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H4.SMR/303 - 20

WORKSHOP
GLOBAL GEOPHYSICAL INFORMATICS WITH APPLICATIONS TO RESEARCH IN EARTHQUAKE PREDICTIONS AND REDUCTION OF SEISMIC RISK

(15 November - 16 December 1988)

PREPRINT

DIAGNOSTICS OF TIMES OF INCREASED PROBABILITY (TIPs) OF STRONG EARTHQUAKES IN THE HIMALAYAN SEISMIC BELT USING PATTERN RECOGNITION ALGORTHM CN

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Diagnostics of Times of Increased Probability (TIPs) of strong earthquakes in the Himalayan seismic belt using pattern recoginition algorithm CN.

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1. Introduction

This paper discusses the results of continued reseach [1,2] on earthquake prediction in the Himalayan region. The region is characterised by contrasting neotectonic movements and hence by rather strong earthquakes. The problem of earthquake prediction is one of successive narrowing of space-time volume in which the probability of a strong earthquake is high. We consider prediction for the region which has linear dimensions of the order of hundreds of kilometers, and time interval of few years. Such prediction is often called intermediate-term. We use earthquake catalog as a data base and try to detect characteristic features of an incipient strong earthquake by analysing sequence of all earthquakes in the region under study. This approach has been realized in two algorithms of TIPS diagnostics (M8 and CN): they were successfully applied to various regions of the world with a wide range of seismo-tectonic settings [3,4].

An earthquake is regarded as strong when it has a magnitude larger than the given threshold M_0. The algorithms are described in detail in [3,4]. They are based on a wide range of phenomena

which reflect characteristics of earthquake flow. Both algorithms are so far phenomenological, though their design reflects the perception of lithosphere as non-linear system featuring deterministic chaos. Application of the algorithm M8 is described in [ ].

2. Algorithm CN.

We have applied a version of CN algorithm described in [3] for discerning Times of increased probabilities (TIPs) of strong earthquakes. This algorithm uses parameters of seismic regime that were found empirically for the California catalog for prediction of strong earthquakes with $M \geq 6.4$.

Parameters of seismicity are presented as function of time, defined on a sequence of main shocks in the region within a sliding time window.

Level of seismic activity

N - number of main shocks with the magnitude above some threshold

Σ - the total energy of main shocks

G - the ratio of numbers of main shocks in two magnitude range

Seismic queiscence

q - "deficiency" of the seismic activity

Variation of seismicity

K - Difference between numbers of main shocks at two successive time-intervals

Spatial concentration

S_{max} - the average area of fractures at the earthquake flow.

Z_{max} - the ratio of the average radius of fractures at foci to the average distance between them

Clustering in time and space

B_{max} - maximal number of aftershocks

Some combinations of these functions for the time periods before strong erthquakes- periods D and the periods of time far from strong erthquake - periods N had been found in [3] for California and Nevada catalogs. These combinations are called attributes D and N respectively (Table 1.1 and 1.2).

Time of Increased Probability (TIP) of appearance of strong erthquake is announced in the region at the moment t if:

1. $\Delta = n_1 - n_2 \geq \Delta$,

2. $\sigma(t) \leq \Sigma$.

Here n_1 n_2 -number of attributes D and N. $\sigma(t)$ - estimates the total fracture area for three preceding years. The **TIP** lasts a year. The TIP may be cancelled: either if a strong earthquake with $M \geq M_\Sigma$ ($\sigma(t) \geq \Sigma$) occurred, or swarm of earthquakes with total energy more then Σ occured (this swarm may include the earthquakes with $M \geq M_0$). Consecutive TIPs may overlap and prolong each other. If no strong earthquake occured during the TIP it is called a false alarm; strong earthquake which was not preceded by a TIP is a failure to predict. The total duration of TIPs is called alarm time . (For California - Nevada standard values of $\Delta = 5$; and $\Sigma = 4.9$.)

3. Data analysis:

The Himalayan region - the northern boundary of the Indian plate, is characterised by varying degrees of seismicity along its lentgth. During the past hundred years the region has experienced four devastating earthquakes of magnitude greater than 8 (fig. 1). One of these occured in the western segment while the other three ocurred in the eastern segment. The present day seismicity is of higher level in the vicinity of the regions of the past devastating earthquakes. These regions have also registerd earthquakes of magnitude ranging between 6 and 7 in the past twenty years. In the rest of the belt the seismicity has been rather low and the heighest magnitude is of the order of 5.5.

For our study we have considerd Himalayan belt bounded by active seismic region around Kangra, the site 1905 earthquake on the west

and the north east India region , the area of 1897 and 1950 earthquakes on the east (fig. 2). The area of study includes adjoining part of the Burmese arc in the east. Keeping in view the spatial distribution of earthquakes and the constraints of the CN algorithm the area is further divided into five regions. The boundries of these regions are given in Table 2 and shown in fig 2. The data base is taken from the NOAA catalogue [5]. We use the features and magnitude thresholds of California-Nevada region for all the subregions. However the thresholds for the discretisation of various functions were determined for each of the regions by studying classwise distribution of the functions. We selected Mo=6.4 due to the following reasons: it is the same threshold as for the territory of California and Nevada for which algorithm CN was first worked out; such earthquakes occur here within the same average time interval (each 7 years).

3.1 Region 1 (Kangra region)

This region is around the epicentral zone of devastating Kangra earthquake of magnitude 8.7 of 1905 (fig. 3). The region is very important from the point of view of seismic risk since the area is thickly populated and has number of industrial installations of river valley projects. The level of seismicity in the region is quite high and confined to shallow depths. The regions has experienced events of magnitude greater than 6 during the past 90 years. The catalog in this region can be considered to be reasonably complete since 1964 (Table 4.1). We therefore attempt examination of TIPs in this region since 1968. During the period 1964 to 1988 there are two earthquakes of magnitude greater than 6.4 (Table 3).

The results of TIPs diagnostics in this region are given in Table 5.1. Time of alarm occupies 86 months (34 %) using standard thresholds of Δ and Σ (Table 5.1a) and the strong earthquake of 1975 is succesfully predicted. However there are two false alarms. By changing the Δ threshold to higher value 7 but keeping the Σ threshold same we obtain some what better results as shown in Table 5.1b. The reduced threshold for Σ (2.8) and the previous threshold for Δ yield same succesful TIP without false alarm (Table 5.1c). The total time of TIP in this case is 4 months (1 %).

