Statistical Analysis of Seismic Data of Sree Subrahmanyaswami Temple, Payyanur, Kerala, India

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ABSTRACT

An investigation of the statistical analysis of earthquake catalogue and development of seismotectonic map for the low seismic region Kannur has been carried out in this paper. Total 502 events of different magnitude scales spanning from 1800 AD to 2024 AD were collected from different national and international sources. Events were homogenized into equivalent moment magnitude (M_w) using Scordilis(2006) relationship. Earthquake data were declustered using Urhammer method to exclude foreshocks and aftershocks within a time and space window and statistical analysis was done. Sources of earthquake events were extracted from Geological Survey of India. Seismotectonic map were developed using QGIS software using the extracted data. The M_c value in this instance is 3.0, falling inside the fulfilled limit. The seismicity parameters b and a values are 0.45 (higher frequency/seismically more active) and 4.0 (high frequency of small magnitude earthquake) correspondingly. b value is matching with lower value of 0.5 and a value is in median range of lower value of 2 to a higher value of 10. From the histogram, it can be deduced that a good number of earthquakes were reported from 1965, which was the beginning of the instrumental era. Prior to 1965, the earthquake reporting was poor and incomplete.

Keywords: Catalogue Homogenization, Declustering, Seismotectonic Map, Magnitude of Completeness, Seimsicity Parameters, Histogram

1. INTRODUCTION :

Some of the largest earthquakes in recorded history have struck India in the last century. Actually, it is estimated that about half of the country is susceptible to strong earthquakes. The northeastern region of the country is also vulnerable because the entire Himalayan belt is prone to powerful earthquakes with a magnitude greater than 8.0. When creating strategies to reduce earthquake tragedies in the country, some significant features of Indian earthquakes should be taken into account. If continuous mitigation measures are not put in place, the features of seismic risk are expected to increase over time. This fact can also be explained by the fact that as the population grows, so do the demands on society's resources for transportation, housing, energy, and water. As a result, further efforts are required to create more structures, including buildings, bridges, reservoirs, dams, and power plants. Therefore, unless the built-up buildings are constructed and maintained to withstand future earthquakes, huge infrastructure development may be the only cause of unexpected earthquake losses, even in places with moderate seismic activity (Padmanabhan *et al.* 2024; Padmanabhan *et al.* 2022). Natural occurrences linked to earthquakes that may negatively affect human activity are known as seismic hazards. Ground failure and shaking are two instances of these occurrences. The extent of an earthquake's devastation is determined by a number of variables, including the earthquake's magnitude, point of emphasis, soil composition, population density, etc. The catastrophic damage of an earthquake can be reduced greatly by appropriately calculating the seismic danger.

Understanding the region's historical seismicity in detail is the first stage in hazard assessment. The first and most important piece of information that provides the main opinion for identifying the earthquake hazard is a good and uniform catalogue that details the location and magnitude of previous earthquakes. The consistency, accuracy, and homogeneity of the earthquake data determine how effective the hazard assessment is. Knowing the nature of the data and its level of completeness is the first stage in any data analysis process. The primary goal of a seismotectonic study is to evaluate the hazards by having a thorough understanding of the study region's seismicity. In order to construct earthquake-resistant structures and lessen the impact of an earthquake in a location, seismic hazard assessment is crucial. With the addition of seismological data from the area, the danger map and assessment must be updated and reviewed on a regular basis. The unexpected earthquakes at Koyna (10 December 1967), Latur (29 September 1993), Jabalpur (21 May 1997), and Bhuj (26 January 2001) highlighted that the intra-plate region of the Indian plate, known as PI, is also prone to death-causing earthquakes. Intraplate earthquakes are caused by the flexural bulge that develops in central India as a result of the Indian plate moving 50 mm per year towards the Eurasian plate (Padmanabhan and Udayakumar 2025).

1.1. Study Area

The Sree Subrahmanya Swami Temple sits at the core of the 500-kilometer-radius circular study area that was chosen for this investigation. The temple's geographic coordinates are 75.20°E longitude and 12.09°N latitude (Green dot in figure 1). Fig.1 displays geographical extent of the study area in India. According to seismic zonation map of India (IS 1893 – 2016) Kerala state comes under zone III and zone II whose PGA values are 0.08g and 0.05g. Rao & Rao's (1984) and Chandra's (1977) earthquake catalogues for Peninsular India were used to comprehend the seismic features of the studied area. Peninsular India (PI) has a number of sedimentary basins. Based on historical seismic activity, these well-known locations can be categorised as moderate seismic regions. At a rate of 50 mm per year, the Indian plate is moving towards the Eurasian plate, creating a flexural bulge in central India and causing intraplate earthquakes. Numerous lineaments and active faults are identified in various locations throughout the research region using the seismological and geological data. The Seismotectonic Atlas of India was used to determine the location and direction of the linear seismic sources, or faults and lineaments. According to the seismotectonic atlas of India, the study region comprises major and minor faults, lineaments, and shear zones; the majority of earthquake epicentres are situated near major lineaments or active faults; Appendix 2 lists all of the seismic sources observed in the study region; the creation of a unified working catalogue for a region under consideration is a crucial task; and a number of sedimentary basins are present in PI.

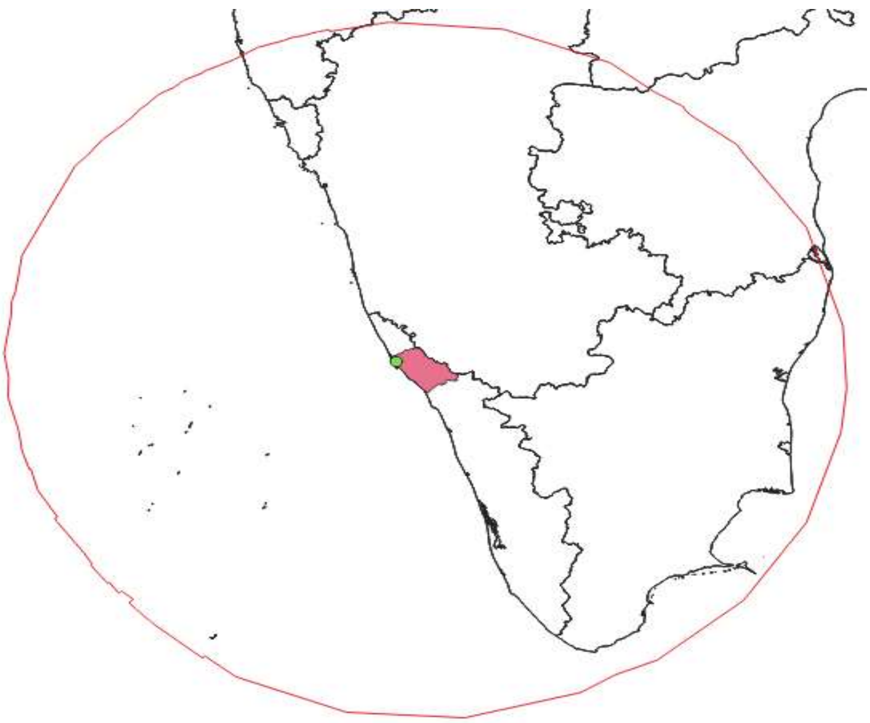

Fig 1: Study area location

2. DATA AND METHODS :

2.1Data Sources

Comprehensive data sets from the literature and those provided by numerous national and international agencies were used to create a complete earthquake catalogue. There are two types of earthquake events that were compiled: historical and instrumental. The historical part of the catalogue was gathered from the literature. An earthquake catalogue is the first essential input for the delineation of seismic source zones and their characterisation, as well as the preparation of a unified working catalogue for a region under consideration. Oldham (1883), Basu (1964), Kelkar (1968), Tandon and Srivastava (1974), Rastogi (1974), Chandra (1977, 1978), Kaila and Sarkar (1978), Rao and Rao (1984), Srivastava and Ramachandran (1985), Biswas and Dasgupta (1986), Guha and Basu (1993), Bilham (2004) etc. were among the researchers who contributed to the compilation of the historical earthquake portion. Several national and international agencies provided a significant amount of the instrumental catalogue. Among the national organisations were the National Geophysical Research Institute (NGRI), the Indira Gandhi Centre for Atomic Research (IGCAR), the Indian Meteorological Department (IMD), and the Guaribidanur Array (GBA). The International Seismological Centre (ISC) data file (covering the years 1964–2010) and the U.S. Geological Survey NEIC catalogue (covering the years 1973–2010) were examples of international agencies. The information about previous earthquakes and seismic sources was gathered from a 500-kilometer radius around Sree Subrahmanyswami Temple in Payyanur, which served as the core of the seismic study area.

2.2 Catalogue Homogenization

It is necessary to convert the various magnitude scales of earthquake events into a single magnitude scale to homogenize the catalogue. The commonly used magnitude scale that is based on the fault characteristics is moment magnitude (M_w). In the present study Scordilis (2006), empirical relations as furnished in equations (1-3) have been used for the unification of the earthquake catalogue.

$$M_w = 0.85(\pm 0.04)\, m_b + 1.03(\pm 0.023) \qquad 3.5 \le m_b \le 6.2 \qquad (1)$$

M_S to M_w (Surface wave magnitude into moment magnitude)

$$M_w = 0.67(\pm 0.005)\, M_S + 2.07(\pm 0.03) \qquad 3.0 \le M_S \le 6.1 \qquad (2)$$

$$M_w = 0.99(\pm 0.02)\, M_S + 0.08(\pm 0.13) \qquad 6.2 \le M_s \le 8.2 \qquad (3)$$

2.3 Declustering of the Catalogue

The main seismic shocks have a Poisson distribution and are isolated events. Gardner and Knopoff (1974) developed the technique used in this study to decluster the catalogue, and Urhammer (1991) improved it. Fig. 2 compares the number of earthquake events from ZMap software before and after declustering. After declustering, there were 502 instances with $Mw \ge 3$ between 1800 and 2024.

