

NOTES

MODERN AND HISTORIC SEISMICITY OF KACHCHH PENINSULA, WESTERN INDIA

INTRODUCTION

The seismic belt of Kachchh (Kutch) extends approximately 250 km (E-W) and 150 km (N-S) and is flanked by Nagar Parkar Fault in the north and the Kathiawar Fault in the south (Biswas, 1982; 1987; Biswas and Deshpande, 1970; Gowd, et al. 1996) (Fig. 1). Portion bounded between these two faults is marked by several E-W trending major faults viz. Katrol Hill Fault (KHF), Kachchh Mainland Fault (KMF), Banni Fault (BF), Island Belt Fault (IBF) and Allah Bund Fault (ABF). Kachchh peninsula has experienced several episodes of earth movements along these major E-W trending faults all throughout the Cenozoic, and these have not only contributed to the evolution of the present day landscape, but have also accentuated the structural pattern (Biswas 1971, Kar 1988, 1993 a, b; Malik et al. *In press*; Sohoni et al. 1999). This continued tectonism is well reflected in the seismicity of the region and in general in the Deccan Shield (Rajendran et al. 1998; Sukhija et al. 1998). Kachchh falls in the seismically active Zone-V of the Indian sub-continent outside the Himalayan seismic belt (IMD, 1983-84), and has a long history of earthquakes of varying magnitudes ranging between ML 3.5 and 8. The record of earthquakes that occurred in Kachchh from 1668 to 1997 reveals that maximum earthquakes (3 to ≥ 5 M) are confined along the ABF, KMF and KHF (Fig. 1). An attempt has been made to compile the historical (non-instrumental) and modern (instrumental) seismic data obtained from various sources.

DATA SOURCES

Seismic data of Kachchh region was procured from (i) the Indian Meteorological Department (IMD), New-Delhi, India, (ii) United States Geological Survey (USGS) incorporating available information from Gazetteer of Kachchh District (1971) and (iii) published literature (Quittmeyer and Jacob 1979; Johnston and Kanter 1990; Gowd et al. 1996; Yeats et al. 1997). In this study the non-instrumental data given with only the intensity or the terms like small, moderate, large and great or slight and strongly felt were taken into consideration. The data obtained was categorised as (a) historic (non-instrumental) and (b) instrumental. The earthquake data listed in the Gazetteer (1971; p. 56-60), shows the historical felt report of earthquakes at various locations in Kachchh region. Key words like very slight, slight, severe, very severe and strong were frequently found in the description. To indicate the equivalent intensity to this data, the intensities mentioned in words were converted first to the Modified Mercalli (MM) scale. Further, the intensities (MM), I, were changed to get M_L (local magnitude) using equation $M = 1 + 2/3$ (Gutenberg and Richter 1956). However, the modern instrumental data from IMD (1996-99) and National Earthquake Information Center- USGS (1998-99) was incorporated with the published information and historic non-instrumental data set. A comprehensive list of earthquakes that visited Kachchh region in the recent times and during historic past was prepared (Table 1). It appears that the area had experienced several earthquakes ranging from $M_L \leq 4$ to 8 and intensities between III and X+(MM) (Quittmeyer and Jacob, 1979; Johnston and Kanter, 1990; Gowd et al. 1996, Yeats et al. 1997). Apart from the large earthquakes with $M > 5$ and < 6 , occurrence of earthquakes with magnitude ranging between ≤ 3 and < 4 are more common in this region. The earthquake data when plotted over the regional structural map of Kachchh peninsula (Fig. 1), has helped in understanding the micro-seismicity.