3.2 Region 2 (Garhwal - Kumaon Himalayas)

Region 2 covers Garhwal and Kumaon himalayan segment (fig.4). This area is also marked by a reasonably high degree of seismicity. Majority of the events are of magnitude between 4. and 5. and the activity in the range of magnitudes greater than 5.5 is rather diffused in time (Table 4.2). The region has experienced earthquakes of magnitude greater than 6 since 1900 of which 5 are during the period 1964 to 1988 (Table 3). Present day seismicity of the region can be understood only by help of NOAA catalog. Due to paucity of seismic station in the vicinity of the region the events in the lower magnitude range are perhaps not well reported. The histogram reflects some what incomplete nature of catalog with break of data in the period 1966 to 1978 or perhaps a quiscence for events of magnitude 5.5 and more.

In this region also we have attempted retrospective prediction of strong earthquake ($M \geq 6.4$) using algorithm CN. The results of our analysis are given in Table 5.2 for 3 different combinations of Δ and Σ thresholds. The standard thresholds yield one failure to predict and one succesful prediction with three false alarms. the total time of TIPs being 84 months (33 %). (Table 5.2a). Changing Δ threshold from five to 7 the number of false alarms are reduced to 2 and TIP duration to 46 months (18%). However the results with higher Δ threshold and lower Σ threshold (7 and 2.8 respectively) yield succesful prediction of event of 1982 and one false alarm with total time of TIPs equal to 30 months (12 %).

The results can be taken to be good. The failure to predict the event of 29-7 80 may be due to incomplet nature of catalog. Nevertheless succesful prediction of 23-1-82 event ,one of the two predictable event reflects the applicability of the algorithm in this region also.

3.3 Region 3 (Nepal - Bihar region)

The region is marked by scattered sesmicity of magnitude range 4.5 to 5.6 during the past 90 years and a devastating earthquake of magnitude 8.4 in 1934. Howewver the area did not register any earthquake of magnitude greater than 6.4 during the period 1964 till July 1988 (Table 4.3, fig.5). The catalog in this region can be considered to be reasonably complete starting from $M = 5.0$. In view of this it was not possible to use algorithm CN due to lack of events.

3.4 Region 4 (Shillong Platue and lower Assam region)

This region is seismically very active and makes the part of northeastern India-Indo -Burma seismic belt (fig.6). The region experienced a strong earthquake of magnitude 8.7 in the year 1897. Also there are some earthquakes of magnitude range 6 to 7.5 during the past 90 years. However there are no such events during 1964 to 1988 , the period of consderation in present study (Table 4.4). The catalog in this region can be considered to be reasonably complete starting from $M = 5.0$. In view of this the scheme could not be applied for reasons as in the case of region 4.

3.5 Region 5 (Assam)

This region is shown in fig.7. We considered only shallow earthquakes with depth ≤ 100. Earthquakes statistics in is given in Table 3. As it is seen from the Table 4.5 within the period from 1964 to 1988 yrs the catalog is complete starting from M ≥ 4.6. The nature of the quiescence in 1967, 1968 is not clear: whether it reflects reality or the catalog's incompleteness.

The strongest earthquakes of the given region since 1900 are compiled in Table 2. We can see that M_{max} here is equal to 7.6. In the period represented by the catalog [ ] there was a relative quiescence, and in this region also the M_0 is selected as 6.4.

Results of TIPs diagnostics are given in Table 5.3. Diagnostics with standard thresholds of Δ and Σ gives the following results: time of alarm occupies 9.6 years (48.3%) where fall two out of three strong earthquakes. If we assume Δ = 7, then the TIP will reduce to 4.7 years (23%) with one failures to predict. Besides, if we decrease σ to 1.3 then the total time of alarm is equal to 45 month (18%).

The first strong earthquake of 1970 with M=6.5 is missed in all three cases. This failure to predict is evidently linked with the quiescence in 1967, 1968 yrs.

3. Conclusions:

Such prediction would be quite acceptable though its reliability is not clear because we modified a posteriori the thresholds Δ and Σ. Naturally, the possibility of TIPs diagnostics with these thresholds is hypothetical, because these thresholds are retrospective and need testing by further monitoring of earthquakes flow, i.e. by forward prediction.

The analysis carried out in the present paper should be considered only as the basis for such testing.

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Table 1.1

The attributes of period D

number	N2	K	G	S	Smax	Zmax	N3	q	Bmax
1.		0							0
2.								0	
3.							0	0	0
4.						0		0	
5.		0					1		0
6.		1				0			0
7.		0				1			0
8.		0	0						0
9.					0	0			
10.		1		0		0			
11.		0 1				0			
12.	0	1				0			
13.		0			1				
14.		0			0				
15.		0		0					
16.		0	1						

Table 1.2

The attributes of period N

number	N2	K	G	S	Smax	Zmax	N3	q	Bmax
1.					1				1
2.						1		1	1
3.				1				1	1
4.		1						1	1
5.							0		1
6.					1				1
7.		1				1			1
8.	1					1			1
9.				1			0	1	
10.					1			1	
11.						1	0		
12.					1		0		
13.		1			1				
14.		1		1					
15.		1				1			
16.		1	1		1				
17.		1			1				
18.		1		1					

Table 2

Boundaries ob regions

N	Name of region	Coordinates
1	Kangra	(33;73), (35;75), (32;80), (30;78)
2	Garhwal - Kumaon	(30;78), (33;80,7), (31;85), (28;82)
3	Nepal - Bihar	(28;82), (31;85), (27,5;90,5), (25;88)
4	Shilong Platue	(25;88), (29,5;92,5), (27,7;94,7), (22;91)
5	Assam	(22;91), (28;95), (28;98), (25;98), (20;95)

Table 3

List of strong earthquakes

in 5 regions of India

N	Date	lat	lon	mag
Region 1, Kangra				
1	20.2.1967	33.66	75.34	6.4
2	19.1.1975	32.46	78.43	6.8
Region 2, Garhwal-Kumaon				
1	6.3.1966	31.50	80.50	6.5
2	29.7.1980	29.60	81.09	6.6
3	23.1.1982	31.70	82.25	6.5
Region 3, Nepal-Bihar				
There are not strong earthquakes				
Region 4, Shilong Platue				
There are not strong earthquakes				
Region 5, Assam				
1	29.7.1970	26.02	95.40	6.5
2	12.8.1976	26.68	97.07	6.4
3	6.8.1988	25.20	95.00	6.9