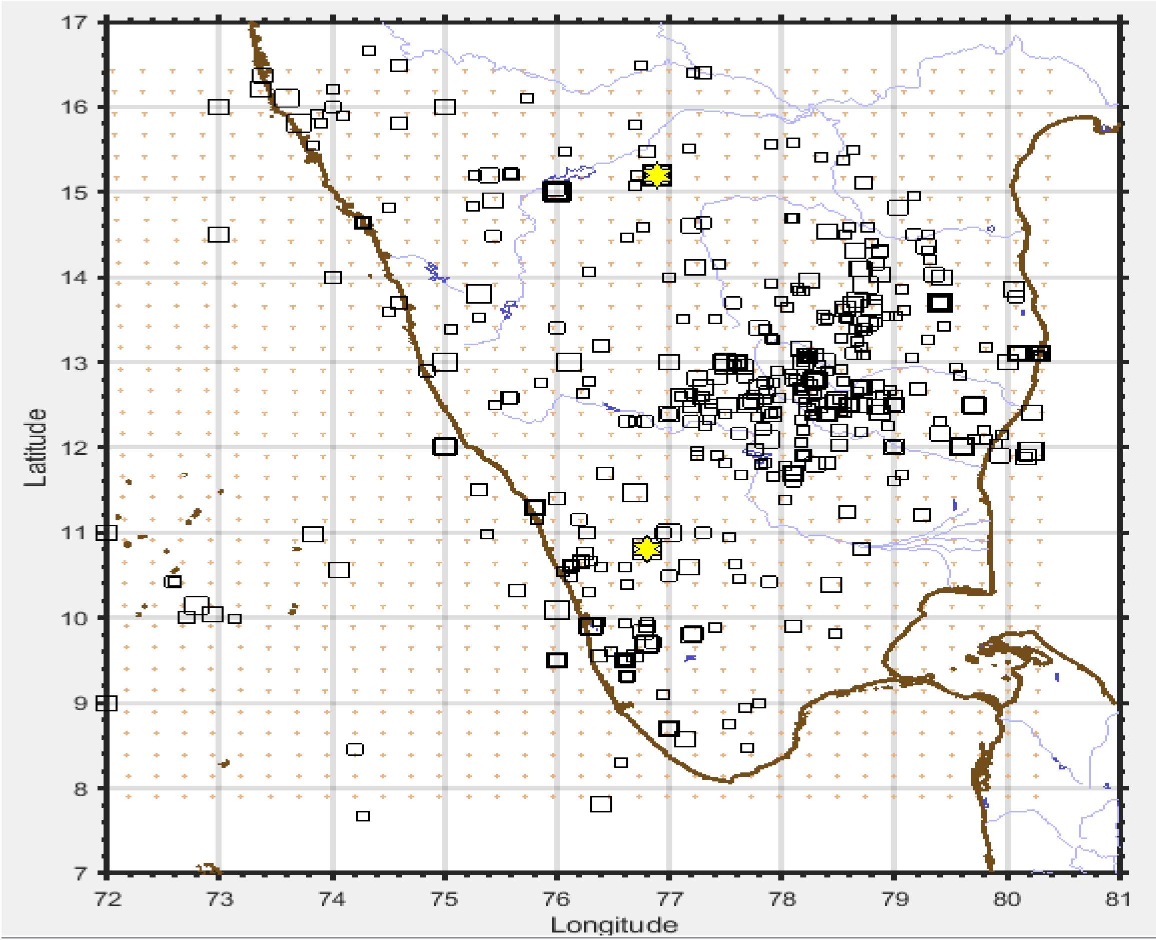

Fig 2: Declustered Catalogue

2.4 Magnitude of Completeness

An earthquake catalog's magnitude of completion (M_c), also known as the threshold or cutoff magnitude, is determined by ZMAP software and is stored in a space-time volume. 100% of the occurrences are observed at this magnitude. The primary source for figuring out seismicity metrics and assessing seismic risks in each location is an extensive and integrated earthquake library (Rydelek and Sacks 1989). The catalogue's chronological and spatial elements are incomplete. Notably, the approach taken to assess the relation parameters is impacted by incompleteness. The M_c value in this instance is 3.0, falling inside the fulfilled limit is shown in Fig.3. The seismicity parameters b and a values are 0.45 (higher frequency/seismically more active) and 4.0 (high frequency of small magnitude earthquake) correspondingly. b value is matching with lower value of 0.5 and a value is in median range of lower value of 2 to a higher value of 10 (Fig.3).

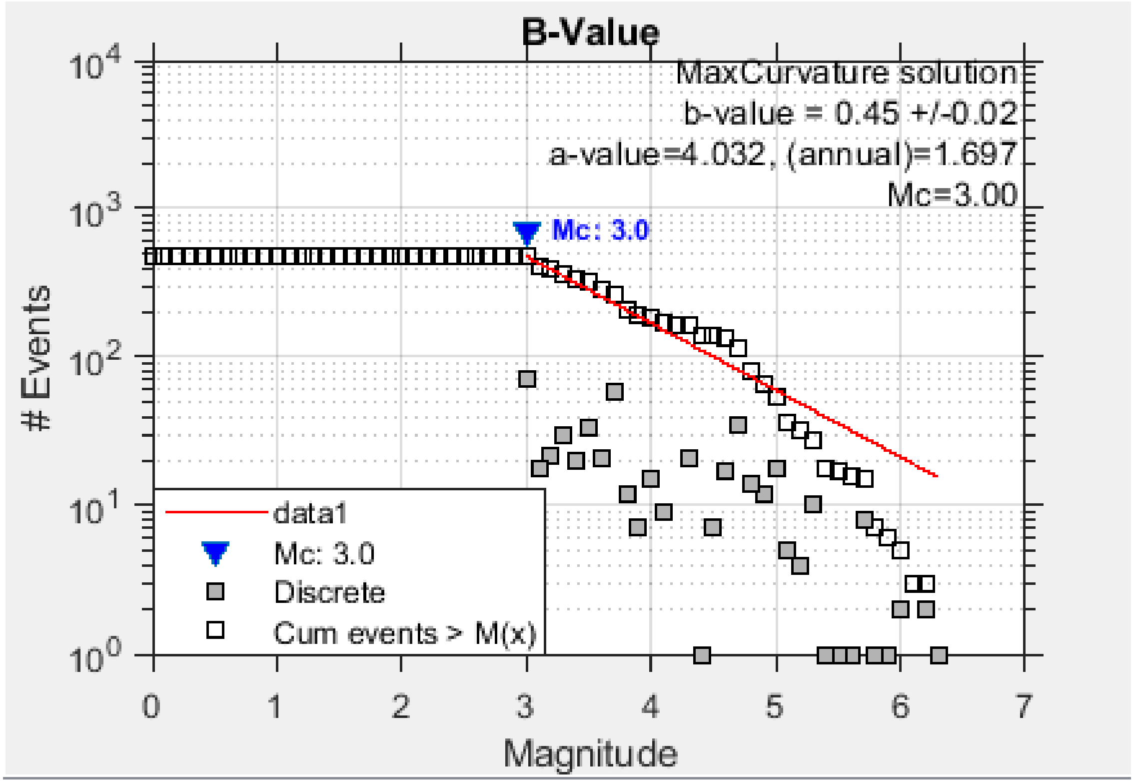

Fig 3: Magnitude of Completeness

2.5 Statistical Analysis of Seismicity Data

The Earthquake catalogue's time magnitude plot is shown in Fig.5. The number of earthquakes per decade were grouped into six magnitude ranges, i.e., $3.0 \le M \le 3.49$, $3.5 \le M \le 3.99$, $4.0 \le M \le 4.49$, $4.5 \le M \le 4.99$, $5.0 \le M \le 5.49$, $5.5 \le M \le 5.99$ and $6.0 \le M \le 6.49$ are presented in Table 1 and the histogram representation of the earthquake data listed in Table 1 is shown in Fig.4.

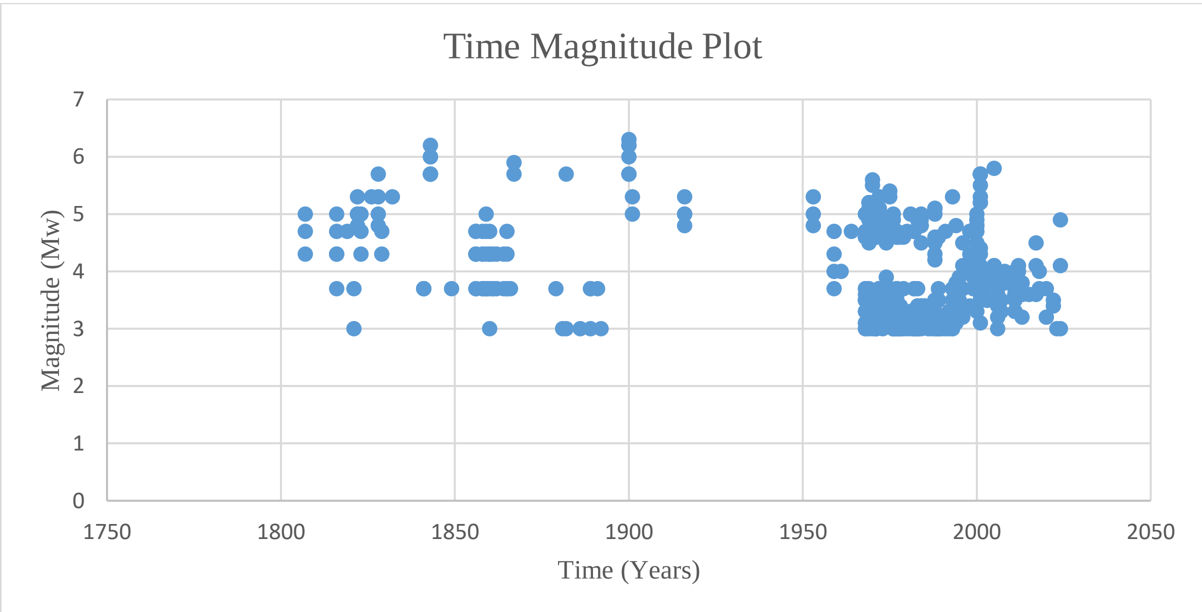

Fig 4: Earthquake catalogue's time magnitude plot

Table 1: Number of earthquakes reported in each decade

Time in years	Number of Earthquakes within a magnitude range							
	3-3.49	3.5-3.99	4-4.49	4.5-4.99	5-5.49	5.5-5.99	6-6.49	Total
2015-2024	4	5	3	2	0	0	0	14
2005-2014	7	25	8	0	0	1	0	41
1995-2004	5	19	17	9	4	5	0	59
1985-1994	41	12	2	5	4	0	0	64
1975-1984	70	20	0	18	5	0	0	113
1965-1974	28	26	0	38	10	2	0	104
1955-1964	0	1	3	3	2	0	0	9
1945-1954	0	0	0	0	0	0	0	0
1935-1944	0	0	0	0	0	0	0	0
1925-1934	0	0	0	0	0	0	0	0
1915-1924	0	0	0	1	3	0	0	4
1905-1914	0	0	0	0	0	0	0	0
1895-1904	0	0	0	0	2	2	4	8
1885-1894	3	3	0	0	0	0	0	6
1875-1884	2	1	0	0	0	1	0	4
1865-1874	0	3	1	1	0	2	0	7
1855-1864	1	13	12	5	1	0	0	32
1845-1854	0	1	0	0	0	0	0	1
1835-1844	0	3	0	0	0	4	3	10
1825-1834	0	0	1	2	4	1	0	8
1815-1824	1	2	3	4	5	0	0	15
1805-1814	0	0	1	1	1	0	0	3

