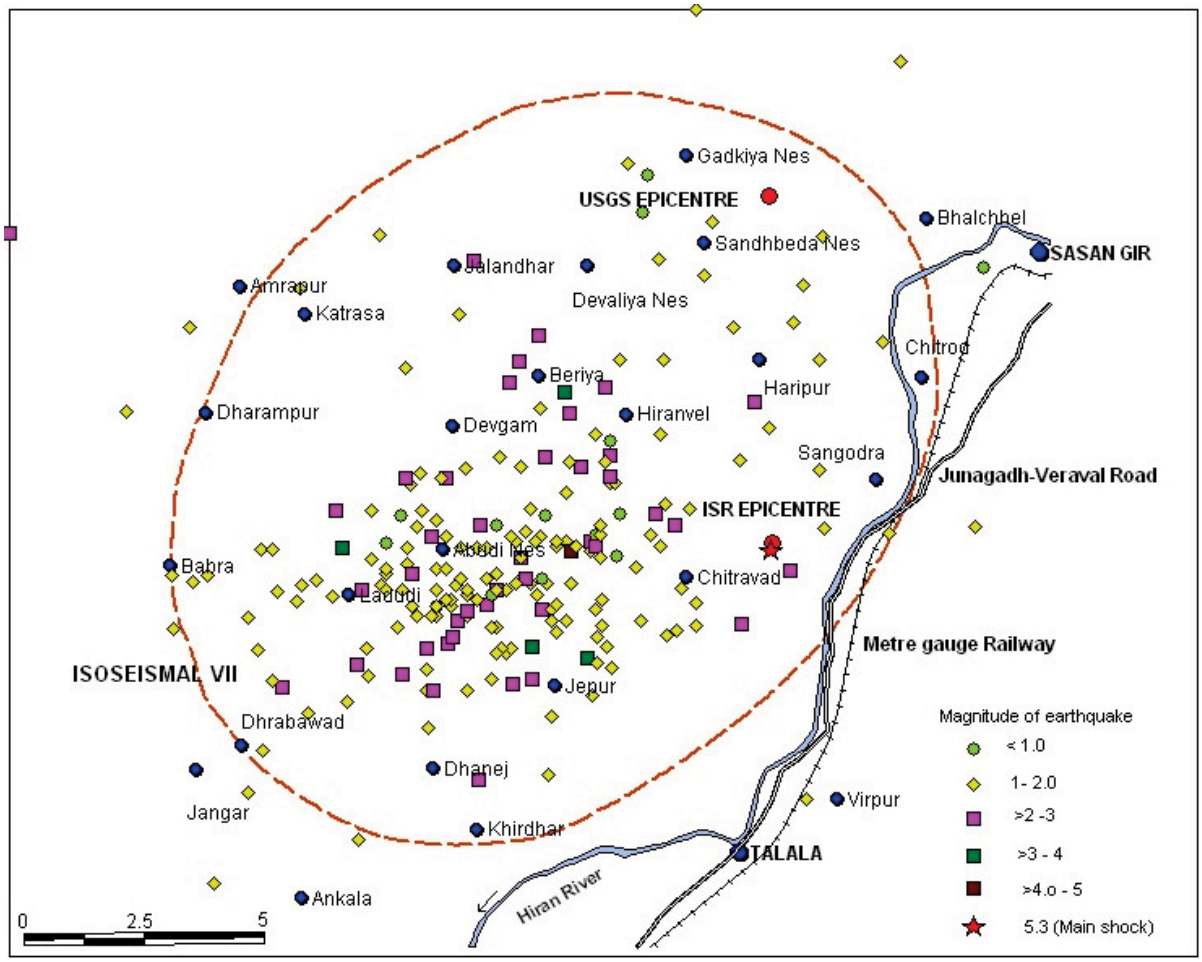

Figure 4.2. Isoseismal map of Sasan Gir earthquake-2011.

Table1
List of recorded Earthquakes in Saurashtra > 4 magnitude (Rastogi et al., 2012).

Year	Month	Date	Lat (N)	Long (E)	Depth	Magnitude	Intensity	Location	Reference
1919	4	21	22	72	----	5.7	VII	Bhavnagar	CHAN
1922	3	13	22	71	----	4.3	V	Jhalavad, Rajkot	CHAN
1930			22.4	71.8	----	4.3	V	Paliyad	CHAN
1935	7	20	21	72.4	----	5.7	VI	Surat	IMD
1938	6		22.3	71.6	----	5	VI	Botad	TAN
1938	6	26	22.3	71.5	----	4.1	VI	Botad	TAN
1938	7	12	22.4	71.8	----	5.5	VI	Paliyad	IMD
1940	10	31	22.5	70.4	-----	5	VI	Jamuanathali, Jamnagar	CHAN
1968			21.6	71.25	----	4.3	V	Amreli	GSI
1968			21.73	70.45	----	4.3	V	Dhoraji	GSI
1975			22.1	71.2	----	4.3	V	Jasdan	GSI
1985	9	3	21.03	70.88	-----	4.3		Visavadar	GERI
1993	8	24	20.6	71.4	29	5		Rajula	IMD
1998	7	19	22.42	70.86		4.4	IV	Rajkot	IMD
2000	8	13	20.98	70.93	7	4.6	VI	Una (Khamba), Junagadh	ISC, IMD
2000	9	12	21.72	72.16	10	4.2	VI	Bhavnagar	IMD
2006	9	30	22.31	70.21	----	4	V	Khankotda, Jamnagar	ISR
2007	11	6	21.16	70.54	----	5	VI	Haripur, Junagadh	ISR
2011	10	20	21.114°	70.54°	8.5	5.3	VII	13 km SE of Sasan Gir, Junagadh.	ISR
2011	10	21	21.114	70.5	----	4.1		09 km SE of Sasan Gir, Junagadh	ISR