Table 4.1

Year	4.0–4.2	4.2–4.4	4.4–4.6	4.6–4.8	4.8–5.0	5.0–5.2	5.2–5.4	5.4–5.6	5.6–5.8	5.8–6.0	6.0–6.2	6.2–6.4	6.4–6.6	6.6–6.8	6.8–7.0	
64	.	.	.	.	2	.	.	.	.	.	.	.	.	.	.	2
65	.	.	1	.	.	.	1	.	.	.	.	.	.	.	.	2
66	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	1
67	.	.	.	.	1	.	.	.	.	.	.	.	1	.	.	2
68	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	1
69	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	0
70	.	.	.	.	1	1	.	.	.	.	.	.	.	.	.	2
71	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	0
72	.	.	.	1	.	.	1	.	.	.	.	.	.	.	.	2
73	1	.	.	1	.	1	.	1	.	.	.	.	.	.	.	4
74	.	.	.	1	1	.	.	.	.	.	.	.	.	.	.	2
75	.	.	.	1	.	.	2	1	.	.	.	.	.	.	1	5
76	.	.	1	.	.	1	.	.	.	.	.	.	.	.	.	2
77	.	.	.	2	2	2	.	1	.	.	.	.	.	.	.	7
78	1	.	.	1	.	1	.	.	.	.	.	.	.	.	.	3
79	.	1	2	.	2	1	.	.	.	.	.	.	.	.	.	6
80	.	1	.	2	.	1	1	.	.	.	.	.	.	.	.	5
81	.	.	1	.	2	.	.	.	1	.	.	.	.	.	.	4
82	.	.	.	1	1	.	.	.	.	.	.	.	.	.	.	2
83	.	.	.	1	.	.	1	.	.	.	.	.	.	.	.	2
84	.	1	.	1	1	.	.	.	.	.	.	.	.	.	.	3
85	.	.	.	1	3	.	.	.	.	.	.	.	.	.	.	4
86	.	.	.	2	1	.	.	1	1	.	.	.	.	.	.	5
87	.	.	.	2	.	.	.	.	.	.	.	.	.	.	.	2
88	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	0
	2	3	5	17	18	9	6	4	2	0	0	0	1	0	1	

68 events

Table 4.2

Year	4.0–4.2	4.2–4.4	4.4–4.6	4.6–4.8	4.8–5.0	5.0–5.2	5.2–5.4	5.4–5.6	5.6–5.8	5.8–6.0	6.0–6.2	6.2–6.4	6.4–6.6	6.6–6.8	6.8–7.0	
64	.	.	.	.	.	1	.	.	.	.	.	1	.	.	.	2
65	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	0
66	.	.	.	.	1	1	.	.	1	.	1	.	1	.	.	5
67	.	.	.	.	1	.	1	.	.	.	.	.	.	.	.	2
68	.	.	.	.	.	1	.	1	.	.	.	.	.	.	.	2
69	.	.	.	.	1	.	2	1	.	.	.	.	.	.	.	4
70	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	1
71	.	.	.	1	.	.	.	1	.	.	.	.	.	.	.	2
72	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	0
73	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	1
74	.	.	1	.	1	.	1	.	.	.	.	.	.	.	.	3
75	1	.	.	.	.	1	.	.	.	.	.	.	.	.	.	2
76	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	1
77	.	.	.	.	1	1	.	.	.	.	.	.	.	.	.	2
78	.	1	.	1	.	.	.	.	.	.	.	.	.	.	.	2
79	.	1	.	.	.	.	.	.	.	1	.	.	.	.	.	2
80	.	.	.	.	.	1	.	.	1	.	.	.	.	1	.	3
81	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	1
82	.	.	2	1	1	.	.	.	.	.	.	.	1	.	.	5
83	.	.	.	1	1	.	.	.	.	.	.	.	.	.	.	2
84	.	2	1	.	2	3	.	.	1	.	.	.	.	.	.	9
85	.	.	1	2	.	.	.	.	.	.	.	.	.	.	.	3
86	.	1	.	1	.	.	.	.	.	.	.	.	.	.	.	2
87	.	.	.	1	1	.	1	.	1	.	.	.	.	.	.	4
88	.	1	.	1	.	.	.	.	.	.	.	.	.	.	.	2
	1	6	6	9	11	9	6	4	4	1	1	1	2	1	0	

62 events

Table 4.3

Magnitude

Year	4.0	4.2	4.4	4.6	4.8	5.0	5.2	5.4	5.6	5.8	6.0	6.2	6.4	6.6	6.8	
64	.	.	1	1	1	.	1	.	.	.	.	1	.	.	.	5
65	.	.	.	.	.	.	1	.	.	.	1	.	.	.	.	2
66	.	.	1	.	.	1	.	.	.	.	.	.	.	.	.	2
67	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	1
68	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	1
69	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	0
70	.	.	.	1	.	.	2	.	.	.	.	.	.	.	.	3
71	.	.	.	.	1	2	.	.	.	.	.	.	.	.	.	3
72	.	.	.	.	2	1	2	.	.	.	.	.	.	.	.	5
73	.	.	.	.	.	.	2	.	.	.	.	.	.	.	.	2
74	.	.	.	.	.	.	.	.	2	.	.	.	.	.	.	2
75	.	2	.	.	2	2	1	1	.	.	.	.	.	.	.	8
76	.	.	.	.	1	1	.	.	.	.	.	.	.	.	.	2
77	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	1
78	.	.	3	1	.	.	2	.	.	.	.	.	.	.	.	6
79	.	2	.	1	1	1	.	.	.	.	.	.	.	.	.	5
80	1	.	1	1	1	.	.	.	.	.	1	.	.	.	.	5
81	.	.	1	.	.	1	.	.	.	.	.	.	.	.	.	2
82	.	1	.	2	.	1	.	.	.	.	.	.	.	.	.	4
83	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	1
84	.	.	2	1	.	.	1	.	.	.	.	.	.	.	.	4
85	.	.	3	1	.	.	.	.	.	.	.	.	.	.	.	4
86	1	.	1	.	.	1	.	1	.	.	.	.	.	.	.	4
87	1	.	.	3	.	.	.	.	.	.	.	.	.	.	.	4
88	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	0
	3	6	13	12	12	11	12	2	2	0	2	1	0	0	0	

(Scale ends at 7.0.)