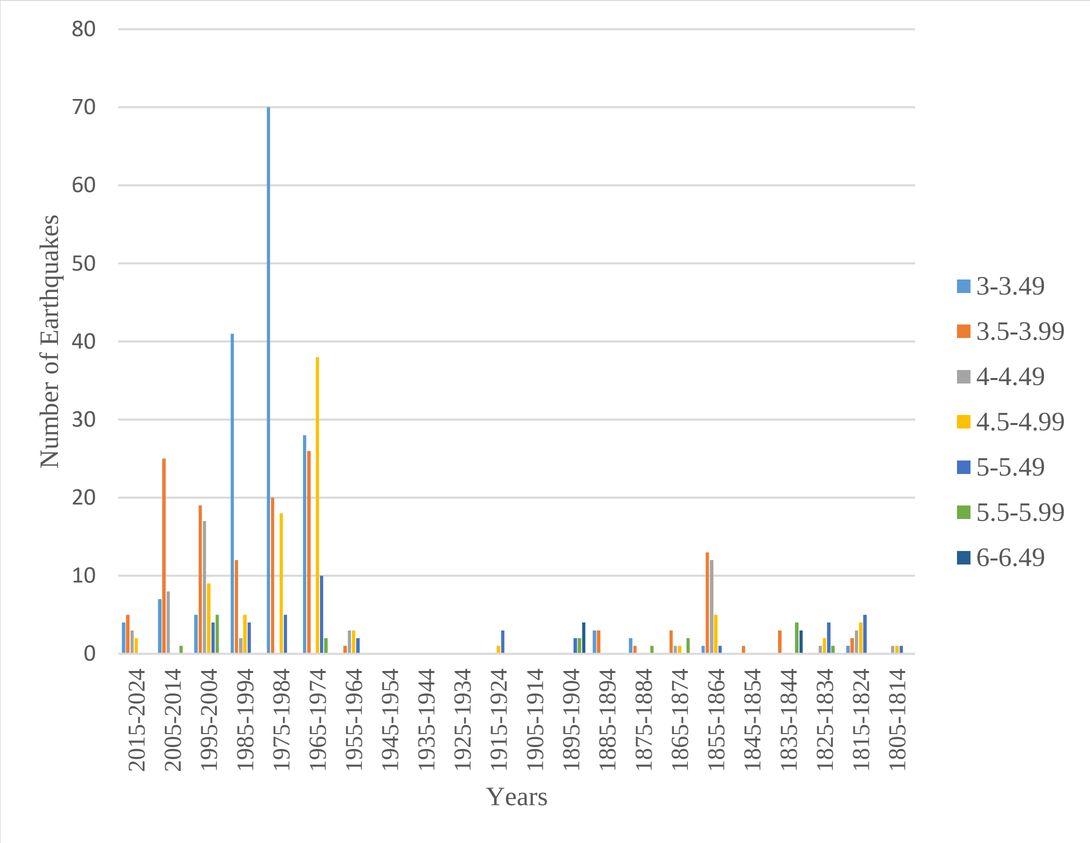

Fig 5: Histogram of the events for the study region

From the histogram (Fig.5), it can be deduced that a good number of earthquakes were reported from 1965, which was the beginning of the instrumental era (Bolt and Brune 1989). Prior to 1965, the earthquake reporting was poor and incomplete. Calculation of seismicity parameter with incomplete data produces inaccurate results. To overcome this problem, completeness analysis can be done to check the completeness of the data.

2.6 Seismotectonic Map

Data about current seismic sources, such as faults, lineaments, shear zones, and past earthquake occurrences, must be acquired in order to carry SHA. Usually, this collection of data is displayed as a seismotectonic map, as Fig.6 illustrates. Declustered earthquake events obtained from ZMAP were superimposed on faults and lineaments to create a seismotectonic map. The capacity to create and modify maps is made easier by geographic information systems (GIS) technology. Colours and symbols can be used in a GIS to highlight particular aspects. Data for seismicity zoning might be inserted, retrieved, handled, managed, and analysed thanks to the use of GIS technologies. The ability of GIS to store and alter data and images is one of its primary advantages in the field of seismic investigations. GIS software is used to digitise the collected data. The faults and lineaments that were taken from the Bhukosh website and used for analysis are shown in Appendix 2.

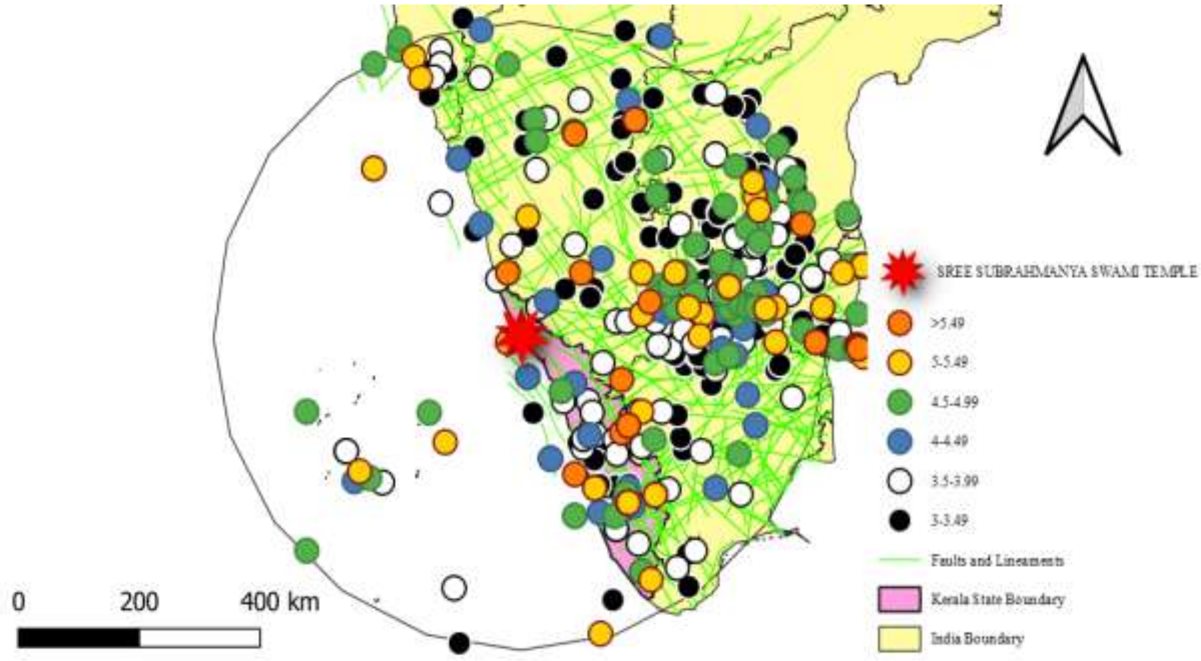

Fig 6: Seismotectonic Map

As can be seen from the seismotectonic map (Fig. 6), the closest faults have the greatest number of earthquake epicentres. Estimating the greatest possible fault magnitude is made easier with the use of this knowledge. Additionally, it is evident that the majority of neotectonic and subsurface faults are situated 50 and 10 km away from the research area, respectively. It is evident that the majority of moderate earthquakes with a magnitude of more than 4.5 occur in the study region's eastern and southern regions. The suggested map forms the foundation for an investigation of SW India's seismic hazards.

3. CONCLUSION :

This work presents an examination into the creation of a seismotectonic map and statistical analysis of the earthquake catalogue for Sree Subrahmanya Swami Temple in Payyanur, Kerala. A total of 502 occurrences from various national and international sources, ranging in magnitude from 1800 AD to 2024 AD, were gathered. The Scordilis (2006) relationship was used to homogenise events into equivalent moment magnitudes (Mw). To eliminate foreshocks and aftershocks within a time and space window, earthquake data were declustered using the Urhammer method, and statistical analysis was performed. The Geological Survey of India provided the sources of earthquake occurrences. Using the collected data, a seismic-tectonic map was created using QGIS software. In this case, the Mc value is 3.0, which is within the satisfied limit. Higher frequency/seismically more active is represented by the seismicity parameters b and a values of 0.45, while high frequency of small magnitude earthquakes is represented by the value of 4.0. The b value matches the lower value of 0.5, and the a value falls within the median range of 2 to 10. The histogram indicates that a significant number of earthquakes were recorded starting in 1965, marking the start of the instrumental era. Before 1965, there was inadequate and insufficient coverage of earthquakes.