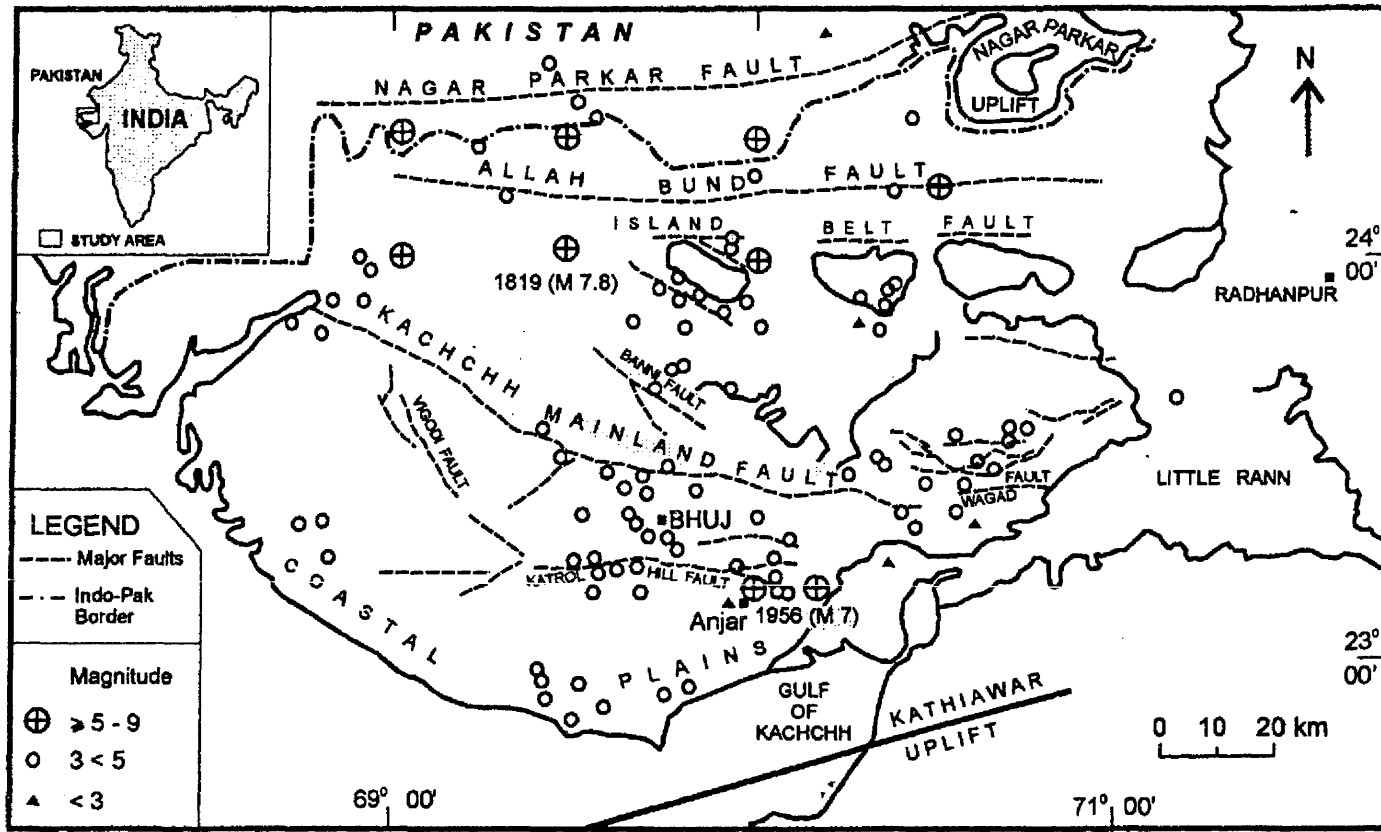


Fig.1. Seismicity of Kachchh in last 200 years from 1668-1997. Data obtained from Indian Meteorological Department, New Delhi, India (1996-97), Quittmeyer and Jacob (1979); Gazetteer of Kachchh District, Gujarat (1971) and USGS, National Earthquake Information Center- (1998-99). Structural map after Biswas and Deshpande, (1970).

Table 1. List of Historical (non-instrumental) and Modern (instrumental) seismicity data of Kachchh between 1668-1996.

