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Earthquake prediction : A case study of an area in the Peninsular India

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ABSTRACT. It is only within the past one decade that the prediction of earthquakes has come to occupy a position within the science of seismology. Until then, this field lay more with astrology and soothsaying. Within this short span of time, countries which are often afflicted with this scourge have made considerable progress in evolving norms to forecast the on-coming of an earthquake. The methodology and determination of reliable parameters to predict an earthquake is still under development.

India is an industrially developing country needs a programme to make a beginning towards prediction of earthquakes. Though northern India is a seismically active region, the southern part of the Peninsula, till recently was considered seismically stable and free from earthquakes. This has been proved an erroneous assumption.

There are a number of areas which are seismically active in the south. One such area is associated with the N.W.—S.E. trending, 60 km long lineament along which the *Idamalayar* river flows. There are evidences to indicate that the lineament, since proved to be a 35 m wide shear zone is likely to be active.

The paper while describing the evidences for such a seismic activity, discusses the feasibility of monitoring the earthquake shocks along the zone.

1. Introduction

No other natural process affects people on this earth more than the geologic violence of earthquakes. Along with war and pestilence, earthquakes rank as one of the world's worst killers. Striking without any warning (?), opening great fissures in mankind's ultimate sanctuary of terra ferma, quakes have inspired terror and awe since man first walked on earth. What if, we could actually predict earthquakes in time, place and magnitude? In 1958, Charles Richter wrote of the "Will-O'-the wisp" of earthquake prediction. Perry Byerly answers questions about the next quake by advising "the longer it has been since the last, the sooner the next one will come". Obviously, prediction involves place, time and magnitude or where, when and how big. The historic and geologic records show "where" in a general way; for the earthquakes repeat themselves. Fault movements generally recur on the same old breaks or related faults and certain geologically young areas have a related high seismicity. When will the next quake occur ? Again, we speak easily only in generalities. Same is the case with magnitudes. Earthquakes can occur along the same fault with the same magnitude as they have had in the past. Greater the length of an active fault, greater the earthquake will be.

2. Seismic status of southern India

Notwithstanding the recorded earthquakes in the past, the Peninsular India was considered to be a stable area, free from this natural malady (Krishnan 1953). This may be due to infrequent shocks, sparse urban and industrial activity in the areas affected in the past by these shocks. Moreover, the recent tangible evidence in the relationship between earthquakes and plate tectonics, places the southern part of the Peninsula in a relatively safe position. It is located within the Indo-Australia plate, well away from its edges, which are earthquake prone (Robert Jones 1975).

However, the recent relative increase in the frequency and the intensity of shocks has thrown justifiable doubts on the widely theorised aseismic status of the southern part of the Peninsula. The rapid increase in the number of shocks as the Koyna earthquake of 1967 might even be a precursor to future earthquakes in the Peninsular region. Earthquakes in the southern India are characterised by the fact that they are all not well correlated to geologic faults. New faults might have appeared, but no significant post quake field work has been done to locate such faults, because of a number of reasons, the most important of which are : (*i*) Vastness and inaccessibility of the terrain and (*ii*) though epicentres and foci have been fairly accurately located the primary and secondary shocks have been felt over vast tracts. For example, the 1975 Hirekarur earthquake (Karnataka), epicentre of which was located at Gadag (Dharwar District), the shocks have been felt as far away as Bangalore and Goa.

3. The need for earthquake prediction studies in south India

With our present knowledge that (*i*) the faulted (active) areas are prone to earthquakes, (*ii*) longer the fault greater the magnitude of shocks, (*iii*) fluid pressure, such as those that build up behind large dams resulting in the injection of water under pressure into existing shear fracture systems increases the activity and (*iv*) with regard to earthquakes arising from plate movements, although the plate move primarily as blocks, the effect of plate interactions extend inland from the plate boundaries resulting in an accumulation of elastic strain well away from the plate boundaries; the area chosen for study should satisfy the above requirements. Attempt has been made in this paper to focus the attention of the earth scientists in an area prone to earthquakes and located in the Peninsular shield so that this area can be included as a case study in the field of earthquake prediction.

4. The Idamalayar lineament

Auden (1947) while investigating the Mattupatty dam in the Munnar high ranges of Kerala, has pointed out to the occurrence of major shear zones in Kerala, one of which lay across the Mattupatty dam site. He subsequently elaborated the occurrence and significance of the zones in the Western Ghats of Kerala as reflected by the straight drainage lineaments of the area (Auden 1951).

