

Geological cues from frequent earth tremors in northern Karnataka, India

The districts of northern Karnataka, India, such as Vijayapura, Kalaburgi and Bidar, have experienced frequent earth tremors and associated subterranean sounds from August to November 2021. Repeated occurrence of such mild tremors has created panic among the local population, and a study has been carried out to understand the possible reasons for such frequent earth tremors in this area. The study area falls in zone-II of the seismic hazard map of India¹. The devastating Killari earthquake of 1993 (magnitude 6.3) is located 120 km NW of the locations where tremors have been reported in Kalaburgi and 160 km NNE of the locations where tremors were reported in Vijayapura. A preliminary field study was conducted on 8 and 9 November 2021 at the request of the Karnataka State Natural Disaster Monitoring Centre (KSNDMC), Bengaluru. The study area is criss-crossed by several lineaments (Figure 1). It is mainly covered by basaltic flows and limited exposure to sedimentary formations of the Bhima Group. Earlier studies in this area revealed seven major lineaments passing through it (Figure 1)². The lineaments are numbered as Ln 1 to Ln 6 from west to east in the study area and show a NW–SE trend, whereas the last lineament (Ln 7) shows a NE–SW trend. This lineament appears to mark the northern limit of the Bhima sediments. The above-mentioned lineaments show continuity with those mapped on the seismotectonic map of India. The main stress regime in Peninsular India is NE compressive stress due to the movement of the Indian Plate, and the NW–SE-trending lineaments appear to be part of the energy-release mechanism developed in this part of the peninsular shield.

Earth tremor data from August to October 2021 were collected from the KSNDMC Permanent Seismic Monitoring Stations Network and the National Centre for Seismology, Vijayapura and Kalaburgi and analysed in depth (Table 1). Overlay analysis of earth tremor data over the lineament system map of the study area revealed that the earth tremor epicentre data were clustered along two lineaments in the area, i.e. Ln 3 and Ln 5. As the study area is covered by basaltic lava flows and its weathered products, the surface manifestation of these lineaments is limited. A quarry near Mulawad, Karnataka, which is more than 22 m

deep, provided some impressive features (Figure 2 a). Here the massive basalt has suffered parallel and conjugate horizontal/lateral shearing with shear bands ranging from 4 cm to half a metre. Along with the shear, strong mylonite has developed. Basaltic slabs on either side (above and below) of the mylonite layer are massive, and this deformational feature provides strong clues of neotectonic activities and the pos-

sible lateral displacement leading to tremors. Similarly, evidence of shearing was observed in an old, deep quarry on the outskirts of Vijayapura city, Karnataka (Figure 2 b). Here too, horizontal shear bands are strongly developed. The observed shearing indicators have provided valuable insights into the microseismic activity in the region. A study of earthquake data from August to October 2021 revealed that