Sl No.	Date	Latitude	Longitude	Location	Intensity MM	Magnitude ML	Depth Km	Ref.
1	06 05 1668	25° 00'	68° 00'	Indus Delta		7.6	—	a, e
2	16 06 1819	24° 00'	70° 00'	Great Rann of Kachchh (ALLAH-BUND)	IX-X	8 (M _L) 7.8 M	—	a, b, e
3	27 01 1820	23° 25'	69° 50'	Bhuj	IV-VI	≥3.7	—	b, e
4	12 11 1820	23° 25'	69° 42'	Bhuj	IV-VI	≥3.7	—	b, e
5	13 08 1821	23° 10'	70° 10'	Anjar	—	5	—	a, e
6	20 07 1828	23° 20'	70° 30'	E of Bhuj around Bhachau	V	≥4.3	—	b, c, e
7	— — 1844	24° 20'	69° 30'	Great Rann E of Lakhpat	—	4.3	—	e
8	19 04 1845	24° 20'	69° 30'	Great Rann E of Lakhpat	IV-V	≥5	—	b, c, e
9	19 06 1845	24° 20'	69° 30'	Great Rann E of Lakhpat	—	6.3	—	e
10	25 04 1845	24° 00'	69° 00'	Great Rann N of Lakhpat	—	6	—	a, e
11	19 06 1845	24° 18'	69° 23'	Lakhpat	VII-VIII	≥6	—	b, c, d, e
12	29 04 1864	24° 00'	70° 00'	Great Rann-Banni Plain	IV-V	5	—	b, c
13	10 06 1882	23° 18'	70° 25'	Bhachau	III	≥3<4	—	d
14	28 06 1882	23° 20'	70° 35'	Lakadia	III	≥3<4	—	d
15	15 12 1882	23° 25'	69° 45'	Bhuj	III	≥3<4	—	d
		23° 10'	70° 05'	Anjar				
		23° 20'	70° 25'	Bhachau				
16	20 08 1888	23° 50'	70° 00'	Khavda	III	≥3<4	—	d
17	01 06 1890	23° 50'	68° 50'	Lakhpat	III	≥3<4	—	d
		23° 50'	70° 35'	Khavda				
		23° 25'	69° 40'	Bhuj				
18	11 01 1892	23° 50'	70° 00'	Lakhpat	III	≥3<4	—	d
19	09 07 1892	23° 30'	70° 43'	Rapar	III	≥3<4	—	d
20	04 11 1893	23° 50'	68° 50'	Lakhpat	III	≥3<4	—	d
21	26 02 1896	23° 50'	69° 40'	Bhuj	III	≥3<4	—	d
22	30 01 1898	23° 10'	70° 05'	Anjar	III	≥3<4	—	d
23	01 04 1898	23° 15'	69° 40'	Bhuj,	III	≥3<4	—	d
		23° 20'	70° 08'	Anjar				
		22° 55'	69° 30'	Mandvi				
24	13 09 1898	23° 18'	69° 45'	Bhuj	III	≥3<4	—	d
		23° 10'	70° 05'	Anjar				
		23° 33'	70° 25'	Bhachau				
		22° 55'	69° 22'	Mandvi				
25	15 10 1898	23° 20'	69° 40'	Bhuj	III	≥3<4	—	d
		23° 10'	70° 10'	Anjar				
		23° 25'	68° 50'	Naliya				
		22° 50'	69° 45'	Mundra				
26	21 12 1900	23° 30'	70° 40'	Rapar	III	≥3<4	—	d
		23° 33'	70° 25'	Bhachau				
27	14 01 1903	24° 00'	70° 00'	Great Rann	—	6	—	a, e
28	09 04 1904	23° 20'	69° 40'	Bhuj	III	≥3<4	—	d
29	28 04 1904	23° 10'	69° 40'	Bhuj	IV-V	≥4	—	d
		23° 20'	70° 10'	Anjar				
30	30 07 1904	23° 50'	70° 20'	Khadir	III	≥3<4	—	d
31	30 11 1904	24° 20'	69° 35'	Lakhpat	III	≥3<4	—	d

Table 1 Contd....

