Seismicity in Central Kerala: Some Observations

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Abstract

Last 15 years had witnessed 3 earthquake events of M>4.5 in parts of Kottayam-Idukki districts of Central Kerala. The twin earthquakes of 2000 and 2001 (M 5.0, 4.8) were a rare phenominon in peninsular India. The damage pattern show that the two mesoseismal areas were separated by about 15 km and isoseismals of both the earthquakes oriented in NNW-SSE directiond. Literature survey had unearthed another set of twin events, slightly south of this area in 1953. This earthquake sequence had some similarities with the 2000-2001 earthquake sequence including the westward migration. Spatially, these events are associated with NNW-SSE lineaments, which are sympathetic to the west coast fault. Epicenters located by instruments for these events were well off from the felt area. Historically, a few more tremors were also reported in this region. Drainage morphometry analysis of this area show deviation from symmetry for the drainages bearing NNW-SSE lineaments. The occurence of tremors and geomorphic anomalies may be indicative of the NNW-SSE fractures (parallel to west coast fault) experiencing adjustment under the present regional stress regime.

Introduction

Until recently Indian shield was considered as stable, relatively free from earthquakes. However, the 1993 Latur and 1997 Jabalpur earthquakes had changed this concept and many studies were initiated to find out similar source zones (eg. Rajendran, 1997; Dole et al., 2000; John and Rajendran, 2005). Available data from various intraplate regions indicate that earthquakes are associated with faults of varying reactivation periods and these may have never been reactivated during the recorded history before (Rajendran and Rajendran, 2004). Some other studies in Peninsular India shows that the failure will occur generally to those faults which are more favorably oriented to failure in the present N-S compressional stress regime (Gowd, et al. 1996). Paleoseismic studies, which are vital for establishing recurrence interval, are restricted to brittle fault zones within the crystalline rocks, where no appreciable Quaternary sediments are available (John, et al., 2006). Thus it is very important to look into the pattern of ongoing earthquake activity so as to constrain the nature of regional seismicity and to identify potential seismic source zones.

The region of Kerala, a part of the stable continental Region (SCR), has experienced occasional seismic activity since historic times (Rajendran and Rajendran, 2004). Three earthquakes occured during the past 15 years, viz,1988 Idukki, 2000 and 2001 Irattupeta/Pala events (Singh et al., Bhattacharya and Dattatrayam, 2002). Bellore (1900) also suggested that the region of North Travencore was the zone of microseismicity in the 19^{th} Century. Earthquake data for the last half are better docimented for Kerala region (Rajendran and Rajendran, 2004), However, all the recent catalogues (GSI, 2000; Chandra, 1977) missed the very important earthquake events in central Kerala. This paper tries to explore this unnoticed 1953 earthquake data and work out its significance in the ongoing activity of the region. We also worked out geomorphic analysis to identify signatures of neotectonic activity in this area.

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Seismicity of the area

The oldest documented earthquake in this area was reported as occurred on 10.01.1821 (Oldham, 1883). Historic events for this area till 1856 were reported in Oldham (1883) and located by Chandra (1977). During our study we located the 1952-53 earthquake events. Most of these earthquakes were shallow and associated with acoustic emissions. The modified list of earthquakes occurred between 9.5°-10°N/76.5°-77°E as given in Table 1. The following text will discuss these earthquake sequences starting from the most recent one.

Table 1. Earthquakes reported from Kottayam district.

Date	Lat° N	Long° E	Inten/Mag	Source
10.01.1821	9.5	76.6	III	OLD
15.09.1841	9.5	76.6	IV	OLD
23.11.1849	9.5	76.6	IV	OLD
01.09.1856	9.5	76.6	V	OLD
31.10.1952	9.59	76.86	IV	Gopal
25.02.1953	9.58	76.83	V	Gopal
21.03.1953	9.56	76.76	V	Gopal
11.01.1981	9.92	76.61	3	GBA
17.02.1981	9.95	76.8	3.3	GBA
02.12.2000	9.69	76.8	VI/ 5.0	IMD/GSI/ CESS
07.01.2001	9.7	76.8	VI/ 4.8	IMD/GSI/ CESS

The earthquake sequence of 2000-2001

The earthquake sequence of 2000-2001 Irattupetta/Pala had been the most recent in this region.These earthquake events occured within an interval of 26 days and the second one produced maximum damage. The first of