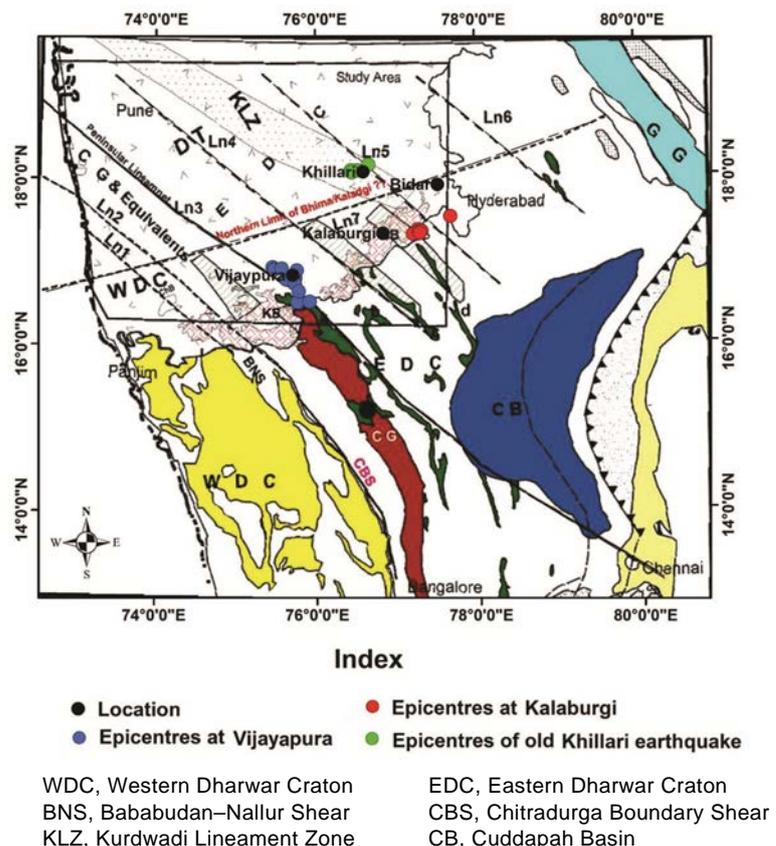


Figure 1. Earth tremor epicentre over the interpreted map of the Deccan Volcanic Province from the integrated analysis of gravity and magnetic data by Rajaram *et al.*².



Figure 2. a, A basalt quarry near the Mulawad, Karnataka showing horizontal shears reflecting neotectonic activity. b, Shear bands prominently seen in a basalt quarry on the outskirts of Vijayapura city, Karnataka.

SCIENTIFIC CORRESPONDENCE

Table 1. List of micro tremors reported by the KSNDMC Permanent Seismic Monitoring Stations Network and the National Centre for Seismology during 2021 (source: KSNDMC)

Date and Time (IST)	Epicentre	Magnitude	Depth (km)	Coordinates (lat. (°N) and long. (°E))
04:09:2021:23:48:17	Vijayapura, Karnataka	3.3	2	16.80, 75.74
04:09:2021:23:49:24	Vijayapura, Karnataka	4.1	2	16.81, 75.71
11:09:2021:08:18:47	Vijayapura, Karnataka	3.2	26	16.82, 75.72
01:10:2021:13:47:06	2.5 km NE of Masuti GP, Basavana Bagewadi taluk, Vijayapura district, Karnataka	2.5	15	16.52, 75.8
01:10:2021:16:10:05	10 km SW of Vijayapura city, Karnataka	2.2	10	16.78, 75.63
02:10:2021:08:31:34	2.9 km NNE of Bijjaragi GP, Vijayapura taluk, Vijayapura district, Karnataka	2	10	16.93, 75.46
05:10:2021:15:10:17	02 km west of Masuti GP, Basavana Bagewadi taluk, Vijayapura district, Karnataka	2.9	10	16.5076, 75.7647
08:10:2021:00:22:06	1.7 km south of Baratagi GP, Vijayapura taluk, Vijayapura district, Karnataka	2.5	8	16.89, 75.76
08:10:2021:00:44:08	2.2 km east of Halchera GP, Kalagi taluk, Kalaburgi district, Karnataka	2.6	10	17.3558, 77.2671
09:10:2021:05:37:53	1.1 km SSW of Korvi, Chincholi taluk, Kalaburgi district, Karnataka	3.2	10	17.3745, 77.2675
10:10:2021:06:05:59	2.1 km NE of Kodadur, Kalagi taluk, Kalaburgi district, Karnataka	3	12	17.3220, 77.2070
11:10:2021:06:31:10	1.1 km ENE of Maniyarpalli, Sangareddy District, Telangana (bordering Karnataka)	2.5	8	17.5298, 77.6734
11:10:2021:21:55:18	1.6 km NNE of Gadikeshwar GP, Chincholi taluk, Kalaburgi, Karnataka	4	5	17.3500, 77.2813
12:10:2021:08:07:08	1.6 km WSW of Kupnoor GP, Chincholi taluk, Kalaburgi, Karnataka	3.5	5	17.3566, 77.3126
12:10:2021:08:18:51	1.5 km SE of Gadikeshwar GP, Chincholi taluk, Kalaburgi, Karnataka	2.8	8	17.33, 77.29
14:10:2021:18:22:05	2.6 km SW of Hittinahalli GP, Vijayapura taluk, Vijayapura district, Karnataka	3.1	10	16.7291, 75.7339
17.10.2021:07:57:38	3.6 km WSW of Mangoli GP, Basavana Bagewadi taluk, Vijayapura district, Karnataka	1.8	8	16.6378, 75.7823
18:10:2021:18:46:47	3.6 km WNW of Somadevarahatti, Tikota taluk, Vijayapura district, Karnataka	1.5	8	16.9023, 75.4812
18:10:2021:19:03:57	3.6 km WNW of Somadevarahatti, Tikota taluk, Vijayapura district, Karnataka	1.2	8	16.9023, 75.4812
19:10:2021:06:11:26	1.4 km WNW of Mannur GP, Basavana Bagewadi taluk, Vijayapura district, Karnataka	2.6	10	16.5121, 75.9190
20:10:2021:10:29:22	2.9 km NNW of Dhanaragi, Vijayapura taluk, Vijayapura district, Karnataka	3.6	18	16.9134, 75.5732