Sl No.	Date	Latitude	Longitude	Location	Intensity MM	Magnitude ML	Depth Km	Ref.
32	10 07 1905	23° 20'	69° 40'	Bhuj	III	≥3<4	—	d
33	11 01 1906	23° 50'	70° 20'	Khadir	III	≥3<4	—	d
34	30 06 1906	23° 50'	69° 45'	Khavda	III	≥3<4	—	d
		24° 20'	69° 35'	Lakhpat				
35	12 03 1907	23° 50'	69° 45'	Khavda	III	≥3<4	—	d
36	12 07 1907	22° 55'	69° 50'	Mundra	III	≥3<4	—	d
37								
38	09 10 1907	23° 50'	69° 45'	Khavda	III	≥3<4	—	d
39	21 10 1907	23° 15'	70° 20'	Bhachau	III	≥3<4	—	d
		23° 20'	70° 35'	Lakadia				
40	29 09 1908	23° 50'	69° 45'	Khavda	III	≥3<4	—	d
41	21 10 1908	23° 50'	69° 45'	Khavda	III	≥3<4	—	d
42								
43	07 02 1909	23° 50'	69° 45'	Khavda	III	≥3<4	—	d
44	09 04 1909	23° 15'	70° 20'	Bhachau	III	≥3<4	—	d
		23° 25'	70° 35'	Lakadia				
		23° 40'	70° 45'	Rapar				
45	24 03 1910	23° 15'	69° 35'	Bhuj	III	≥3<4	—	d
46	01 08 1910	23° 50'	69° 40'	Khavda	III	≥3<4	—	d
47	13 12 1910	23° 15'	69° 35'	Bhuj	III	≥3<4	—	d
		23° 15'	70° 20'	Bhachau				
		23° 25'	70° 35'	Lakadia				
		23° 40'	70° 45'	Rapar				
		23° 50'	69° 40'	Khavda				
48	16 13 1910	23° 15'	70° 20'	Bhachau	II-III	≤2≤3.5	—	d
		23° 20'	70° 35'	Lakadia				
		23° 50'	70° 20'	Khadir				
49	23 01 1911	23° 25'	70° 35'	Lakadia	II-III	≤2≤3.5	—	d
50	11 10 1911	24° 20'	69° 30'	Lakhpat	III	≥3<4	—	d
51	01 10 1912	23° 50'	69° 45'	Khavda	III	≥3<4	—	d
52	07 11 1912	23° 50'	70° 20'	Khadir	III	≥3<4	—	d
53	26 06 1913	23° 45'	69° 45'	Khavda	III	≥3<4	—	d
54	10 06 1918	23° 30'	70° 25'	Bhachau	III	≥3<4	—	d
55	18 10 1920	23° 30'	70° 45'	Rapar	III	≥3<4	—	d
56	13 11 1920	23° 20'	69° 40'	Bhuj	III	≥3<4	—	d
57	26 10 1921	25° 00'	68° 00'	Indus Delta, Great Rann	—	5.5	—	a, e
58	27 10 1921	23° 50'	68° 50'	Lakhpat	III	≥3<4	—	d
		23° 50'	68° 40'	Narayan Sarovar				
		23° 25'	69° 40'	Bhuj				
		23° 20'	68° 50'	Naliya				
59	09 02 1922	23° 25'	70° 40'	Chitrod	III	≥3<4	—	d
60	13 03 1922	23° 25'	69° 22'	Mandvi	III	≥3<4	—	d
61	07 08 1923	23° 15'	69° 40'	Bhuj				
		22° 55'	69° 25'	Mandvi	III	≥3<4	—	d
62	05 03 1924	23° 55'	69° 50'	Khavda	III	≥3<4	—	d
63	25 10 1924	23° 40'	68° 55'	Khavda	III	≥3<4	—	d
64	01 10 1925	23° 50'	69° 40'	Khavda	III	≥3<4	—	d
65	13 10 1925			Shikra	III	≥3<4	—	d
				Jungi				
66	26 12 1926	23° 55'	69° 42'	Khavda	III	≥3<4	—	d
67	18 11 1927	23° 25'	69° 40'	Bhuj	III	≥3<4	—	d
		23° 35'	70° 25'	Bhachau				
		23° 15'	70° 10'	Anjar				

Table 1 Contd....