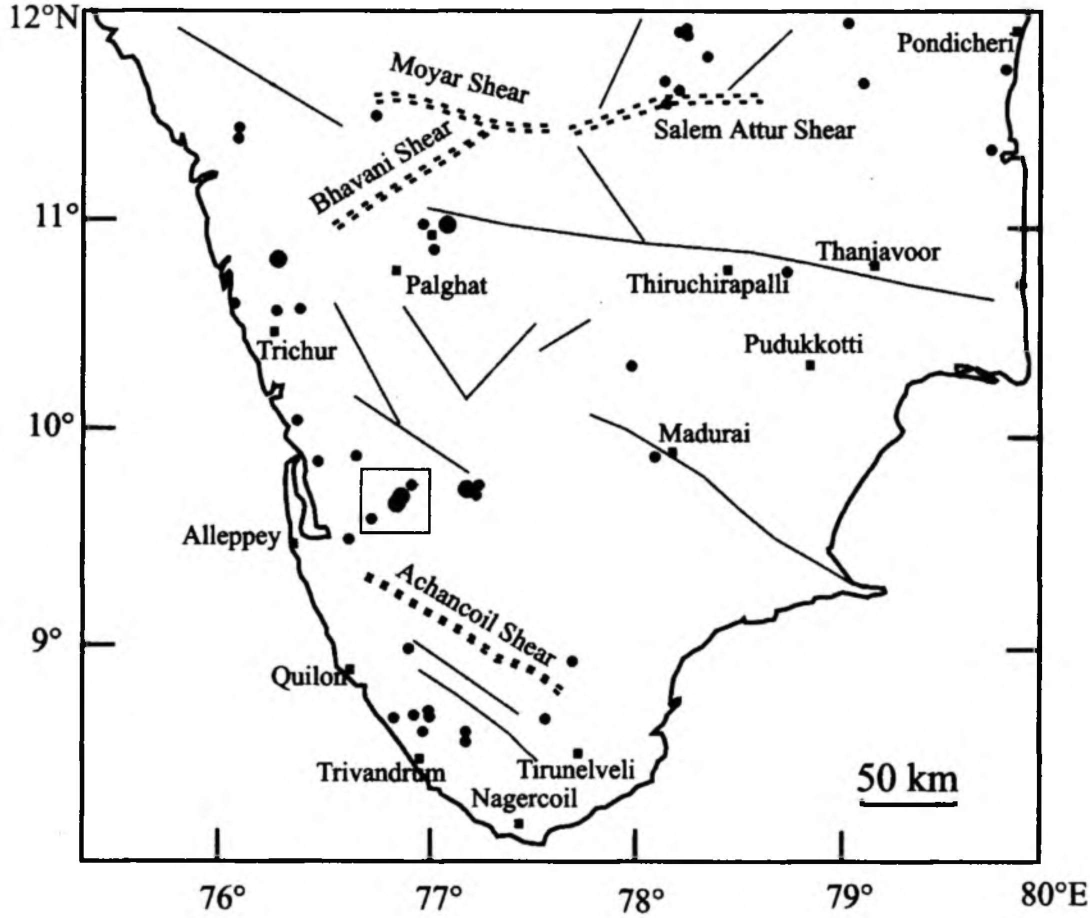

Fig.1. Historic and recent earthquakes in peninsular India area; Majot fault/lineaments and shear zones are also marked (modified after Rajendran and Rajendran, 2004). Rectangle is the area of ongoing activity evaluated in this study.

this sequence (M5.0) occurred in the morning of 12th December 2000 (Bhattacharya and Dattatrayam, 2002 and Harendranath et al., 2005). This earthquake was felt widely in Kerala and adjoining parts of Tamil Nadu (Fig. 2). Cracks appeared in some houses in the epicentral area. A few buildings in Melukavu region developed cracks. A new Polio Home in Melukavu and a 50 year old church constructed on overburden of a hill slope at Meladukkam formed distinct shear cracks in NW-SE walls and peeling off of large chunks of plaster were observed. This earthquake was followed by a series of aftershocks. Some open wells went dry in Kanjirapalli area, 20 km south of the epicentre, after this earthquake (Harendranath, et al., 2005). Based on the damage pattern it is assumed that the epicentre of the event falls between Melukavu and Meladukkam.