76 events

Table 4.4

Magnitude

Year	4.0	4.2	4.4	4.6	4.8	5.0	5.2	5.4	5.6	5.8	6.0	6.2	6.4	6.6	6.8	
64	.	.	.	.	.	.	.	.	2	1	.	.	.	.	.	3
65	.	1	.	.	.	1	1	.	.	.	.	.	.	.	.	3
66	.	.	1	1	2	1	.	1	.	.	.	.	.	.	.	6
67	.	.	1	.	1	4	.	.	.	1	.	.	.	.	.	7
68	1	.	.	.	1	.	3	.	.	.	.	.	.	.	.	5
69	.	.	1	.	1	2	.	.	.	.	.	.	.	.	.	4
70	.	.	.	.	1	.	.	1	.	.	.	.	.	.	.	2
71	.	1	.	1	.	.	1	1	.	.	.	.	.	.	.	4
72	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	0
73	.	.	.	.	3	.	1	.	.	.	.	.	.	.	.	4
74	.	.	1	2	.	.	.	.	.	.	.	.	.	.	.	3
75	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	0
76	.	.	.	2	.	.	.	.	.	.	.	.	.	.	.	2
77	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	1
78	.	.	1	.	1	.	.	.	.	.	.	.	.	.	.	2
79	.	1	2	1	1	.	.	.	.	.	.	.	.	.	.	5
80	.	.	.	.	1	1	.	.	.	.	.	.	.	.	.	2
81	.	.	1	.		.	.	.	.	.	.	.	.	.	.	1
82	.	1	1	4	2	3	.	.	.	.	.	.	.	.	.	11
83	.	.	.	.	1	.	1	.	.	.	.	.	.	.	.	2
84	.	.	1	1	1	1	2	.	.	.	.	.	.	.	.	6
85	.	1	1	1	1	1	1	.	1	.	.	.	.	.	.	7
86	.	.	1	1	1	.	2	.	.	.	.	.	.	.	.	5
87	1	.	2	1	4	1	.	.	.	.	.	.	.	.	.	9
88	1	.	.	.	1	.	.	.	.	1	.	.	.	.	.	3
	3	5	14	15	23	16	12	3	3	3	0	0	0	0	0	

(Scale ends at 7.0.)

97 events

Table 4.5

Year	Magnitude 4.0–4.2	4.2–4.4	4.4–4.6	4.6–4.8	4.8–5.0	5.0–5.2	5.2–5.4	5.4–5.6	5.6–5.8	5.8–6.0	6.0–6.2	6.2–6.4	6.4–6.6	6.6–6.8	6.8–7.0	
64	1	.	.	.	.	.	.	2	1	.	1	.	.	.	.	5
65	.	.	1	.	.	.	.	3	.	2	.	.	.	.	.	6
66	1	2	1	1	2	1	2	.	1	.	.	.	.	.	.	11
67	.	.	.	3	2	.	.	.	.	.	1	.	.	.	.	6
68	.	.	.	2	.	.	.	.	.	.	.	.	.	.	.	2
69	.	.	.	2	1	.	2	2	.	.	.	.	.	.	.	7
70	.	.	.	1	1	1	1	1	.	.	.	.	1	.	.	6
71	.	.	.	1	1	2	2	1	.	.	1	.	.	.	.	8
72	.	.	1	.	.	.	2	.	.	.	.	.	.	.	.	3
73	.	1	1	1	2	1	1	.	.	1	.	.	.	.	.	8
74	.	.	1	1	2	1	.	.	.	.	.	.	.	.	.	5
75	.	.	1	2	1	1	2	.	1	.	.	.	.	.	.	8
76	3	.	.	1	2	1	.	1	.	.	.	.	1	.	.	9
77	.	.	3	3	.	.	1	.	1	.	.	.	.	.	.	8
78	1	1	4	3	2	2	.	.	.	.	.	.	.	.	.	13
79	.	.	2	2	3	2	2	1	.	.	.	.	.	.	.	12
80	.	.	.	4	1	2	1	.	.	.	.	.	.	.	.	8
81	.	.	1	7	3	3	1	.	.	.	.	.	.	.	.	15
82	.	1	.	4	3	2	.	.	.	.	.	.	.	.	.	10
83	.	1	1	2	2	3	2	.	.	.	.	.	.	.	.	11
84	1	.	5	2	3	.	1	.	1	1	.	.	.	.	.	14
85	.	1	3	1	1	3	1	.	.	.	.	.	.	.	.	10
86	.	.	3	1	3	3	2	2	.	.	.	.	.	.	.	14
87	.	1	1	4	2	1	1	.	.	1	.	.	.	.	.	11
88	.	.	1	.	2	.	.	.	.	.	.	.	.	.	1	4
	7	8	30	48	39	29	24	13	5	5	3	0	2	0	1	

214 events

KANGRA (region 1) Table 5.1

Results of TIPs diagnosis with

Δ: 5 Σ=4.9

Start of TIP	Strong earthqauke Date	M	End of false alarm	Duration of TIP, month
11. 1973	19. 1. 1975	6. 8		14
1. 1975			1. 1979	48
7. 1981			7. 1983	24

Number of strong earthquakes = 1 Number of succeses = 1

Total time of TIPs = 86month (34. 00%)

Δ: 7 Σ=4.9

Start of TIP	Strong earthqauke Date	M	End of false alarm	Duration of TIP, month
9. 1974	19. 1. 1975	6. 8		4
1. 1975			1. 1976	12
3. 1976			1. 1979	34

Number of strong earthquakes = 1 Number of succeses = 1

Total time of TIPs = 50month (20. 00%)

Δ: 7 Σ=2. 8

Start of TIP	Strong earthqauke Date	M	End of false alarm	Duration of TIP, month
9. 1974	19. 1. 1975	6. 8		4

Number of strong earthquakes = 1 Number of succeses = 1

Total time of TIPs = 4month (1. 00%)

GARHWAL-KUAMON (region 2) Table 5.2

Results of TIPs diagnosis with

Δ= 5 Σ=4.9

Start of TIP	Strong earthqauke Date	M	End of false alarm	Duration of TIP, month
3.1968			5.1970	26
	29. 7.1980	6.6		failure
9.1980	23. 1.1982	6.5		16
1.1982			5.1984	28
9.1984			11.1985	14

Number of strong earthquakes = 2 Number of succeses = 1

Total time of TIPs = 84month (33.00%)

Δ= 7 Σ=4.9

Start of TIP	Strong earthqauke Date	M	End of false alarm	Duration of TIP, month
	29. 7.1980	6.6		failure
9.1980	23. 1.1982	6.5		16
1.1982			5.1983	16
9.1984			11.1985	14