Sl No.	Date	Latitude	Longitude	Location	Intensity MM	Magnitude ML	Depth Km	Ref.
		23° 30'	70° 45'	Rapar				
		23° 50'	69° 45'	Khavda				
68	30 12 1930	23° 55'	69° 45'	Khavda	III	≥3<4	—	d
69	06 03 1932	23° 50'	70° 20'	Khadir	III	≥3<4	—	d
70	25 01 1935	23° 35'	70° 40'	Rapar	III	≥3<4	—	d
71	23 07 1935	23° 15'	69° 30'	Bhuj	III	≥3<4	—	d
72	12 12 1939			Shikarpur	III	<3	—	d
73	31 10 1940	24° 10'	70° 30'	North East of Khadir in Great Rann of Kachchh		5.8-6	—	a, e
74	13 11 1940	23° 34'	70° 20'	Anjar	III	<3	—	d
		23° 15'	69° 30'	Bhuj				
		23° 55'	69° 50'	Khavda				
75	30 01 1941	23° 50'	70° 15'	Khadir	III	<3	—	d
76	28 11 1945			Bharapar	III	<3	—	d
77	21 07 1956	23° 10'	70° 00'	Anjar	VIII-IX	7	—	a,c,d,e
78	22 07 1956	23° 10'	70° 00'	Anjar	III (AFTER-SHOCKS?)	<3	—	d
79	26 03 1965	24° 18'	70° 00'	North of Khavda in Great Rann of Kachchh	—	5.3	33	a,c
80	27 05 1966	24° 46'	70° 09'	Northeast of Khavda in Thar Desert (Pakistan)	—	5	5	a
81	04 06 1976	24° 52'	68° 45'	North of Allah Bund in Delta complex Zone (Pakistan)	—	5.1	—	a
82	26 04 1981	24° 13'	69° 51'	North of Khavda in Great Rann of Kachchh	—	4.1	—	a
83	31 01 1982	24° 22'	70° 24'	North of Khadir in Great Rann of Kachchh	—	4.8	—	a
84	18 07 1982	24° 40'	71° 06'	Rapar	—	4.8	33	a
85	07 04 1985	24° 37'	70° 14'	North of Khavda in Great Rann of Kachchh	—	4.4	33	a
86	10 04 1987	24° 33'	70° 08'	North of Khavda in Great Rann of Kachchh	—	<2	10	a
87	17 07 1988	25° 10'	70° 00'	North of Khavda in Thar Desert (Pakistan)	—	<2	33	a
88	20 01 1991	23° 08'	69° 50'	South East of Anjar	—	<2	35	a
89	10 09 1991	24° 17'	69° 08'	Great Rann of Kachchh	—	4.7	35	a
90	10 09 1991	24° 29'	69° 21'	Great Rann of Kachchh	—	4.7	26	a
91	04 05 1992	25° 30'	69° 30'	North of Allah Bund (Pakistan)	—	3.5	33	a
92	09 02 1993	25° 00'	69° 00'	North of Allah Bund (Pakistan)	—	4.3	33	a
93	17 02 1996	23° 20'	69° 40'	South of Bhuj	—	4.5	33	a

Source : (a) India Meteorological Department, New Delhi (1997); (b) Quittmeyer and Jacob, (1979), Bull. Seism. Soc. of America, vol. 69(3): 773-824; (c) Gowd et al. (1996), Pageoph, vol. 146, pp.1-26. (d) Gazetteer of Kachchh District, (1971) Govt. Press; (e) USGS, National Earthquake Information Center (1998-99).

The earthquake data base of Kachchh shows that there are so many instrumentally as well as geologically unrecorded events. But for a very strong event recorded at the Indus Delta in 1668 (M 7.6), virtually no data was available till 1819 (Allah Bund Event). Since then many earthquakes have been recorded in Kachchh during the span of 19th and 20th century.

The earthquake plot (Fig. 1) suggests that the earthquakes with larger magnitudes ≥ 5 and lower magnitudes < 4 have occurred in the vicinity or along major E-W trending faults. It has been observed that more number of earthquakes with $M > 5$ are concentrated along the ABF, and only two events with $M \geq 5$ (i.e. 1821 and 1956) are recorded along the KHF. Whereas, numerous small earthquakes with $M < 4$ have occurred along the KMF and KHF. This suggests that during recent times large amount of accumulated stresses were released along the ABF as compared to KMF and KHF. According to Sohoni et al. (1999) and Malik et al. (*In press*) the rocky Kachchh mainland have been experiencing differential uplifts along the fault bounded blocks confined to the KMF and KHF. It is envisaged that the differential uplifts in the region might have led to the distribution of stress accumulation along these major faults and were the main cause for the occurrence of low magnitude earthquakes in the rocky Kachchh mainland.

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