Table 2. Drainage basin asymmetry factor derived for the area

Basin No.	Basin Area Km^2	Basin Right area Km^2	Assymetry Factor (AF)	Deviation from normal
1	34.65	14.65	42.28	8
2	46.55	21.675	46.56	3
3	37.35	20	53.55	7
4	46.5	29.57	63.59	14
5	13.5	7.225	53.52	3
6	17.576	8.05	45.8	4
7	16.3	11.4	69.93	20
8	31.225	9.475	30.34	20
9	22.925	7.9	34.46	16
10	10.825	4.85	44.8	5
11	49.35	27.75	56.23	6
12	29.775	13.175	53.18	3
13	45.775	27.6	60.24	10
14	37.375	23.675	63.375	13
15	28.425	16.75	58.92	9
16	18.025	14.15	78.44	28
17	29.575	9.05	30.60	19
18	19.425	8.35	42.98	7
19	61.125	25.55	41.26	9
20	14.775	2.4	16.24	34
21	45.35	23.925	52.09	2
22	17.225	10.6	61.55	12
23	48.625	30.025	61.74	12
24	54.55	21.8	98.96	10
25	39.425	13.15	33.35	17
26	63.65	42.15	66.22	16
27	14.675	6	40.88	9
28	8.975	5.325	59.33	9
29	61.05	23.975	39.27	11
30	66.5	28.3	42.55	8
31	29.05	15.525	53.44	3
32	24.225	10.125	41.79	8
33	30.075	18.425	61.26	11
34	21.05	13.3	63.18	13
35	11.05	3.65	33.03	17
36	37.575	13.725	36.52	13
37	42.7	15.825	37.06	13
38	16.5	11.025	66.81	17
39	36.625	19.975	54.54	5
40	35.025	21.525	61.456	11
41	37.55	23.7	63.11	13
42	11.325	3.7	32.67	17
43	27.85	10.275	36.894	13
44	8.275	5.9	71.3	21
45	23.425	10.15	43.32	7
46	50.225	30.425	60.57	11
47	18.925	10.6	56.01	6
48	17.075	6.225	36.45	14
49	15.4	3.75	24.35	25

On 7 January 2001 another earthquake of magnitude 4.8 occurred in this area. This was more damaging around Pala (Harendranath, et al., 2005). The 64 year old St: Gergory church in Kizaparayar near Pala suffered cracks in the floor and walls. A statue of Mary resting on the top of the church building fell towards south (Bhattacharya and Dattatrayam, 2002). This earthquake was also followed by thirty two aftershocks in the next two days. Damages caused during this earthquake appeared to be more than those in the previous one of 12th December 2000. The Damage pattern indicated that the epicentre was near Kizhaparayar (Fig. 3).

An appreciable difference in the epicentral location are derived on the basis of instrumental records and field data, when plotted in large scale map (refer Fig. 3 and Table 1 for details). Field data showed that these two earthquakes were from different source zones (Fig. 2) and separated by 15 km (Harendranath, et al., 2005) where the second one occured west of the first one. However, the isoseismals of both these events show NNW-SSE elongation may be indicating a strike slip fault.

The events of 1981

Two unnoticed events occured in 1981 (Table 1). Both these events were instrumentally detected and occurred on 11.01.1981 (M 3.0) and 17.02.1981 (M 3.3). The two events occurred within 38 days and no felt report available for these earthquakes.

The 1953 earthquake sequences

A similar earthquake sequence was reported in 1953 (Gopal, 1953). However, these events are missed in earthquake catalogues of peninsular India. The following description of the earthquakes are from the GSI report (Gopal, 1953) and from local newspaper. On the night of the 25th of February 1953 a big tremor associated with a loud explosive noise was reported. This earthquake was felt all over north Travencore and the houses shivered at many places. This tremor was the strongest in the series and people from Kangirapalli reported that the earthquake lasted for 10 to 15 seconds. Some houses in Kanjirapally, Mundakayam and Punjar developed cracks in the walls. Thus, the maximum intensity of this event can be taken as V in the MM Scale. On seeing this felt