Jacob and Narayanaswamy (1969) have postulated creative ideas on the origin of the straight pattern of drainage lineaments, and the origin of the Palghat gap in which one such major lineament terminates. According to them (*i*) the N-S and NNW-SSE linear drainage pattern which are more or less at right angles to the strike direction of the formations may be due to shearing, (*ii*) if L.C. King's postulations on residual peneplains all over the world were to be accepted, the linear drainage pattern observed in the area may be expressive of the bed rock shearing not earlier than lower tertiary. Nevertheless, Jacob and Narayanaswamy opined that the ancient shear zones coinciding with the N-S and NNW-SSE trends had been rejuvenated in relatively recent times.

The *Idamalayar* river is a major tributary of the *Periyar* river in Kerala State. A multi-purpose project is under construction across this river at Ennakal (10° 13′ 15″N, 76°42′30″E : 58B/12). The dam site is located on a NNW-SSE trending lineament which towards northwest of the dam runs nearly straight for over a distance of 60 km. This lineament cuts across the regional E-W foliation and the Idamalayar, Chalakudy and Bharatapuzha catchments and the water divides that separate these catchments; with elevation differences ranging from 145 m to 1450 m. The E-W regional strike that is cut across by this lineament is considered younger than the Dharwarian strike and may have a bearing on the Palghat gap (Krishnan 1953). This 60 km long fracture is termed as the 'Idamalayar Lineament.'

Although the Idamalayar project was investigated on and off (Seshagiri *et al.* 1965), it was in 1971 the significance of this straight drainage lineament was recognised by Krishnaswamy (1971). The regional geological mapping of the area has revealed the occurrence of a dolerite dyke parallel to and in close proximity to the drainage lineament cutting across the Idamalayar and Chalakudy catchments. Detailed drilling at the dam site has since proved that the dyke has cut across the granite gneiss and that the contacts of the dyke are intensely sheared. Subsequent exploratory drifts driven at the site have afforded visual data of the existence of a 45 m wide shear zone trending N40°W-S40°E, dipping at 85° towards southwest (Subramaniyam 1973).

5. Age of the Idamalayar shear zone

Studies by the Geological Survey of India in the area between Ponnanai and Quilon in Kerala have brought out the existence of two faults in the quaternary formations (Mahadevan 1962). These faults are parallel to the west coast of India and the Idamalayar shear zone (Karunakaran and Mahadevan (*see* Ref). It is a strong probability that the Idamalayar lineament and the recent faults are tectonically related to the formation of the west coast. The geochronological Lab. of the Geological Survey of India has dated the Idamalayar dyke to be 75 (±2.5) million years. The dyke is intruded along a pre-existing shear zone and the contacts of the dyke have since been sheared again. Hence, the Idamalayar shear zone is younger than 75 million years. Efforts are under way to date the sheared material at the contact. Indirect evidences indicate the shear zone is younger than lower miocene, for, the Idamalayar shear zone terminates at the Palghat gap for which a lower miocene age is assigned. This would suggest that the gap was in existence when the shear zone was formed. It is not unlikely if the age of the shear zone turns out to be pliocene or later (Krishnaswamy 1971).

6. Seismic status of the Idamalayar shear zone

The supposedly stable Kerala area has been subjected to earthquakes of various magnitudes in the recent past. Quite a few of these could be correlated to the Idamalayar shear zone. Coimbatore town was rocked by an earthquake of magnitude 6.0 in 1900 (Basu 1964). This figure was later revised to 6.5 by the India Meteorological Department. The epicentre of the Coimbatore earthquake is 30 km to the east of a major lineament, in continuity with the Idamalayar shear zone. Epicentres worked out from macroseismic data differ from the instrumental epicentres. Epicentre of the Coimbatore earthquake may be within 25 km east of the lineament. The focal depth of the quake is placed at 55 km. With these parameters, the dip of the shear zone would range between 70° to 75° to the east (Krishnaswamy 1971). The surface trace of this extends straight across the Idamalayar, Chalakudy and Bharatapuzha catchments. Such a course indicates a near vertical or steep easterly dip. Such steep dipping features often exhibit variations in the direction of dip, thus explaining the 85° westerly dip of the Idamalayar shear zone observed in the drifts. It can therefore be surmised that the Coimbatore earthquake of 1900 originated on the down dip extention of Idamalayar shear zone.

There are a few other recent tremors which can also be correlated to the Idamalayar shear zone. All these lie on, or east of the Indamalayar shear zone. They are tabulated below:

Name of shock and year	Epicentre/ affected area
(*i*) Neriamangalam earthquake 1953	10° 00′ N, 76° 48′ E
(*ii*) Kottayam earthquake 1953	9° 25′ to 9° 45′ N, 76° 35′ to 77° 0′ E
(*iii*) Mangalam earthquake 1960	Spread over an area of 30 km × 8 km around 10° 24′ N, 76° 48′ E
(*iv*) Sarkarapatty 1967	10° 24′ N, 76° 48′ E
(*v*) Sholayar earthquakes 1969 & 1971	10° 18′ N, 76° 46′ E

7. Effects of fluid pressure on active faults

It has been widely recognised that injection of fluids under pressure activate a shear fracture and trigger an earthquake. Seismicity associated with reservoir filling such as at lake Mead, Kariba, Kremasta and Koyna may be attributed to this phenomenon.