Number of strong earthquakes = 2 Number of succeses = 1

Total time of TIPs = 46month (18.00%)

Δ= 7 Σ=2.8

Start of TIP	Strong earthqauke Date	M	End of false alarm	Duration of TIP, month
	29. 7.1980	6.6		failure
9.1980	23. 1.1982	6.5		16
9.1984			11.1985	14

Number of strong earthquakes = 2 Number of succeses = 1

Total time of TIPs = 30month (12.00%)

ASSAM (region 5) Table 5.3

Result of TIPs diagnosis with

Δ= 5 Σ=4.9

Start of TIP	Strong earthqauke Date	M	End of false alarm	Duration of TIP, month
	29. 7.1970	6.5		failure
9.1970			7.1973	34
1.1976	12. 8.1976	6.4		7
8.1976			3.1979	31
1.1985	6. 8.1988	6.9		44

Number of strong earthquakes = 3 Number of succeses = 2

Total time of TIPs = 116month (48.30%)

Δ= 7 Σ=4.9

Start of TIP	Strong earthqauke Date	M	End of false alarm	Duration of TIP, month
	29. 7.1970	6.5		failure
7.1976	12. 8.1976	6.4		1
8.1976			7.1977	11
1.1985	6. 8.1988	6.9		44

Number of strong earthquakes = 3 Number of succeses = 2

Total time of TIPs = 56month (23.30%)

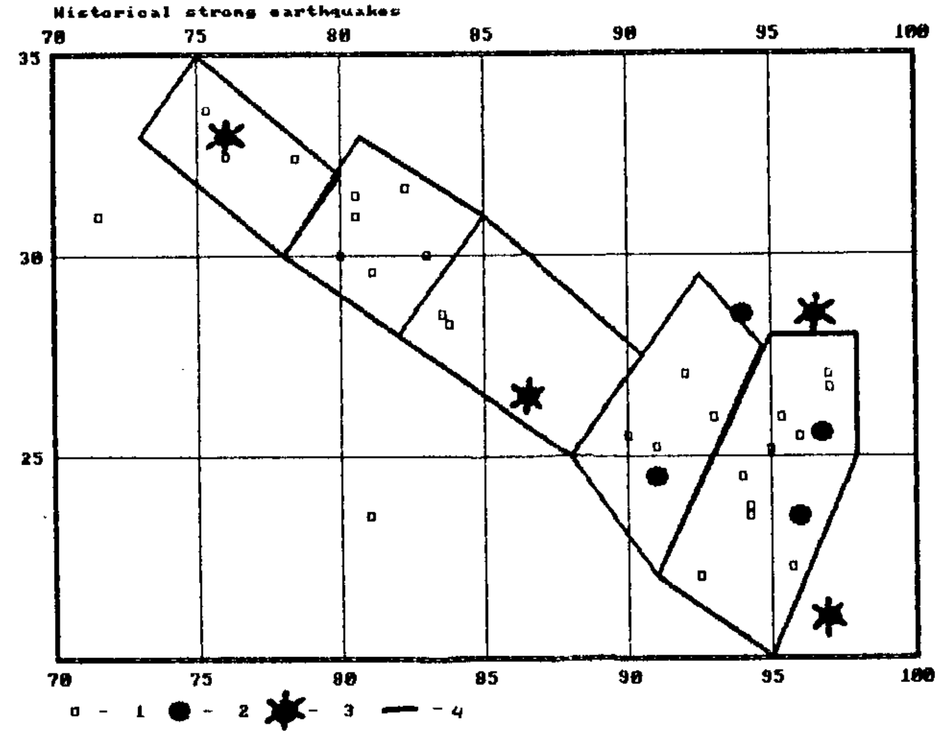
Δ= 7 Σ=1.3

Start of TIP	Strong earthqauke Date	M	End of false alarm	Duration of TIP, month
	29. 7.1970	6.5		failure
7.1976	12. 8.1976	6.4		1
1.1985	6. 8.1988	6.9		44

Number of strong earthquakes = 3 Number of succeses = 2

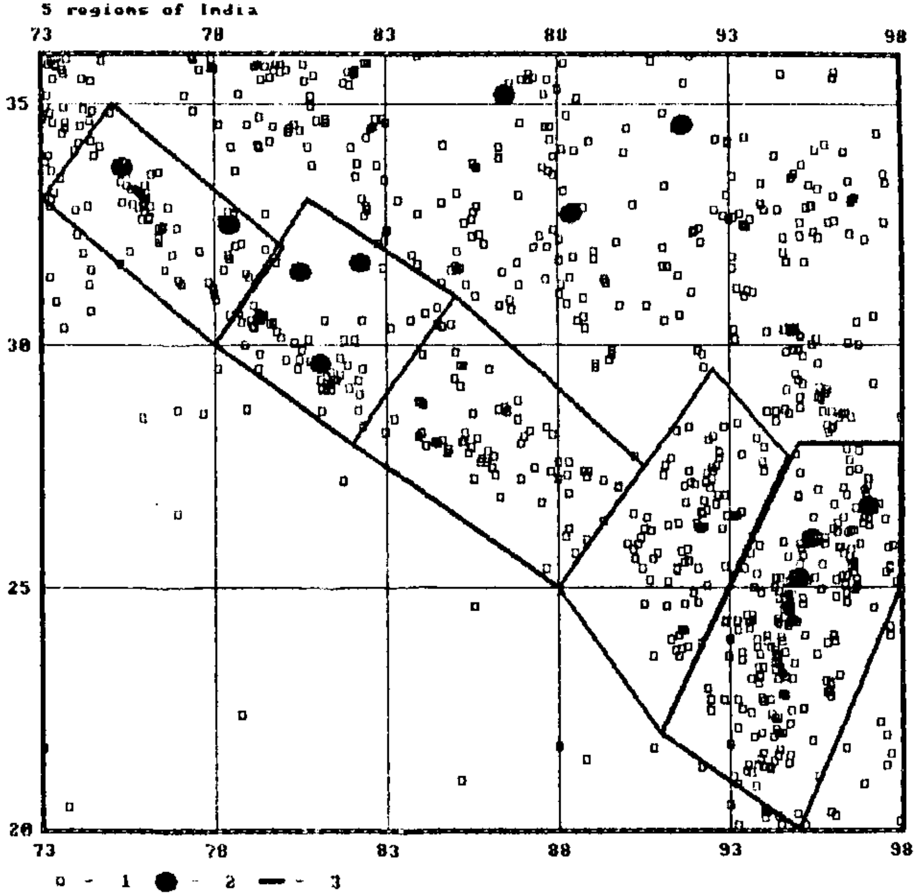
Total time of TIPs = 45month (18.80%)