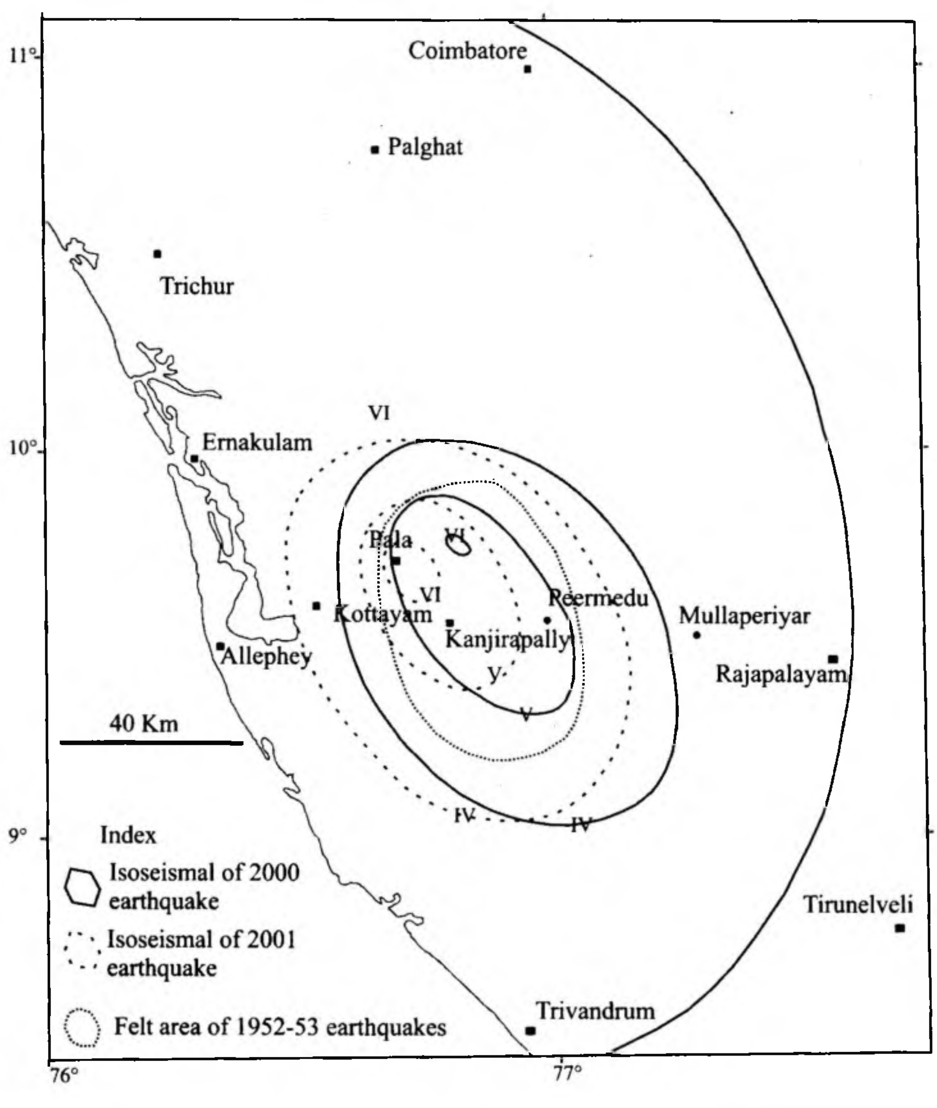

Fig. 2. Isoseismals of 2000-2001 earthquakes (after Harendranah et al., 2005) and the felt area of 1952-1953 earthquake sequence (calculated from Gopal, 1953).