Appendix 1 - 502 earthquake events considered in the analysis

Sl.No.	Longitude	Latitude	Year	Month	Date	M_W	Depth	Hour	Min.	Sec.	Source
1	80.1	13.1	1807	12	9	4.3	0	0	0	0	OLD
2	80.1	13.1	1807	12	9	4.7	0	0	0	0	USGS
3	80.3	13.1	1807	12	10	5	0	0	0	0	OLD
4	80.3	13.1	1816	8	0	3.7	0	0	0	0	USGS
5	80.3	13.1	1816	7	0	4.3	0	0	0	0	OLD
6	80.3	13.1	1816	8	0	4.3	0	0	0	0	OLD
7	80.3	13.1	1816	9	15	4.7	0	0	0	0	USGS
8	80.3	13.1	1816	9	16	5	0	0	0	0	OLD
9	79.6	12	1819	6	20	4.7	0	0	0	0	USGS
10	76.6	9.5	1821	1	10	3	0	0	0	0	USGS
11	76.6	9.5	1821	1	10	3.7	0	0	0	0	OLD
12	79	12	1822	1	29	4.8	0	0	0	0	IMD
13	79	12	1822	1	29	5	0	5	53	28	NCS
14	79.7	12.5	1822	1	29	5	0	0	0	0	OLD
15	79.7	12.5	1822	1	29	5.3	0	0	0	0	USGS
16	76.6	9.5	1823	3	2	4.3	0	0	0	0	OLD
17	76.6	9.5	1823	3	2	4.7	0	0	0	0	USGS
18	80	13	1823	3	2	5	0	0	0	0	OLD
19	73.6	16.1	1826	3	20	5.3	0	0	0	0	USGS
20	73	14.5	1828	8	22	4.8	0	0	0	0	IMD
21	73	14.50	1828	8	22	5	0	5	53	28	NCS
22	75	13	1828	8	22	5.3	0	0	0	0	USGS
23	75	13	1828	8	22	5.7	0	0	0	0	OLD
24	77.6	13	1829	3	12	4.3	0	0	0	0	OLD
25	77.6	13	1829	3	13	4.7	0	0	0	0	USGS
26	73.7	15.8	1832	10	4	5.3	0	0	0	0	USGS
27	76.6	9.5	1841	9	15	3.7	0	0	0	0	USGS
28	76.6	9.5	1841	9	15	3.7	0	0	0	0	USGS
29	76.6	9.5	1841	11	15	3.7	0	0	0	0	OLD
30	76	15	1843	4	1	5.7	0	0	0	0	IMD

31	76	15	1843	4	1	6	0	5	53	28	NCS
32	76.9	15.2	1843	3	31	5.7	0	0	0	0	OLD
33	76.9	15.2	1843	4	1	5.7	0	0	0	0	USGS
34	76.9	15.2	1843	3	31	6	0	0	0	0	USGS
35	76.9	15.2	1843	4	1	6.2	0	0	0	0	USGS
36	79.4	13.7	1843	4	1	5.7	0	0	0	0	GUB
37	76.6	9.5	1849	11	23	3.7	0	0	0	0	USGS
38	76	9.5	1856	9	1	4.3	0	0	0	0	OLD
39	76	9.5	1856	9	1	4.7	0	0	0	0	USGS
40	77	8.7	1856	8	11	3.7	0	0	0	0	USGS
41	77	8.7	1856	8	25	4.3	0	0	0	0	OLD
42	77	8.7	1856	8	25	4.7	0	0	0	0	USGS
43	78.1	9.9	1856	3	17	3.7	0	0	0	0	USGS
44	78.1	9.9	1856	3	17	4.3	0	0	0	0	KPKM
45	76	11.4	1858	8	13	3.7	0	0	0	0	USGS
46	76	11.4	1858	8	23	3.7	0	0	0	0	USGS
47	76	11.4	1858	8	23	4.3	0	0	0	0	IMD
48	78.4	12.4	1858	12	30	4.3	0	0	0	0	OLD
49	78.4	12.4	1858	12	30	4.7	0	0	0	0	USGS
50	78.1	11.6	1859	12	17	3.7	0	0	0	0	USGS
51	78.6	12.5	1859	2	5	3.7	0	0	0	0	USGS
52	78.6	12.5	1859	12	17	3.7	0	0	0	0	USGS
53	78.6	12.5	1859	2	5	4.3	0	0	0	0	OLD
54	79	12.5	1859	1	0	3.7	0	0	0	0	USGS
55	79	12.5	1859	1	3	4.7	0	0	0	0	USGS
56	79	12.5	1859	1	3	5	0	0	0	0	USGS
57	78.2	11.9	1860	1	20	3	0	0	0	0	USGS
58	78.2	11.9	1860	1	17	3.7	0	0	0	0	USGS
59	78.2	11.9	1860	1	17	4.3	0	0	0	0	KPKM
60	78.2	11.9	1860	6	17	4.3	0	0	0	0	OLD
61	79.4	13.7	1860	2	2	4.3	0	0	0	0	OLD
62	79.4	13.7	1860	2	2	4.7	0	0	0	0	USGS

63	77.3	16.4	1861	7	24	3.7	0	0	0	0	USGS
64	78.2	11.9	1861	3	4	3.7	0	0	0	0	USGS
65	78.2	11.9	1861	3	4	4.3	0	0	0	0	KPKM
66	77.3	16.4	1862	1	13	3.7	0	0	0	0	USGS
67	77.3	16.4	1862	1	13	4.3	0	0	0	0	OLD
68	78.7	10.8	1864	1	5	3.7	0	0	0	0	USGS
69	78.7	10.8	1864	1	5	4.3	0	0	0	0	KPKM
70	76.62	12.3	1865	6	4	3.7	0	0	0	0	UGS
71	76.95	11	1865	6	24	3.7	0	0	0	0	UGS
72	78.7	12.7	1865	8	2	4.3	0	0	0	0	OLD
73	78.7	12.7	1865	8	2	4.7	0	0	0	0	USGS
74	75.43	14.48	1866	2	12	3.7	0	0	0	0	OLD
75	79.6	12	1867	7	3	5.7	0	0	0	0	MIL
76	79.6	12	1867	7	3	5.9	0	0	0	0	USGS
77	77.85	12.75	1879	6	17	3.7	0	0	0	0	UGS
78	77.7	8.48	1881	3	16	3	0	0	0	0	UGS
79	76.7	11.46	1882	2	28	5.7	0	0	0	0	MIL
80	77.58	12.96	1882	4	0	3	0	0	0	0	UGS
81	74.33	16.66	1886	5	13	3	0	0	0	0	UGS
82	74.85	12.9	1889	3	31	3.7	0	0	0	0	UGS
83	80.3	13.08	1889	8	12	3	0	0	0	0	UGS
84	80.3	13.1	1889	8	12	3.7	0	0	0	0	USGS
85	77.6	12.96	1891	2	17	3.7	0	0	0	0	UGS
86	80.3	13.08	1892	5	6	3	0	0	0	0	UGS
87	76.7	10.7	1900	2	8	5.7	70	0	0	0	IMD
88	76.7	10.7	1900	2	8	6.2	0	0	0	0	USGS
89	76.70	10.70	1900	2	8	6	70	5	21	10	NCS
90	76.8	10.8	1900	2	7	5.7	70	0	0	0	BASU
91	76.8	10.8	1900	2	7	6.2	0	0	0	0	USGS
92	76.8	10.8	1900	1	7	6.3	0	0	0	0	KaiJa et al (1978)
93	75	12	1901	4	27	5	0	0	0	0	TR1

94	75	12	1901	4	27	5.3	0	0	0	0	USGS
95	77	13	1916	1	7	4.8	0	0	0	0	IMD
96	77	13	1916	1	7	5	0	5	30	0	NCS
97	77.5	13	1916	1	7	5	0	0	0	0	IMD
98	77.5	13	1916	1	7	5.3	0	0	0	0	USGS
99	76.3	9.9	1953	7	26	4.8	0	0	0	0	IMD
100	76.3	9.9	1953	7	26	5.3	0	0	0	0	USGS
101	76.30	9.90	1953	7	26	5	0	5	30	0	NCS
102	75.3	11.5	1959	7	27	3.7	0	0	0	0	IMD
103	75.3	11.5	1959	7	27	4	0	0	0	0	USGS
104	78.1	11.7	1959	12	17	4.3	0	0	0	0	GUB
105	78.1	11.7	1959	12	17	4.7	0	0	0	0	USGS
106	75.8	11.3	1961	9	0	4	0	0	0	0	USGS
107	75.8	11.3	1964	10	0	4.7	0	0	0	0	USGS
108	74	16.2	1968	11	4	3.5	0	0	0	0	USGS
109	76.57	8.29	1968	9	25	3	0	0	0	0	IMD
110	77.78	12.35	1968	5	10	3.3	0	0	0	0	KPKM
111	77.83	12.22	1968	8	26	3.7	0	0	0	0	KPKM
112	77.91	12.4	1968	8	2	5	0	0	0	0	KPKM
113	78.18	12.32	1968	6	8	3.3	0	0	0	0	KPKM
114	78.28	12.49	1968	7	16	3.1	0	0	0	0	KPKM
115	78.55	12.77	1968	1	16	3.6	0	0	0	0	KPKM
116	78.7	12.18	1968	5	15	3	0	0	0	0	KPKM
117	78.85	12.48	1968	8	13	5	0	0	0	0	KPKM
118	78.87	14.03	1968	4	13	4.7	0	0	0	0	KPKM
119	79	12	1968	8	15	3.7	0	0	0	0	GBA
120	79.03	14.82	1968	5	12	4.6	0	0	0	0	KPKM
121	79.28	14.36	1968	12	9	4.6	0	0	0	0	KPKM
122	79.82	12.1	1968	5	21	3.1	0	0	0	0	KPKM
123	79.91	12.05	1968	5	23	3.5	0	0	0	0	KPKM
124	79.94	11.91	1968	5	28	4.6	0	0	0	0	KPKM
125	79.95	12.14	1968	5	25	3.5	0	0	0	0	KPKM

126	80.17	11.89	1968	5	3	3.5	0	0	0	0	KPKM
127	80.17	11.89	1968	5	4	3.5	0	0	0	0	KPKM
128	77.18	10.6	1969	1	3	4.7	0	0	0	0	KPKM
129	77.23	14.11	1969	2	5	4.7	0	0	0	0	KPKM
130	77.3	14.64	1969	11	26	3.7	0	0	0	0	KPKM
131	77.35	12.33	1969	8	15	3.3	0	0	0	0	KPKM
132	77.62	10.45	1969	7	29	3	0	0	0	0	KPKM
133	77.72	12.54	1969	9	21	4.7	0	0	0	0	KPKM
134	77.74	12.62	1969	5	6	3.6	0	0	0	0	KPKM
135	77.74	12.55	1969	9	29	4.6	0	0	0	0	KPKM
136	77.87	12.09	1969	6	4	5.2	0	0	0	0	KPKM
137	78.4	14.53	1969	7	4	4.9	0	0	0	0	KPKM
138	78.45	10.39	1969	5	19	4.9	0	0	0	0	KPKM
139	78.69	14.1	1969	7	1	5.1	0	0	0	0	KPKM
140	78.7	14.1	1969	1	16	4.5	0	0	0	0	USGS
141	78.71	13.37	1969	3	31	3.4	0	0	0	0	KPKM
142	78.73	13.09	1969	6	13	3.4	0	0	0	0	KPKM
143	78.75	13.9	1969	1	16	5.2	0	0	0	0	KPKM
144	78.79	13.64	1969	11	10	4.7	0	0	0	0	KPKM
145	78.86	12.41	1969	8	14	4.7	0	0	0	0	KPKM
146	79.35	14.03	1969	9	8	4.6	0	0	0	0	KPKM
147	76.1	13	1970	2	12	5.5	0	0	0	0	GBA
148	77.12	12.58	1970	1	19	5.6	0	0	0	0	KPKM
149	77.2	14.6	1970	2	20	4.6	0	0	0	0	GBA
150	77.93	12.75	1970	2	12	3.4	0	0	0	0	KPKM
151	78.1	14.7	1970	4	3	3	0	0	0	0	USGS
152	77	12.4	1971	1	17	4.6	0	0	0	0	USGS
153	77	12.4	1971	3	6	4.6	0	0	0	0	USGS
154	77	12.4	1971	3	27	4.7	0	0	0	0	USGS
155	77	12.4	1971	1	17	4.9	0	0	0	0	HYB
156	77	12.4	1971	3	6	4.9	0	0	0	0	HYB
157	77	12.4	1971	3	27	4.9	0	0	0	0	HYB