Figure 3. Earth tremor epicentre in Karnataka and adjoining states from August to October 2021 (source: <https://seismo.gov.in/MIS/riseq/earthquake>).

earth tremors in Kalaburgi, Bidar and Vijayapura are not isolated as the adjoining states also reported low-magnitude earth tremors during this period (Figure 3). The tremors in the study area are part of a large energy-release mechanism operating in Peninsular India.

In the study area, Ln 1 represents the Bababudan–Nallur Shear (BNS) which continues below the Deccan Traps. Ln 2 represents the Chitradurga Boundary Shear (CBS) which continues offshore for over 300 km. Ln 3 is part of a major lineament (Peninsular Lineament) and goes cross-country from Chennai across the Peninsula below the Deccan Traps to the south of Mumbai towards Saurashtra. The earth's tremors in and around Vijayapura appear to be linked to energy release along this lin-

eamment. The importance of the Peninsular lineament in the 167.2 Ma reconstruction of Gondwanaland has been discussed by Reeves³. According to him, the Peninsular lineament is prone to reactivation, shares its alignment with the NE coast of Madagascar and Seychelles margin, and might have played an important role during the break-up of Gondwanaland. Further studies are required to understand the full implication of Ln 3. Ln 4 coincides with the Bhima River in the south. A part of this lineament is also referred to as the Ghod lineament in the literature⁴. Ln 5 and Ln 6 are possibly faults related to the Godavari rifting. The region between Ln 4 and Ln 5 is described as the Kurdwadi Lineament Zone (KLZ), where structural disturbances at great crustal depths are speculated based

on satellite imagery and field verification⁵. The earth tremors in Kalaburgi appear to be linked with structural disturbances in the KLZ. Ln 5 passes through Khillari and has been reactivated from time to time. The Greenstone belts and Kaladgi Bhima sediments continue below the Deccan Traps, but do not extend beyond the NE–SW-trending Ln 7.

Thus, a preliminary study of earth tremors in Kalaburgi, Bidar and Vijayapura areas reveals that the lineament system existing in the area and reactivation/structural disturbance within the lineament zone, especially near Ln 3 and the KLZ, appear to have played a vital role in the development of frequent earth tremors in this area. The spatial correlation between the clustering of earth tremor epicentre and the existing lineaments in the study area points to the exigent need to undertake detailed studies on reactivation and stress built up along these lineaments as they pass through several

districts of Karnataka, Maharashtra, Andhra Pradesh and Telangana. Crustal deformation studies might be important in this context as the high-stress rate observed on the surface is likely to translate to a high-stress rate at depths where earthquakes typically nucleate. So understanding the stressing rate might help understand the seismic hazard of the area in future.

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