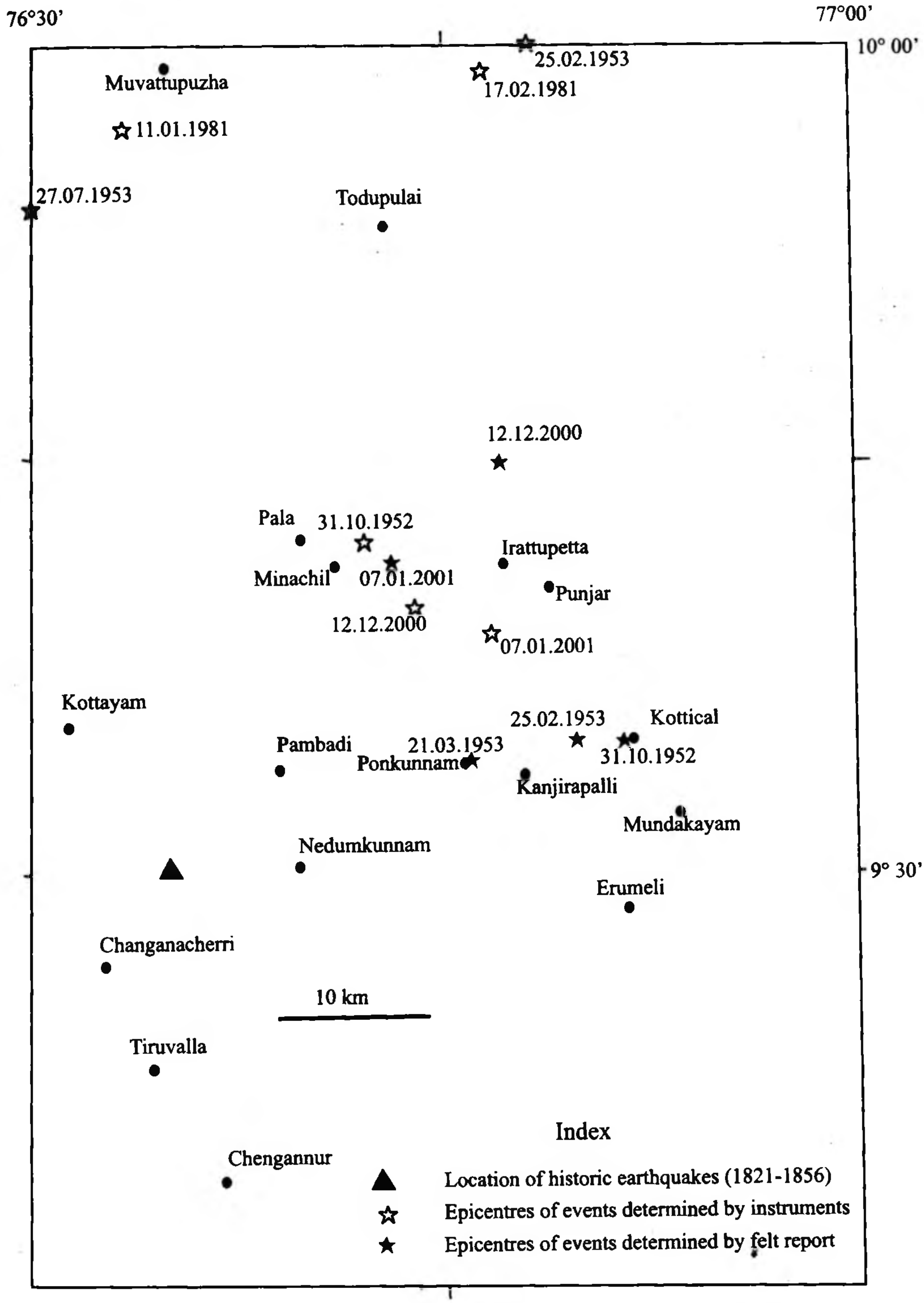

Fig. 3. Seismicity of the area, between 95°-10°N and 76.5°-77°E, from historic to recent. Filled stars are locations of earthquake based on the felt reports. Open stars are instrumental locations. Filled triangles are locations assigned by Chandra (1977) for earthquakes between 1821 and 1856 (see table 1 for details).

report the earthquake epicentre can be put in an area between Kanjirapally, Mundakayam and Punjar (Fig 2). A Series of aftershocks was reported intermittently after this earthquake for many weeks in this area.

On 21st March another big earthquake occurred in the region. The event was accompanied by a loud explosive sound followed by a long rumbling noise for one or two minutes. A number of cracks along corners and above windows and doorways are developed in the small and old post office building in Ponkunnam. We consider this as the epicentre of the event as it showed an enhanced damage at this place equivalent to the intensity of V in the MM Scale. The earthquake was recorded in different seismic observatories and the epicenter was tentatively calculated as at 10°N 76.8°E (Gopal, 1953).

These two earthquakes were occured within 21 days. Instrumental data are available only of the second event and are well off from the field data (Fig. 3). The epicentral area of these earthquakes were separated by about 10 km and notably the second event occured west of the first event. More significantly these events were occurred south of the 2000-2001 events.

Earthquake of 1952

Report of an earlier earthquake, which occured on the 31st of October 1952, was documented by Gopal (1953). The children of a school ran out of the classes out of fear at Kuttikal where the intensity was reported to be maximum and can be considered as the epicentre of this event. This earthquake was felt by people all over the area about 200 sq miles and followed by three aftershocks. Even though this earthquake (M3.7) was included in various list of catelogues, date of the event was not given. The instrumental location of this earthquake falls on 9.6-76.7 (Fig. 3) which is again away from the felt area. There were no important events reported till 25th of February 1953.

Other Historic events of the area

Oldham (1883) reported three events in this area between 1821-1849 (Table 1). However, he has not given any specific locations for the felt area. Chandra (1977), while evaluating the peninsular India earthquakes, put the location of these events tentatively as 9.5°N-76.6°E. Since there are no documents available for the verification of the location, later workers used this data in there interpretations (eg. GSI, 2000; Rao and Rao, 1984; Rajendran and Rajendran, 2004).