158	77.24	11.91	1971	12	16	3.2	0	0	0	0	KPKM
159	77.43	11.9	1971	9	5	3.5	0	0	0	0	KPKM
160	77.51	12.49	1971	5	23	4.8	0	0	0	0	KPKM
161	77.65	12.95	1971	5	30	4.6	0	0	0	0	KPKM
162	78.04	11.39	1971	5	16	3	0	0	0	0	KPKM
163	78.24	13.96	1971	5	22	4.8	0	0	0	0	KPKM
164	78.3	12.8	1971	11	26	4.7	0	0	0	0	USGS
165	78.3	12.8	1971	11	26	5	0	0	0	0	USGS
166	78.3	12.8	1971	11	26	5.2	0	0	0	0	HYB
167	78.49	12.56	1971	11	12	4.7	0	0	0	0	KPKM
168	78.56	12.41	1971	4	16	3.6	0	0	0	0	KPKM
169	78.63	13.68	1971	5	10	4.7	0	0	0	0	KPKM
170	79.08	13.62	1971	5	14	3	0	0	0	0	KPKM
171	79.3	14.3	1971	8	3	3	0	0	0	0	KPKM
172	79.55	12.94	1971	1	27	3.5	0	0	0	0	KPKM
173	79.58	12.85	1971	1	26	3	0	0	0	0	KPKM
174	80.17	11.89	1971	8	4	4.7	0	0	0	0	KPKM
175	80.22	12.41	1971	5	31	4.8	0	0	0	0	KPKM
176	77	12.4	1972	4	24	3.7	0	0	0	0	IKD
177	77	12.4	1972	5	17	4.8	0	0	0	0	USGS
178	77	12.4	1972	5	16	4.9	0	0	0	0	USGS
179	77	12.4	1972	5	16	5.1	0	0	0	0	HYB
180	77	12.4	1972	5	17	5.1	0	0	0	0	HYB
181	77	11	1972	7	29	5.3	0	0	0	0	USGS
182	77.38	12.51	1972	2	15	3.3	0	0	0	0	KPKM
183	78.1	15.58	1972	1	5	3.5	0	0	0	0	KPKM
184	78.1	12.8	1972	12	28	3.7	0	0	0	0	HYB
185	78.12	12.8	1972	2	7	3.6	0	0	0	0	KPKM
186	78.3	12.8	1972	11	28	3.7	0	0	0	0	KPKM
187	78.3	12.8	1972	12	28	3.7	0	0	0	0	USGS
188	78.63	13.11	1972	3	16	3.7	0	0	0	0	KPKM
189	80.07	13.85	1972	3	23	4.7	0	0	0	0	KPKM

190	77.25	12.81	1973	10	20	4.6	0	0	0	0	KPKM
191	78.31	12.49	1973	12	21	4.7	0	0	0	0	KPKM
192	78.52	12.57	1973	9	22	3.4	0	0	0	0	KPKM
193	78.59	13.51	1973	12	30	3.1	0	0	0	0	KPKM
194	78.63	15.5	1973	11	15	3	0	0	0	0	KPKM
195	77.32	12.25	1974	12	19	3.5	0	0	0	0	KPKM
196	77.87	12.66	1974	12	20	3.7	0	0	0	0	KPKM
197	77.97	12.59	1974	1	15	3.4	0	0	0	0	KPKM
198	78.22	12.7	1974	3	7	4.9	0	0	0	0	KPKM
199	78.3	12.8	1974	5	23	3.9	0	0	0	0	USGS
200	78.3	12.8	1974	7	31	4.5	0	0	0	0	USGS
201	78.3	12.8	1974	5	23	4.6	0	0	0	0	HYB
202	78.3	12.8	1974	7	31	4.8	0	0	0	0	HYB
203	78.61	14.58	1974	1	24	3.2	0	0	0	0	KPKM
204	78.65	13.38	1974	5	13	3.5	0	0	0	0	KPKM
205	78.73	13.41	1974	1	24	3.3	0	0	0	0	KPKM
206	78.76	14.58	1974	1	23	3.2	0	0	0	0	KPKM
207	78.79	14.4	1974	1	27	3.1	0	0	0	0	KPKM
208	78.83	13.47	1974	1	25	3.2	0	0	0	0	KPKM
209	78.84	13.73	1974	1	24	3.4	0	0	0	0	KPKM
210	79.06	13.85	1974	10	3	3.5	0	0	0	0	KPKM
211	79.81	13.17	1974	2	3	3.6	0	0	0	0	KPKM
212	75.3	13.8	1975	5	12	5.4	0	0	0	0	GOS
213	76	15	1975	5	12	4.8	0	0	0	0	IMD
214	76	15	1975	5	12	5.3	0	0	0	0	USGS
215	77.27	12.57	1975	1	7	3.1	0	0	0	0	KPKM
216	77.67	12.83	1975	12	28	3.7	0	0	0	0	KPKM
217	79.3	14.5	1975	3	28	3.1	0	0	0	0	USGS
218	77.25	11.96	1976	12	11	3.6	0	0	0	0	KPKM
219	77.64	11.67	1976	3	3	3.1	0	0	0	0	KPKM
220	77.82	11.8	1976	3	28	3	0	0	0	0	KPKM
221	77.86	12.57	1976	12	24	3.5	0	0	0	0	KPKM

222	77.91	15.57	1976	1	17	3	0	0	0	0	KPKM
223	77.91	13.28	1976	6	18	3	0	0	0	0	KPKM
224	77.92	11.66	1976	8	10	3.3	0	0	0	0	KPKM
225	77.93	13.27	1976	3	4	3	0	0	0	0	KPKM
226	78.03	11.78	1976	11	10	3	0	0	0	0	KPKM
227	78.1	14.7	1976	1	9	3.5	0	0	0	0	KPKM
228	78.1	14.7	1976	2	9	3.5	0	0	0	0	USGS
229	78.53	13.28	1976	9	12	3.3	0	0	0	0	KPKM
230	78.54	13.63	1976	1	22	3	0	0	0	0	KPKM
231	78.55	15.37	1976	10	4	3.3	0	0	0	0	KPKM
232	78.66	14.3	1976	2	9	5	0	0	0	0	KPKM
233	78.67	13.74	1976	5	18	4.9	0	0	0	0	KPKM
234	79.01	12.61	1976	6	23	3.6	0	0	0	0	KPKM
235	79.16	13.06	1976	11	13	3.3	0	0	0	0	KPKM
236	79.416	14	1976	8	7	4.7	0	0	0	0	KPKM
237	80.23	13.14	1976	7	22	3.4	0	0	0	0	KPKM
238	73.83	15.55	1977	5	25	3	0	0	0	0	KPKM
239	75.982	15.036	1977	12	11	4.6	0	0	0	0	GBA
240	77.128	13.514	1977	10	24	3.4	0	0	0	0	KPKM
241	77.49	11.82	1977	2	4	3.4	0	0	0	0	KPKM
242	77.506	12.95	1977	9	24	4.7	0	0	0	0	KPKM
243	77.85	11.81	1977	5	18	3	0	0	0	0	KPKM
244	77.86	13.39	1977	7	12	3	0	0	0	0	KPKM
245	78.001	13.713	1977	9	5	3	0	0	0	0	KPKM
246	78.047	13.643	1977	9	3	3	0	0	0	0	KPKM
247	78.08	14.69	1977	7	13	3	0	0	0	0	KPKM
248	78.08	12.86	1977	7	17	3	0	0	0	0	KPKM
249	78.167	12.675	1977	8	14	3	0	0	0	0	KPKM
250	78.19	13.83	1977	7	18	3	0	0	0	0	KPKM
251	78.2	13	1977	12	8	3	0	0	0	0	KPKM
252	78.2	13	1977	12	7	3.3	0	0	0	0	KPKM
253	78.214	12.533	1977	12	22	3.6	0	0	0	0	KPKM

254	78.234	12.777	1977	1	16	3.6	0	0	0	0	KPKM
255	78.27	12.37	1977	7	3	3	0	0	0	0	KPKM
256	78.29	12.62	1977	8	13	3.6	0	0	0	0	KPKM
257	78.388	13.514	1977	10	23	3.7	0	0	0	0	KPKM
258	78.48	12.54	1977	6	10	4.7	0	0	0	0	KPKM
259	78.529	12.91	1977	10	5	3	0	0	0	0	KPKM
260	78.558	13.517	1977	11	12	3	0	0	0	0	KPKM
261	78.567	13.637	1977	8	16	4.7	0	0	0	0	KPKM
262	78.681	13.239	1977	10	7	3.1	0	0	0	0	KPKM
263	78.72	13.39	1977	8	4	3.7	0	0	0	0	KPKM
264	78.76	13.45	1977	8	12	4.6	0	0	0	0	KPKM
265	78.83	14.15	1977	2	5	3.7	0	0	0	0	KPKM
266	78.936	13.548	1977	10	23	3.5	0	0	0	0	KPKM
267	79.01	13.54	1977	1	8	3.5	0	0	0	0	KPKM
268	79.17	14.5	1977	1	6	3.7	0	0	0	0	KPKM
269	79.43	13.419	1977	10	9	3	0	0	0	0	KPKM
270	80.269	13.091	1977	9	11	3.5	0	0	0	0	KPKM
271	75.379	10.983	1978	3	10	3	0	0	0	0	GBA
272	77.8	13.4	1978	8	8	4.6	0	0	0	0	KPKM
273	78.2	13	1978	7	6	3	0	0	0	0	KPKM
274	78.2	13	1978	9	27	3	0	0	0	0	KPKM
275	78.2	13	1978	9	3	3.3	0	0	0	0	KPKM
276	78.249	13.108	1978	9	30	3.4	0	0	0	0	GBA
277	78.378	13.558	1978	2	7	3	0	0	0	0	GBA
278	77	10.5	1979	2	16	3.7	0	0	0	0	CVR
279	77.3	12.6	1979	9	21	3.1	0	0	0	0	CVR
280	77.9	12.4	1979	6	9	3	0	0	0	0	KPKM
281	77.94	12.403	1979	6	9	3.2	0	0	0	0	GBA
282	78.3	11.8	1979	4	18	4.6	0	0	0	0	BRR
283	74.5	13.6	1980	12	20	3	0	0	0	0	CVR
284	76.62	14.473	1980	9	3	3.2	0	0	0	0	GBA
285	77.3	12.7	1980	5	3	4.7	0	0	0	0	KPKM