The Idamalayar shear zone is being submerged by a number of man made lakes. The proposed Idamalayar reservoir would itself extend for over a length of 10 km over the shear zone. The water spread of the Poringalkuthu scheme encompasses parts of the shear zone. The reservoir of the Parambikulam-Aliyar also spreads over a part of the shear zone, while the Mangalam reservoir is located right on the shear zone. Although the effect of reservoir loading to be able to create or trigger an earthquake is a debatable question, there exists sufficient experimental data to indicate that injection of fluids into deep crustal fractures activates an event (Evanas 1966).

8. Suitability of the Idamalayar lineament for earthquake prediction studies

From the foregoing data, it is interpreted that the Idamalayar shear zone is (*i*) likely to be active, (*ii*) extends over a considerable length and (*iii*) chances of fluid injection into the fracture exists. This, therefore is a potential area for future earhquakes and should be considered as an ideal site for earthquake prediction studies.

Countries which are frequently affected by earthquakes such as, Japan, U.S.A., U.S.S.R., and China have evolved certain parameters that would help in predicting earthquakes. Observations ranging from the curious behaviour of animals, birds and fishes to the monitoring the dilatancy in rocks have proved effective in predicting the time, place and magnitude of earthquakes. Programmes encompassing some or all the parameters have been evolved in U.S.A. and Japan for aiding earthquake prediction (Rikitake 1975). Advantage could be derived from the experience of these countries. However, in selecting a field of study, care has to be taken that maximum knowledge is derived with the minimum expenditure of time and money. With this in view, the following are suggested for monitoring the Idamalayar shear zone :

(1) *Determination of seismic velocity by explosion seismology*

Significant relationships between the V_p/V_s velocities and the occurrence of an earthquake due to dilatancy in the rocks have been observed prior to an earthquake. Regular operations consisting of periodic explosions and measurement of variations in wave velocities at stations near the Idamalayar shear zone may be taken up.

Installation of a local network of seismograph stations to establish the background data has already been recommended (Krishnaswamy 1971). These stations together with the Idikki network would yield valuable data on the seismicity of the Kerala State and the adjoining territories.

(2) *Measurement of radon gas content in wells*

In almost all recorded cases, there have been measureable increases in the radon gas content in the water in wells, prior to an earthquake. This omnious increase in the radon gas content is attributed to the dilatancy in rocks preceding an earthquake. Radon gas content in the water wells adjacent to the Idamalayar shear zone could be periodically checked to notice any positive anomaly.

(3) *Geodetic measurements*

It is of particular importance that possible land deformations which take place, could be discovered by analysing the results of levelling and triangulation surveys carried out before and after an earthquake.

The available evidences indicate that the Idamalayar shear zone is a tear fault. To monitor the tear movement at a possible slow annual rate, geodetic traingulation stations may be established on either side of the shear zone to check the coordinate values of the stations periodically (Krishnaswamy 1971).

(4) *Tide-gauge measurements*

A crustal movement is not necessarily connected with the occurrence of a large scale earthquake although such movements related to an earthquake are also on record, which have been measured by means of tilt meters and strain meters.

The recent rapid erosion of Kerala coast may also be due to a gradual rise of the sea bed or conversely the subsidence of the Kerala coast. An indepth study of the tide gauge measurements and the frequency of the earthquake shocks may indicate whether there is any correlation between the two.

Installation of tide gauges along the coast of Kerala and periodical measurement are suggested for this purpose.

9. Conclusions

We have a long way to go to have a weather type of forecast for earthquake predictions. Nevertheless considerable progress has been made in earthquake prediction studies.

South India can no longer be considered to be aseismic; a number of faults of quaternary age have been discovered and seismic activity along them at a future date appears probable.

The 60 km long Idamalayar shear zone is thought to be one of the younger faults and an age of pliocene has been assigned to the fault. A number of reservoirs have been constructed in this 60 km long shear zone which is the causative fault for the 1900 Coimbatore earthquake with a magnitude of 6.5. These factors make the Idamalayar lineament a potential seismic hazard zone and thus qualifies for embarking on a systematic and scientific earthquake prediction studies over it.

Periodic monitoring of velocity of V_p and V_s waves, establishing a network of seismograph stations; geodetic measurements to evaluate movement along the tear fault and tide gauge measurements to ascertain the subsidence of land or raising of the sea bed may be undertaken so as to predetermine any precursory indications of future earthquakes.

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