Relation with Geology and Structure

Charnokites and biotite gneiss constitute the major rock types of the area (Fig.4). Granite and garnet biotite gneiss occur in patches. Occurrence of dolerite dykes are the most noted rock units in the area. Magnetite quartzite, calc granulite and quartzite are also occur in vein forms. Calc granulites are the major intrusions in the biotite gneiss where as the quartzites occur in both charnokite and biotite.

There are 5 major sets of lineaments identified in Kerala (Nair, 1990). However, NNW-SSE and WNW-ESE lineaments are dominant in this area (Fig. 4). The WNW-ESE Periyar lineament is located on the northern side of the area. The contact between charnokite biotite gneiss makes another major WNW-ESE lineament, which is also marked by dyke activity. A WNW-ESE lineament demarcates charnokite and biotite gneiss. These lineaments are also marked by extensive dyke formation. A few more WNW-ESE trending lineaments are also found in this area where (Fig. 4).The NNW-SSE trending lineaments are another prominent set in the region. The dyke activity is also prominent along these lineaments. The well known Idamalayar lineament which cuts the E-W trending Palghat-Cauveri shear zone can also be traced in this area.

Muvattupuzha river and Meenachal river are the major drainages in the region. In general, drainages in Kerala are flowing either in NNW direction or NW direction before entering into low lands. After entering low lands the rivers take southward turn. However, the Meenachal river, which follows a general E-W trend, turns southward near Irattupeta, within the uplands, followed by a northward turn before reaching Pala. It appears that these change in orientation of river flow is induced by the two NNW-SSE lineaments. Spacially, the two earthquake sequences of 2000-2001 and 1952-1953 coincide with these lineaments (Fig. 4). Another important observation in this