286	77.5	12.4	1980	12	25	3.2	0	0	0	0	CVR
287	74.067	10.561	1981	2	24	5	0	0	0	0	GBA
288	76.612	9.927	1981	6	30	3	0	0	0	0	GBA
289	76.808	9.951	1981	2	17	3.3	0	0	0	0	GBA
290	76.719	15.189	1982	8	12	3.2	0	0	0	0	GBA
291	78.2	13	1982	2	7	3	0	0	0	0	KPKM
292	78.2	13.1	1982	9	8	3	0	0	0	0	KPKM
293	78.2	13	1982	11	3	3	0	0	0	0	KPKM
294	78.2	13	1982	1	27	3.3	0	0	0	0	KPKM
295	78.2	13	1982	3	13	4.7	0	0	0	0	KPKM
296	78.208	13.107	1982	9	11	3	0	0	0	0	GBA
297	78.214	13.072	1982	3	5	3.3	0	0	0	0	GBA
298	78.217	13.063	1982	11	19	3	0	0	0	0	GBA
299	78.221	13.068	1982	3	29	4.7	0	0	0	0	GBA
300	78.228	13.064	1982	2	8	3.3	0	0	0	0	GBA
301	78.3	12.4	1982	1	24	3	0	0	0	0	CVR
302	78.3	12.8	1982	2	24	3.7	0	0	0	0	BRR
303	78.3	12.8	1982	3	13	3.7	0	0	0	0	USGS
304	73.829	10.987	1983	10	7	4.9	0	0	0	0	GBA
305	76	13.4	1983	10	21	3.7	0	0	0	0	CVR
306	77.1	12.6	1983	4	22	3	0	0	0	0	KPKM
307	77.187	12.635	1983	4	21	3	0	0	0	0	GBA
308	78.2	13	1983	3	27	3	0	0	0	0	KPKM
309	78.2	12.2	1983	7	5	3.2	0	0	0	0	KPKM
310	78.2	13	1983	10	1	3.3	0	0	0	0	KPKM
311	78.2	13	1983	2	5	3.4	0	0	0	0	KPKM
312	78.204	13.058	1983	3	29	3	0	0	0	0	GBA
313	78.221	13.068	1983	10	4	3.3	0	0	0	0	GBA
314	78.25	13.08	1983	2	6	3.4	0	0	0	0	GBA
315	79.802	12.208	1983	7	11	3.2	0	0	0	0	GBA
316	77.43	12.82	1984	3	20	4.5	21	16	15	29	NCS
317	77.7	12.5	1984	3	20	5	0	0	0	0	KPKM

318	77.8	12.7	1984	3	20	4.8	0	0	0	0	USGS
319	78.2	13.1	1984	7	12	3	0	0	0	0	KPKM
320	78.2	13.1	1984	7	3	3.4	0	0	0	0	KPKM
321	78.2	13	1984	9	12	3.4	0	0	0	0	KPKM
322	78.6	12.5	1984	11	27	4.8	0	0	0	0	KPKM
323	78.7	12.5	1984	11	28	3.3	0	0	0	0	KPKM
324	78.7	12.5	1984	12	3	4.9	0	0	0	0	KPKM
325	74.278	7.668	1985	11	8	3.3	0	0	0	0	GBA
326	77.4	13.5	1985	5	7	3.1	0	0	0	0	KPKM
327	78.2	13	1985	7	19	3.1	0	0	0	0	KPKM
328	78.2	13	1985	8	22	3.2	0	0	0	0	KPKM
329	78.2	13.1	1985	9	23	3.4	0	0	0	0	KPKM
330	78.201	13.111	1985	8	23	3.4	0	0	0	0	GBA
331	79	11.6	1985	10	22	3.3	0	0	0	0	KPKM
332	79.061	11.673	1985	9	22	3.3	0	0	0	0	GBA
333	76.369	9.946	1986	1	23	3	0	0	0	0	GBA
334	78.21	13.046	1986	10	19	3.1	0	0	0	0	KPKM
335	78.21	13.102	1986	12	3	3.3	0	0	0	0	KPKM
336	78.219	13.038	1986	10	14	3.1	0	0	0	0	GBA
337	78.24	13.079	1986	12	20	3.1	0	0	0	0	KPKM
338	79.4	12.302	1986	9	28	3.2	0	0	0	0	KPKM
339	78.2	13.106	1987	3	17	3.2	0	0	0	0	KPKM
340	78.56	14.507	1987	8	24	3	0	0	0	0	KPKM
341	75.857	12.764	1988	7	26	3	0	0	0	0	GBA
342	76.385	7.805	1988	5	1	5	0	0	0	0	GBA
343	77.136	8.582	1988	6	7	5.1	0	0	0	0	GBA
344	77.2	9.8	1988	6	8	3.5	5	0	0	0	NGRI
345	77.2	9.8	1988	6	7	5.1	5	0	0	0	NGRI
346	77.21	9.81	1988	7	6	4.3	0	0	0	0	Rastogi et al(I 995)
347	77.21	9.81	1988	6	7	4.5	50	8	37	0	NCS
348	77.21	9.81	1988	6	7	4.2	50	20	56	0	NCS

349	77.21	9.81	1988	6	8	3.5	50	8	34	0	NCS
350	77.531	8.752	1988	6	8	3.5	0	0	0	0	GBA
351	77.682	8.948	1988	8	26	3.2	0	0	0	0	GBA
352	78.36	15.401	1988	1	22	3.3	0	0	0	0	KPKM
353	79.169	14.953	1988	3	16	3	0	0	0	0	GBA
354	79.406	12.165	1988	5	19	4.6	0	0	0	0	GBA
355	75.73	16.11	1989	1	25	3	0	0	0	0	GBA
356	76.28	12.77	1989	8	24	3	0	0	0	0	GBA
357	76.7	15.07	1989	8	23	3.1	0	0	0	0	GBA
358	77.22	16.4	1989	1	25	3	0	0	0	0	GBA
359	77.57	13.69	1989	3	26	3.7	0	0	0	0	GBA
360	77.9	13.92	1989	8	1	3	0	0	0	0	GBA
361	78.39	13.02	1989	4	6	4.6	0	0	0	0	GBA
362	78.48	9.81	1989	5	7	3.5	0	0	0	0	KPKM
363	78.68	12.66	1989	4	23	3.5	0	0	0	0	GBA
364	79.31	14.21	1989	3	25	3	0	0	0	0	GBA
365	77.17	15.51	1990	9	29	3	0	0	0	0	GBA
366	76.28	14.06	1991	3	28	3.2	0	0	0	0	GBA
367	78.18	13.15	1991	4	19	4.7	0	0	0	0	GBA
368	78.53	12.43	1991	1	7	3	0	0	0	0	GBA
369	75.27	15.19	1992	9	12	3.2	0	0	0	0	GBA
370	76.75	16.48	1992	4	21	3.3	0	0	0	0	GBA
371	79.7	12.1	1992	9	16	3	0	0	0	0	GBA
372	72.79	10.14	1993	8	24	5.3	0	0	0	0	GBA
373	75.3	13.53	1993	4	20	3	0	0	0	0	GBA
374	76.76	14.59	1993	5	18	3.1	0	0	0	0	GBA
375	77.2	12.3	1993	11	14	3.7	0	0	0	0	GBA
376	77.45	14.15	1993	4	6	3	0	0	0	0	GBA
377	77.58	10.63	1993	9	17	3.3	0	0	0	0	GBA
378	78.71	13.18	1993	10	28	3.3	0	0	0	0	GBA
379	78.94	12.26	1993	6	6	3.5	0	0	0	0	GBA
380	79.29	13.26	1993	7	29	3.2	0	0	0	0	GBA

381	73	16	1994	2	1	4.8	0	9	30	55	NAO
382	73.13	9.98	1994	3	21	3.6	0	0	0	0	GBA
383	74.2	8.46	1994	11	1	3.7	0	0	0	0	GBA
384	75.06	13.39	1994	10	21	3.5	0	0	0	0	GBA
385	76.25	10.75	1994	12	2	3.8	15	21	36	57	NCS
386	76.69	15.79	1994	1	13	3.4	0	0	0	0	GBA
387	78.14	13.87	1994	5	20	3.2	0	0	0	0	GBA
388	78.15	13.84	1994	5	14	3.1	0	0	0	0	GBA
389	74	14	1995	3	12	3.9	0	8	22	38	NAO
390	78.40	13.50	1995	9	20	3.5	33	5	16	43	NCS
391	78.96	12.67	1995	4	29	3.3	0	0	0	0	GBA
392	74	16	1996	4	26	3.7	0	12	19	26	NAO
393	75.40	15.20	1996	1	9	4.5	33	8	15	15	NCS
394	76.80	9.90	1996	3	19	4.1	33	22	2	40	NCS
395	77	14	1996	11	10	3.2	0	8	59	41	NAO
396	72	9	1998	1	14	4.7	0	18	54	7	NAO
397	74.50	14.81	1998	11	25	3.4	20	8	20	25	NCS
398	75.43	14.90	1998	7	20	4.7	15	4	8	7	NCS
399	76.4	13.2	1998	2	4	4	10	21	18	16	NDI
400	76.40	13.20	1998	2	5	4	0	2	48	16	NCS
401	78.22	12.448	1998	8	25	4.1	15	12	54	25	NDI
402	78.22	12.45	1998	8	25	4.3	15	18	24	25	NCS
403	75.638	10.325	1999	9	11	3.9	15	3	9	2	NDI
404	75.64	10.32	1999	9	11	4.1	15	8	39	2	NCS
405	78.87	14.30	1999	5	3	4	33	0	51	0	NCS
406	78.873	14.298	1999	5	2	3.7	33	19	21	1	NDI
407	72	11	2000	8	3	4.9	0	21	19	49	NAO
408	73.37	16.21	2000	12	8	4.7	33	13	23	0	BJI
409	74.59	15.80	2000	4	24	3.9	4	16	43	38	NCS
410	74.60	13.7	2000	1	1	4.1	33	14	54	53	NCS
411	75	16	2000	3	12	4.8	0	18	3	46	NAO
412	75.25	14.83	2000	8	14	3.3	37	11	46	41	NCS