Fig. 1



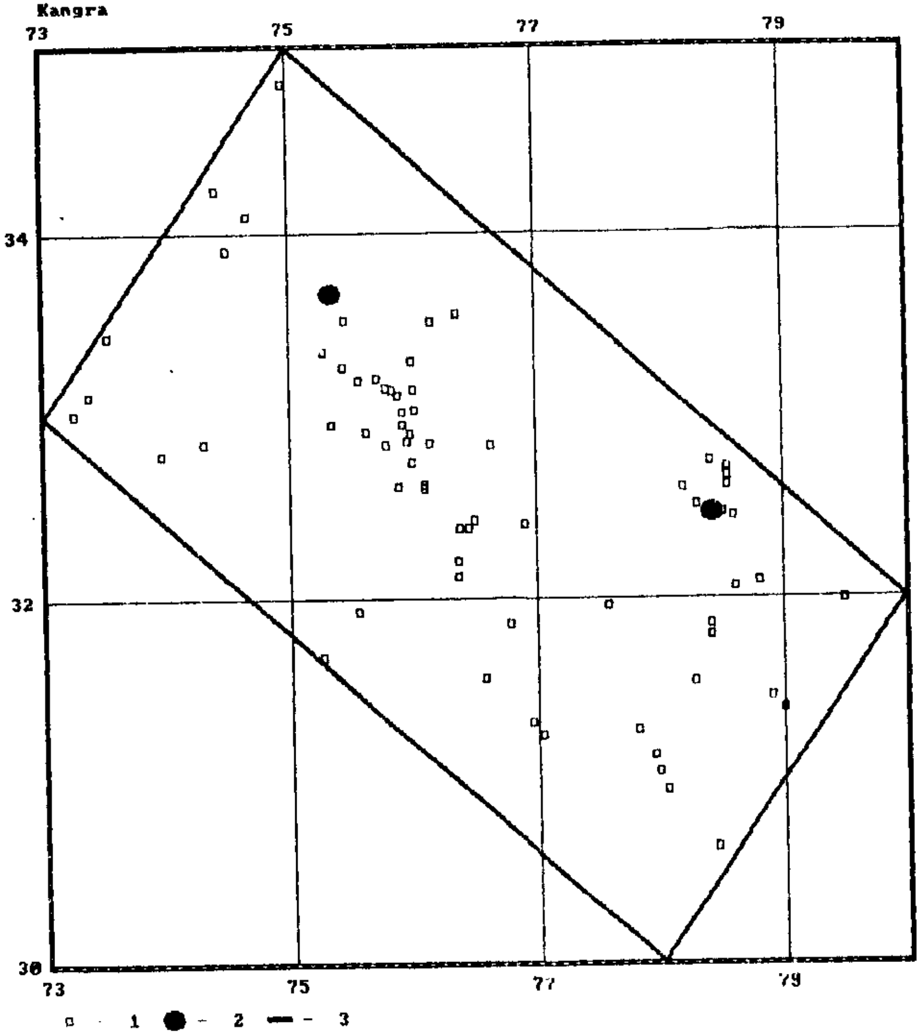
1 - magnitude 6.4 ≤ M < 7.5; 2 - magnitude 7.5 ≤ M < 8.0;
3 - magnitude M ≥ 8.0; 4 - boundaries of regions

Fig. 2



1 - magnitude M < 6.4; 2 - magnitude M ≥ 6.4;
3 - boundaries of regions

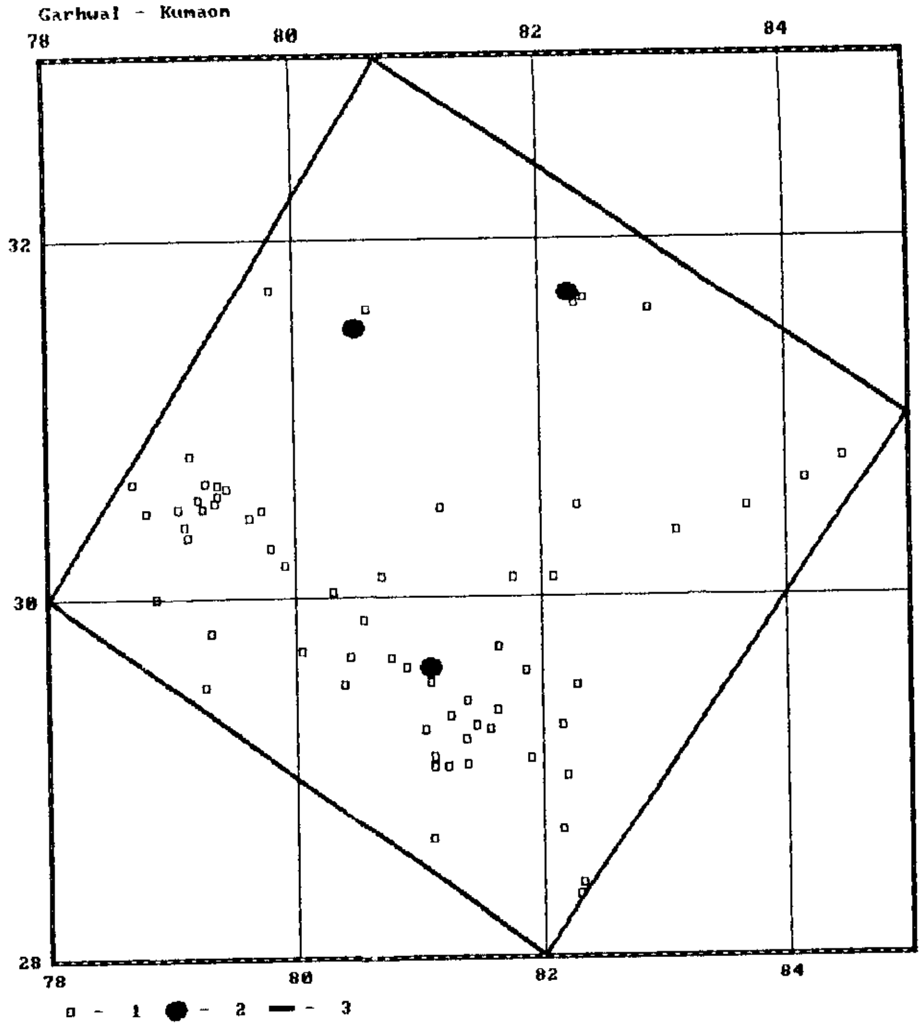
Fig 3



1 - magnitude M < 6.4; 2 - magnitude M ≥ 6.4;