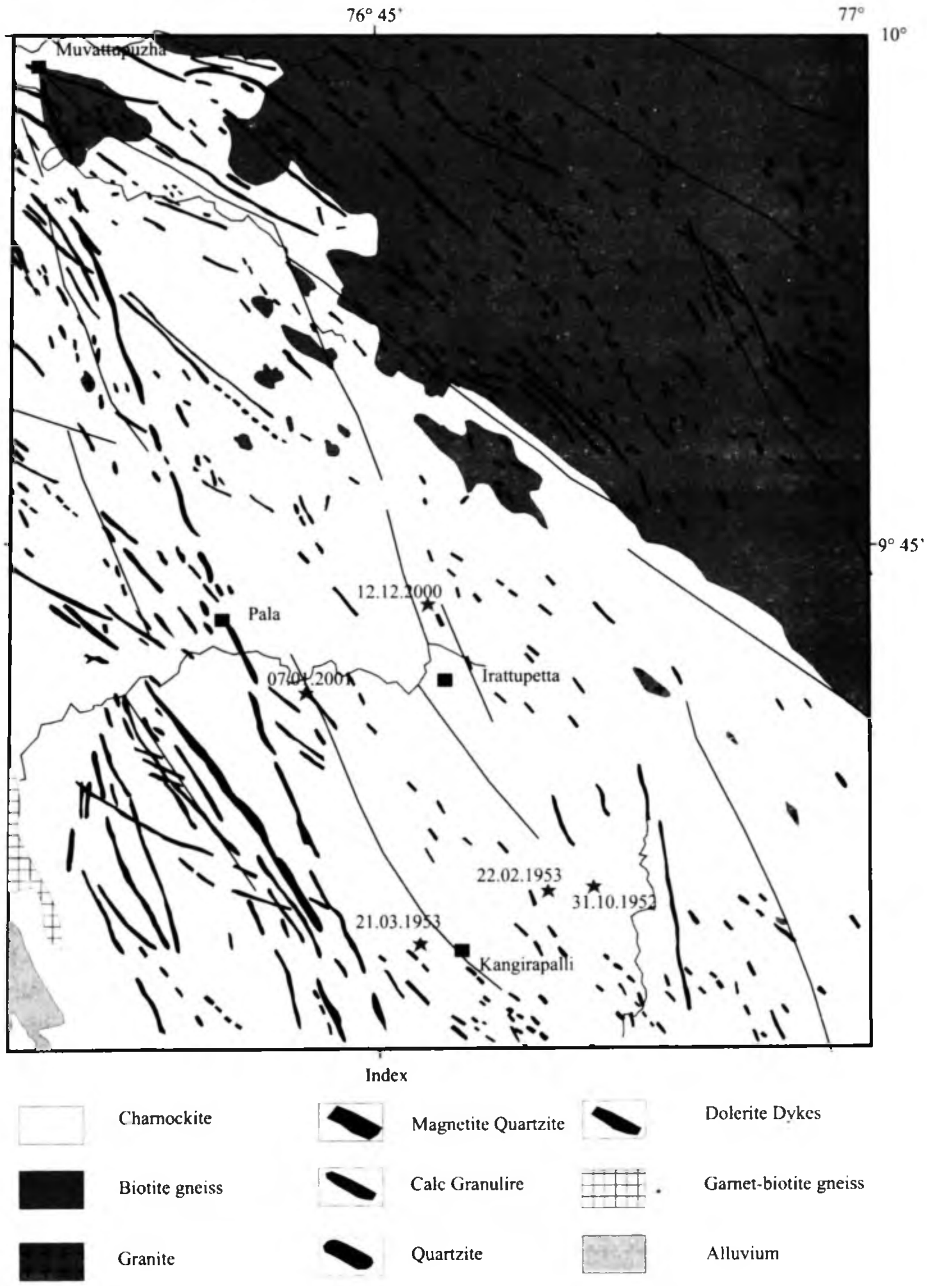

Fig. 4. Seismicity of the area with respect to geology; lineaments identified in this study is also incorporated. Only earthquakes of 1952-1953 and 2000-2001 are plotted.

earthquake sequence is that after the 2000 December earthquake some of the open wells went dry in Kangirapally area which is the epicentrai area of 1953 event.This could be due to the opening of older fractures generated by 1953 earthquakes by the present ones.

Morphometric evaluation

For quick assessment in respect of active tectonism we employed one of the widely used morphometric index, assymetry factor (AF), to this area. The AF is defined as $AF=100(^{A_r}/_{A_t})$, where A_r is the area of the basin to the right of the trunk stream and A_t is defined as the total area of the drainage basin. For a stream network that developed and continues to flow in a stable setting and uniform lithology, AF should be equal to about 50, whereas unstable setting would give a deflection from normal value either <50 or >50 (Keller and Pinter, 1996; John and Rajendran, 2008).

The area had been divided into 49 sub-basins (Fig.5) having 4^{th} order streams to which the asymmetry factor is calculated. The values