413	76.7046	9.5602	2000	12	12	4	0	1	23	59	IDC
414	76.74	9.67	2000	12	16	4.1	10	4	24	22	NCS
415	76.744	9.666	2000	12	15	3.9	10	22	54	22	NDI
416	76.763	9.824	2000	12	12	4.5	10	1	23	58	ISC
417	76.79	9.69	2000	12	12	4.8	14	1	23	59.3	IMD
418	76.79	9.69	2000	12	12	5	14	6	53	59	NCS
419	76.795	9.689	2000	12	12	4.8	14.9	1	23	59	NDI
420	76.87	9.64	2000	12	12	4	4	17	37	12	NCS
421	76.12	10.48	2001	8	25	3.6	15	5	54	34	NCS
422	76.121	10.484	2001	8	25	3.1	15	0	24	35	NDI
423	76.62	9.31	2001	1	7	3.8	15	8	57	21	NCS
424	76.621	9.314	2001	1	7	3.5	15	3	27	21	NDI
425	76.797	9.688	2001	1	7	5.2	16	2	56	0	NDI
426	76.80	9.69	2001	1	7	5.2	16	8	26	0	NCS
427	77.36	12.444	2001	1	29	4.3	15	2	37	52	NDI
428	77.36	12.44	2001	1	29	4.4	15	8	7	51	NCS
429	78.18	12.6	2001	1	4	3.8	10	4	18	45	NCS
430	78.181	12.056	2001	1	3	3.5	10	22	48	46	NDI
431	78.735	15.109	2001	6	15	4	15	7	48	47	NDI
432	80.088	13.773	2001	6	8	3.7	15	2	38	31	NDI
433	80.21	11.96	2001	9	25	5.7	10	0	0	0	USGS
434	80.214	11.956	2001	9	25	5.5	10	6	0	0	USGS
435	80.214	11.956	2001	9	25	5.7	10	14	56	44	NEIC
436	80.227	11.9454	2001	9	25	5.7	10	14	56	44	NEIC
437	80.238	11.907	2001	9	25	5.7	10	14	56	44	NEIC
438	80.31	11.79	2001	9	25	5.3	23	14	56	46.3	IMD
439	80.44	11.833	2001	9	25	4.1	33	17	7	9	NDI
440	76.077	15.484	2002	7	10	3.6	10	14	9	12	NDI
441	76.8	15.48	2002	7	10	4	10	19	39	12	NCS
442	72.59	10.43	2003	11	8	3.8	10	21	27	28	NCS
443	72.593	10.432	2003	11	8	3.5	10	15	57	29	NDI
444	74.266	14.641	2003	7	12	3.5	30.2	13	44	56	NDI

445	74.27	14.64	2003	7	12	4	30	19	14	55	NCS
446	75.585	15.219	2003	11	4	3.5	5	18	24	59	NDI
447	75.59	15.22	2003	11	4	3.8	5	23	54	59	NCS
448	74.60	16.49	2005	7	4	4	5	6	52	40	NCS
449	76	10.1	2005	7	25	5.8	10	0	0	0	IMD
450	78.2921	13.091	2005	11	2	3.9	10	18	14	52	ISC
451	78.32	12.95	2005	11	2	4.1	15	23	44	55	NCS
452	78.516	12.018	2005	3	22	3.9	4	1	50	7	NDI
453	78.52	12.2	2005	3	22	4.1	4	7	20	7	NCS
454	76.125	10.609	2006	12	20	3.5	10	13	49	40	NDI
455	76.13	10.61	2006	12	20	3.8	10	19	19	39	NCS
456	76.22	10.66	2006	12	27	4	5	6	44	9	NCS
457	76.221	10.657	2006	12	27	3.8	5	1	14	9	NDI
458	76.31	10.67	2006	12	21	3	10	19	12	35	NDI
459	76.31	10.67	2006	12	22	3.5	10	0	42	35	NCS
460	76.4	10.6	2006	12	20	3.2	10.5	0	0	0	IMD
461	76.6	10.6	2006	12	27	3.6	10	0	0	0	IMD
462	77.3	11	2006	10	7	3.7	15	0	0	0	IMD
463	78.4	12.9	2006	8	4	3.4	15	0	0	0	IMD
464	76.29	10.31	2007	10	3	3.3	10	4	31	33	NCS
465	76.95	9.10	2007	2	2	3.5	17	7	54	27	NCS
466	78.838	12.715	2008	6	7	3.8	19	18	5	21	NDI
467	78.84	12.72	2008	6	7	4	19	23	35	21	NCS
468	76.37	9.55	2011	7	26	4	10	13	9	16	NCS
469	76.48	9.60	2011	7	26	3.6	10	14	15	55	NCS
470	76.85	9.71	2011	11	26	3.7	10	3	14	57	NCS
471	77.4	9.88	2011	11	18	3.5	15	5	45	35	NCS
472	77.53	10.95	2011	11	15	3.3	10	22	29	32	NCS
473	77.89	10.43	2011	5	18	3.7	10	6	37	25	NCS
474	77.96	12.9	2011	6	21	3.3	10	5	21	35	NCS
475	78.16	12.7	2011	6	21	3.6	10	8	25	37	NCS
476	78.89	12.61	2011	8	29	3.6	13	21	11	7	NCS

477	79.25	11.20	2011	8	12	3.9	12	11	36	29	NCS
478	75.58	12.59	2012	10	14	4.1	10	14	21	56	NCS
479	76.2	11.15	2012	6	20	3.7	11	14	16	26	NCS
480	77.62	12.17	2012	5	27	3.7	8	23	59	7	NCS
481	77.77	11.98	2012	11	29	3.8	20	3	49	18	NCS
482	78.58	11.24	2012	3	27	4	11	10	19	27	NCS
483	74.1	15.89	2013	1	8	3.2	10	16	6	57	NCS
484	75.83	11.15	2013	2	26	3.6	10	22	56	35	NCS
485	76.26	10.99	2013	12	8	3.8	5	10	3	34	NCS
486	76.42	11.7	2013	12	9	3.8	17	16	24	26	NCS
487	76.63	10.39	2013	10	6	3.6	33	14	58	38	NCS
488	79.21	12.69	2013	9	26	3.8	15	8	17	45	NCS
489	73.90	15.81	2015	7	23	3.6	10	11	34	13	NCS
490	73.3863	16.3657	2017	8	19	4.5	10	16	52	26	USGS
491	77.20	12.48	2017	4	18	4.1	10	7	36	11	NCS
492	77.8	9	2017	12	27	3.6	5	20	45	52	NCS
493	75.59	12.58	2018	7	9	3.7	10	12	52	18	NCS
494	78.4	11.81	2018	7	22	4	6	7	47	30	NCS
495	76.7	12.3	2020	4	3	3.2	40	17	17	50	NCS
496	76.78	12.30	2020	4	3	3.7	7	17	18	8	NCS
497	75.45	12.50	2022	6	28	3.5	5	7	45	27	NCS
498	76.23	12.64	2022	6	23	3.4	10	4	37	13	NCS
499	73.86	15.91	2023	7	29	3	5	20	51	8	NCS
500	72.71	10.00	2024	4	11	4.1	27	0	15	50	NCS
501	72.9404	10.0467	2024	4	10	4.9	10	18	45	49	USGS
502	76.05	10.55	2024	6	15	3	7	8	15	26	NCS

Appndix 2 – Seismic Sources

Sl. No.	Seismic Source	Name	Length (m)
1	Neotectonic Fault	Main Fault N45 Degrees E	120412.139
2	Fault Involving Basement	Amirdi Fault	96450.51048

3	Fault Involving Basement	Pambar River Fault	94613.966
4	Neotectonic Fault	Tirukkavilur - Pondcherry Fault	64587.89944
5	Fault Involving Basement	Javadi Hills Fault	87265.19809
6	Strike Slip Fault		13964.00877
7	Fault Involving Basement	Mettur East Fault	36396.08942
8	Fault Involving Basement	Arkavati Fault	120333.3532
9	Neotectonic Fault		49105.53063
10	Neotectonic Fault	Palar River Fault	168331.0828
11	Neotectonic Fault	Main Fault N 45 Degrees E	65828.75153
12	Fault Involving Basement		17467.96175
13	Fault Involving Basement	Chitradurga Boundary Fault	80904.77194
14	Fault Involving Basement and Cover		80378.93558
15	Fault Involving Basement		78572.57979
16	Fault Involving Basement	Tenmalai Fault	70218.26356
17	Neotectonic Fault	Crystalline - Sedimentary Contact Fault	26125.57259
18	Fault Involving Basement		27602.21157
19	Fault Involving Basement	Tekkadi-Kodaivannalur Fault	48041.89196
20	Strike Slip Fault / Buried Ridge Boundary		151448.3702
21	Neotectonic Fault	Vaigai River Fault	175991.8675
22	Fault Involving Basement		27770.87099
23	Neotectonic Fault	Rajamatam - Devipattinam Fault	100983.4723

24	Fault Involving Basement and Cover		82465.58003
25	Strike Slip Fault / Buried Ridge Boundary		153318.7657
26	Fault Involving Basement	Periyar Fault	83822.50417
27	Neotectonic Fault	Manamelkudi - Tondi Fault	34970.91183
28	Neotectonic Fault	Amaradakki Fault	51099.10003
29	Strike Slip Fault / Buried Ridge Boundary		194908.587
30	Fault Involving Basement	Ottapalam-Kuttampuzha Fault	98415.52648
31	Fault Involving Basement	Kottagudi-Kokkal-Palani Fault	58267.47959
32	Fault Involving Basement	Valparai-Anaimudi Fault	44698.58615
33	Fault Involving Basement	Malayattur-Vada kkanetreri Fault	35593.92325
34	Strike Slip Fault / Buried Ridge Boundary		106478.6134
35	Fault Involving Basement		36830.99531
36	Fault Involving Basement	Ayakkudi-Virupaksha Fault	29073.98914
37	Fault Involving Basement	Pattikkad-Kollengol Fault	39921.26468
38	Neotectonic Fault	Cauveri Fault	195784.1021
39	Strike Slip Fault		69755.76851
40	Neotectonic Fault	Cauveri Fault	130270.7004
41	Fault Involving Basement and Cover	Attur Fault	159765.2024
42	Fault Involving Basement	Bhavani-Kanumudi Fault	60862.69043
43	Strike Slip Fault / Buried Ridge Boundary		124609.371
44	Fault Involving Basement	Tiruppur Fault	84483.32065