3 - boundaries of regions

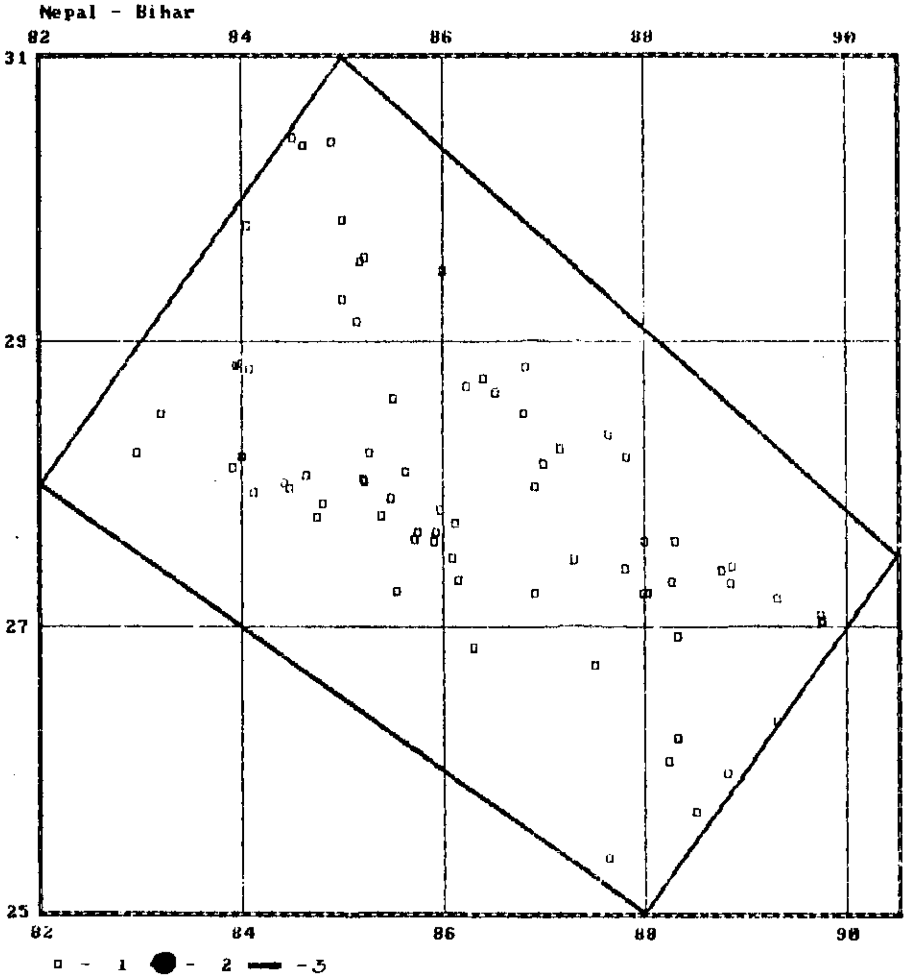
Fig 4



1 - magnitude M < 6.4; 2 - magnitude M ≥ 6.4;

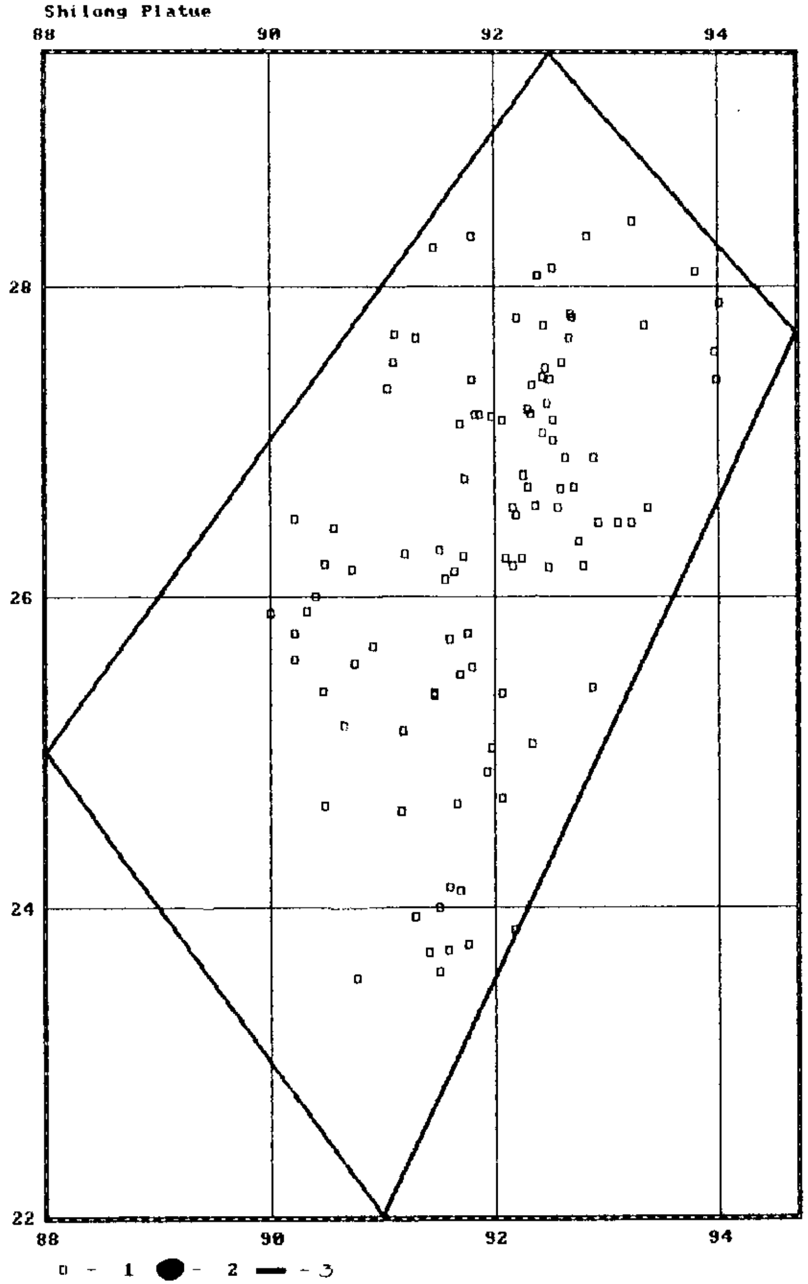
3 - boundaries of regions

Fig. 5



1 - magnitude M < 6.4; 2 - magnitude M ≥ 6.4;