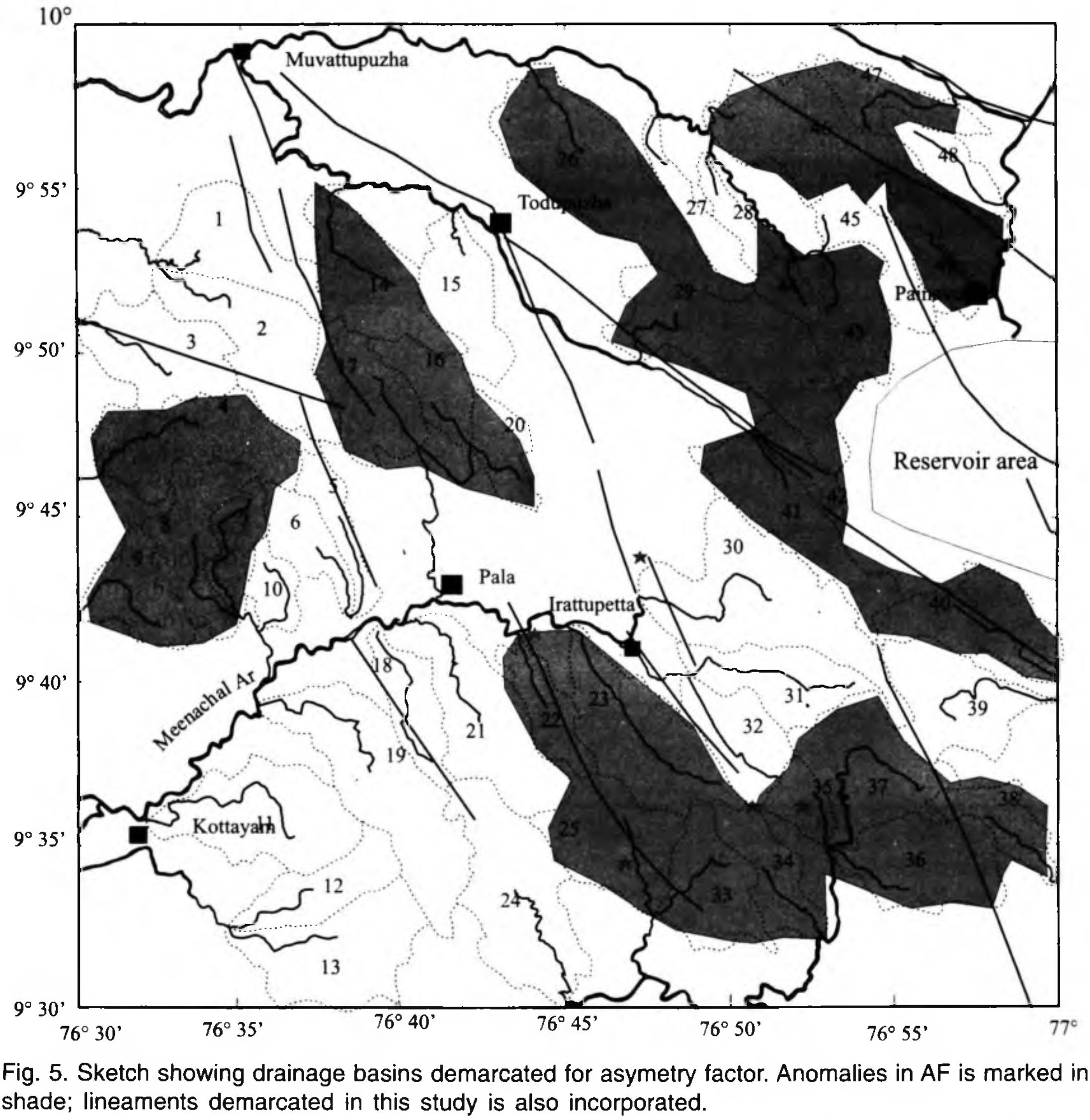

Fig. 5. Sketch showing drainage basins demarcated for asymetry factor. Anomalies in AF is marked in shade; lineaments demarcated in this study is also incorporated.

of asymmetry factor calculated for these sub-basins are shown in Table 2. Out of 49 basins, 22 basins (45% of 49) are showing only within 10% of deviation from the symmetry (50). We consider 10 as the standard deviation to symmetry. Rest of the basins show higher anomalies, that is >10 % from the symmetry. These basins generally align parallel to the NNW-SSE trending lineaments (Fig. 5). This may indicate that these may be active so as to affect the symmetry of the drainage basins. Asymmetry Factor (AF) was generally used for detecting tectonic tilt in a basin area (Hare and Gardner, 1985). However, in this study we do not find any active regional tilting.

Discussion

The occurence of twin earthquakes in a time span of 26 days is a rare phenominon in Peninsular India. Some authors suggested these earthquakes had been generated from two distinct source zones, since the mesoseismal areas were separated by 15 km (Harendranath et al., 2004). Even though the first event was bigger in magnitude (M 5.0), greater damage was witnessed in case of second of M 4.8. Similar events have occured in 1953 south of this area within a span of 24 days. The epicentre of the first event can be tentatively taken as east of Kanjirapalli, where as the second event seems to have occurred west of the first one at Ponkunnam.The maximum intensity assessed from the damage reports are V to both these events.

The contact between charnokite and biotite could be the oldest structure (WNW-ESE) because the other rock units are in vein form (due to the fractures developed after the two rock units formed). The granite bodies in charnokite and calc granulites in biotite are also formed in this direction. Thus the WNW-ESE structures/ lineaments can be considered as the oldest in the region. NNW-SSE direction is the trend of west coast fault. The dolerite dykes and a few quartzite dykes are found emplaced in this direction. The presence of dyke activity is more in charnokite than biotite gneiss. The occurrence of dolerite dykes in WNW-ESE direction shows the reactivation of these structures during the formation of the west coast fault or Deccan volcanism.

The Dec. 12, 2000 and 7 Jan. 2001 earthquakes are spacially associated with two different NNW-SSE lineaments (Fig. 4). The earthquake sequence of 1952-1953 also seems to be associated with these lineaments. Near Irattupetta and Pala the course of E-W flowing Meenachal river is influenced by these two sets of NNW-SSE lineaments. The incidence of the open wells going dry in Kanjirapalli region following 12th December 2000 earthquake also suggests the relation of NNW-SSE lineaments with the ongoing activity. Since the events are shallow we interpret that the subsequent events were triggered by the first one and might be from the adjoining source zones. This is also supported by the westward migration of the two earthquake sequences. Due to the possible error in location it is difficult to relate the other earthquake events reported from this area to any of the available structures.

Geomorphic analysis further supports the above observations that the NNW-SSE lineaments may be active. In a similar study John (2003) identified an active fault through Remote Sensing and Geomorphology. A detailed study reveals that this fault is active and showing episodic movement. Thus our observation in this area warrants detailed and close study/monitoring of these structures which are conveniently oriented for failure in the present stress regime.

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