45	Strike Slip Fault / Buried Ridge Boundary		137325.1258
46	Strike Slip Fault / Buried Ridge Boundary		22814.20355
47	Fault Involving Basement	Mettur East Fault	81968.02467
48	Fault Involving Basement	Bhavali Fault	87209.23326
49	Fault Involving Basement		44206.41381
50	Minor Lineament	Bennihalla Lineament	150436.0123
51	Minor Lineament	Mandari Lineament	133711.6747
52	Fault Involving Basement	Malaprabha Fault	93899.60942
53	Minor Lineament	Kaiga Motimakki Lineament	213332.4012
54	Minor Lineament	Chandragutti-Kurnool Lineament	545643.448
55	Fault Involving Basement and Cover	Gani-Kalva Fault	91004.76169
56	Fault Involving Basement and Cover	Pyapalli Fault	28769.3811
57	Minor Lineament	Bennihalla Lineament	210810.0564
58	Fault Involving Basement and Cover	Wajrakarur Fault	37370.31257
59	Fault Involving Basement and Cover	Krishna River Fault	208367.1119
60	Fault Involving Basement and Cover	Tintini Fault	33860.19102
61	Fault Involving Basement and Cover		69238.96702
62	Minor Lineament	Chapora Lineament	213057.678
63	Neotectonic Fault	Main Fault N45 Degrees E	120412.139
64	Fault Involving Basement	Amirdi Fault	96450.51048
65	Fault Involving Basement	Pambar River Fault	94613.966

66	Fault Involving Basement	Mettur East Fault	36396.08942
67	Fault Involving Basement		26012.88175
68	Fault Involving Basement	Arkavati Fault	120333.3532
69	Fault Involving Basement	Sakleshpur - Bettadpur Fault	83118.25013
70	Minor Lineament	Vedavati Lineament	337234.2537
71	Minor Lineament	Bhadra Lineament	118758.7581
72	Fault Involving Basement	Yagachi Fault	27381.57628
73	Fault Involving Basement	Chikmagalur Fault	76456.28497
74	Fault Involving Basement and Cove / Gravity Fault		173621.207
75	Fault Involving Basement	Chitradurga Boundary Fault	80904.77194
76	Minor Lineament	Bhadra Lineament	97359.76733
77	Fault Involving Basement	Kadiri Fault	46019.59378
78	Minor Lineament	Chandragutti-Kurnool liament	147791.8926
79	Fault Involving Basement		19783.97843
80	Fault Involving Basement	Gulcheru Fault	21277.02813
81	Fault Involving Basement	Bukkapatnam Fault	43238.50031
82	Fault Involving Basement	Kumadavati - Narihalla Fault	143375.708
83	Fault Involving Basement	Dharma - Tungabhadrra Fault	150565.9437
84	Fault Involving Basement and Cover	Gudekota-Rampura Fault	49397.88552
85	Fault Involving Basement and Cove / Gravity Fault		195530.6762
86	Fault Involving Basement and Cove / Gravity Fault		146715.5229

87	Fault Involving Basement	Mettur East Fault	81968.02467
88	Fault Involving Basement	Bhavali Fault	87209.23326
89	Minor Lineament	Bennihalla Lineament	150436.0123
90	Minor Lineament	Mandari Lineament	133711.6747
91	Fault Involving Basement	Malaprabha Fault	93899.60942
92	Minor Lineament	Kaiga Motimakki Lineament	213332.4012
93	Fault Involving Basement and Cover		62688.48011
94	Minor Lineament	Chapora Lineament	213057.678
95	Neotectonic Fault	Main Fault N45 Degrees E	120412.139
96	Fault Involving Basement	Amirdi Fault	96450.51048
97	Fault Involving Basement	Pambar River Fault	94613.966
98	Neotectonic Fault	Tirukkavilur - Pondcherry Fault	64587.89944
99	Fault Involving Basement	Javadi Hills Fault	87265.19809
100	Strike Slip Fault		13964.00877
101	Fault Involving Basement	Mettur East Fault	36396.08942
102	Fault Involving Basement	Arkavati Fault	120333.3532
103	Neotectonic Fault		49105.53063
104	Neotectonic Fault	Palar River Fault	168331.0828
105	Neotectonic Fault	Main Fault N 45 Degrees E	65828.75153
106	Fault Involving Basement		17467.96175
107	Fault Involving Basement	Chitradurga Boundary Fault	80904.77194
108	Fault Involving Basement and Cover		80378.93558
109	Fault Involving Basement		78572.57979

110	Fault Involving Basement	Tenmalai Fault	70218.26356
111	Neotectonic Fault	Crystalline - Sedimentary Contact Fault	26125.57259
112	Fault Involving Basement		27602.21157
113	Fault Involving Basement	Tekkadi-Kodaivannalur Fault	48041.89196
114	Strike Slip Fault / Buried Ridge Boundary		151448.3702
115	Neotectonic Fault	Vaigai River Fault	175991.8675
116	Fault Involving Basement		27770.87099
117	Neotectonic Fault	Rajamatam - Devipattinam Fault	100983.4723
118	Fault Involving Basement and Cover		82465.58003
119	Strike Slip Fault / Buried Ridge Boundary		153318.7657
120	Fault Involving Basement	Periyar Fault	83822.50417
121	Neotectonic Fault	Manamelkudi - Tondi Fault	34970.91183
122	Neotectonic Fault	Amaradakki Fault	51099.10003
123	Strike Slip Fault / Buried Ridge Boundary		194908.587
124	Fault Involving Basement	Ottapalam-Kuttampuzha Fault	98415.52648
125	Fault Involving Basement	Kottagudi-Kokkal-Palani Fault	58267.47959
126	Fault Involving Basement	Valparai-Anaimudi Fault	44698.58615
127	Fault Involving Basement	Malayattur-Vada kkanetreri Fault	35593.92325
128	Strike Slip Fault / Buried Ridge Boundary		106478.6134
129	Fault Involving Basement		36830.99531

130	Fault Involving Basement	Ayakkudi-Virupaksha Fault	29073.98914
131	Fault Involving Basement	Pattikkad-Kollengol Fault	39921.26468
132	Neotectonic Fault	Cauveri Fault	195784.1021
133	Strike Slip Fault		69755.76851
134	Neotectonic Fault	Cauveri Fault	130270.7004
135	Fault Involving Basement and Cover	Attur Fault	159765.2024
136	Fault Involving Basement	Bhavani-Kanumudi Fault	60862.69043
137	Strike Slip Fault / Buried Ridge Boundary		124609.371
138	Fault Involving Basement	Tiruppur Fault	84483.32065
139	Strike Slip Fault / Buried Ridge Boundary		137325.1258
140	Strike Slip Fault / Buried Ridge Boundary		22814.20355
141	Fault Involving Basement	Mettur East Fault	81968.02467
142	Fault Involving Basement	Bhavali Fault	87209.23326
143	Fault Involving Basement		44206.41381
144	Minor Lineament	Mandari Lineament	133711.6747
145	Fault Involving Basement	Malaprabha Fault	93899.60942
146	Minor Lineament	Kaiga Motimakki Lineament	213332.4012
147	Fault Involving Basement and Cover		46452.35582
148	Fault Involving Basement and Cove / Gravity Fault		226241.7342
149	Fault Involving Basement and Cove / Gravity Fault		34799.22868

150	Minor Lineament	Chandragutti-Kurnool Lineament	545643.448
151	Minor Lineament	Bennihalla Lineament	210810.0564
152	Fault Involving Basement and Cover	Krishna River Fault	208367.1119
153	Fault Involving Basement and Cover	Tintini Fault	33860.19102
154	Fault Involving Basement and Cover		69238.96702
155	Minor Lineament	Chapora Lineament	213057.678
156	Minor Lineament	Chandragutti-Kurnool Lineament	545643.448
157	Fault Involving Basement and Cover	Gani-Kalva Fault	91004.76169
158	Fault Involving Basement and Cover	Pyapalli Fault	28769.3811
159	Minor Lineament	Bennihalla Lineament	210810.0564
160	Fault Involving Basement and Cover	Wajrakarur Fault	37370.31257
161	Fault Involving Basement	Javadi Hills Fault	87265.19809
162	Fault Involving Basement	Arkavati Fault	120333.3532
163	Neotectonic Fault	Palar River Fault	168331.0828
164	Neotectonic Fault	Main Fault N 45 Degrees E	65828.75153
165	Minor Lineament	Vedavati Lineament	337234.2537
166	Fault Involving Basement		17467.96175
167	Fault Involving Basement	Chitradurga Boundary Fault	80904.77194
168	Fault Involving Basement and Cover	Tirumala Fault	23312.08991
169	Fault Involving Basement and Cover	Karkambadi-Swarnamukhi Fault	102155.558
170	Fault Involving Basement	Kadiri Fault	46019.59378
171	Fault Involving Basement		19783.97843

172	Fault Involving Basement	Gulcheru Fault	21277.02813
173	Fault Involving Basement	Bukkapatnam Fault	43238.50031
174	Fault Involving Cover	Papaghani Fault	52510.71326
175	Fault Involving Cover		21226.66075
176	Fault Involving Basement and Cover	Gudekota-Rampura Fault	49397.88552
177	Fault Involving Basement		26012.88175
178	Fault Involving Basement	Arkavati Fault	120333.3532
179	Fault Involving Basement	Sakleshpur - Bettadpur Fault	83118.25013
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186	Fault Involving Basement	Ottapalam-Kuttampuzha Fault	98415.52648
187	Fault Involving Basement and Cove / Gravity Fault		173350.8393
188	Fault Involving Basement	Kottagudi-Kokkal-Palani Fault	58267.47959
189	Fault Involving Basement	Valparai-Anaimudi Fault	44698.58615
190	Fault Involving Basement	Malayattur-Vada kkanetreri Fault	35593.92325
191	Fault Involving Basement and Cove / Gravity Fault		195530.6762

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193	Fault Involving Basement	Pattikkad-Kollengol Fault	39921.26468
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195	Neotectonic Fault	Cauveri Fault	130270.7004
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860	Shear Zone		167250.5352

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