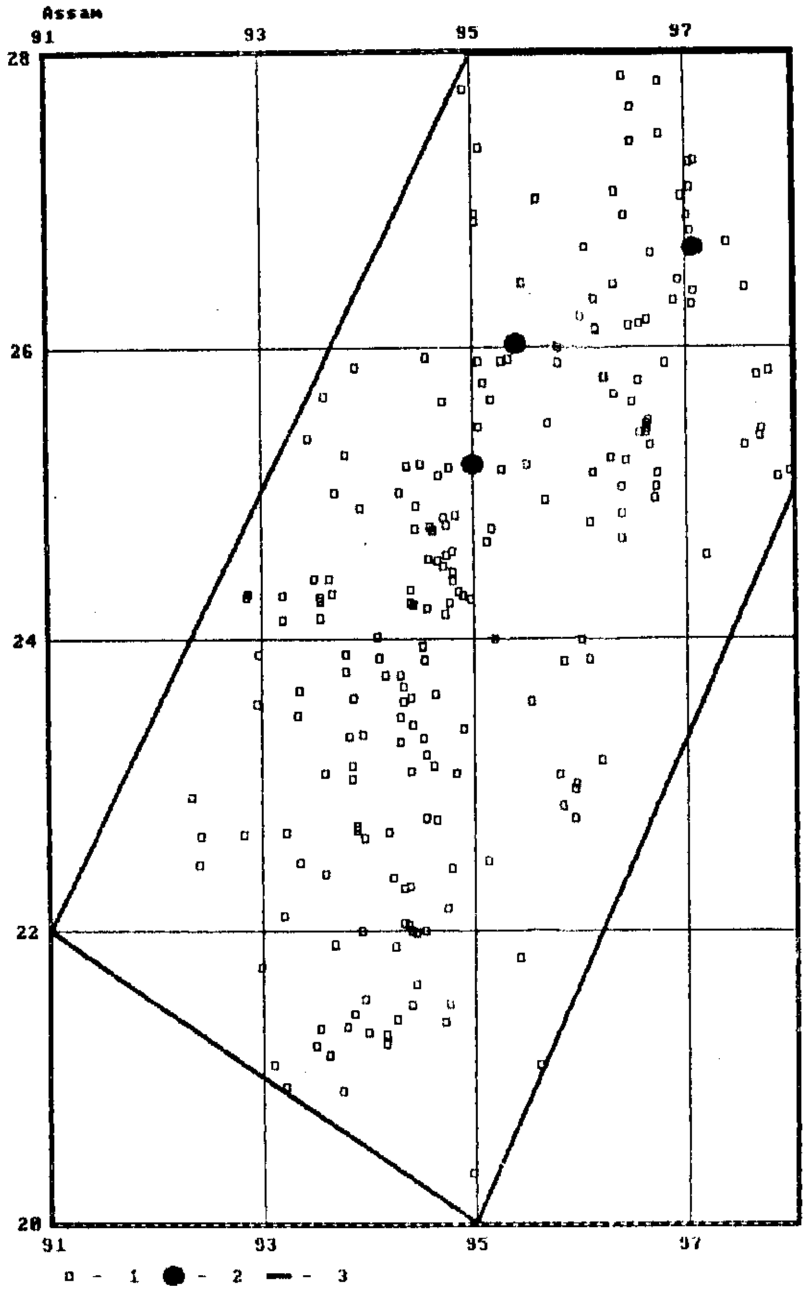
3 - boundaries of regions



1 - magnitude M < 6.4; 2 - magnitude M ≥ 6.4;

3 - boundaries of regions

Fig. 7



1 - magnitude M < 6.4; 2 - magnitude M ≥ 6.4;

3 - boundaries of regions

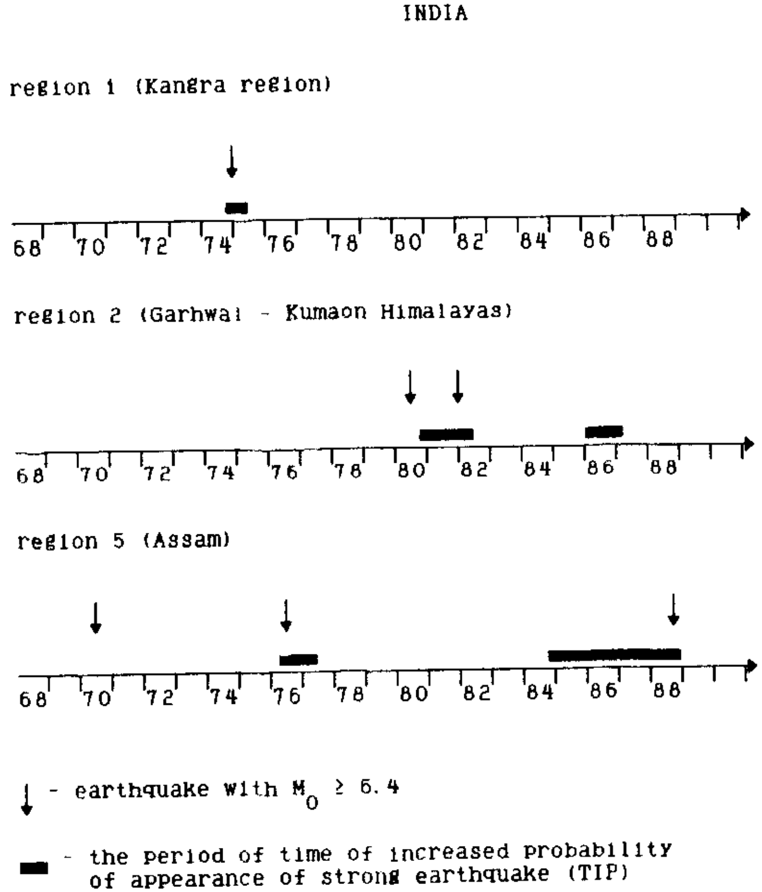


FIG. 8