

## THE LATUR EARTHQUAKE

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### INTRODUCTION

Earthquakes are generally assumed to be elastic waves radiating out from a rupture in the Earth that slips suddenly and generally in a brittle manner. Since the advent of the concept of Plate Tectonics, substantial progress has been made in understanding the processes causing earthquakes, but much of the attention of seismologists has been devoted to those recorded at the plate boundaries. Earthquakes originating from continental interiors have been relatively few in comparison and were regarded so far as isolated incidences of stress release due to reasons not immediately explainable. However, such incidences though less frequent have caused great damage to human life and property and there is a growing opinion now that intra-plate seismicity which is far less understood deserves serious attention (Johnston and Canter, 1990).

### INTRAPLATE SEISMICITY

Peninsular India has also been largely regarded as one of the aseismic (stable), ancient continental blocks on the globe, which has not been subjected to orogenic movements or episodes of folding in younger geological history. Such a belief was probably founded also be-

cause very few earthquakes have interfered with its stability, in the living memory, and because of their fragmentary historical record as compared to the earthquakes which frequented the Himalayan region. Systematic recording of peninsular earthquakes began sometime in the middle of this century after the installation of a seismograph at the IMD, Pune. The region covering Nasik, Phaltan, Rahuri, Pimpalgaon, Dhoni, Wai, Karad, Pandharpur and Hukeri is said to have suffered an earthquake of intensity VII in August 1764. The coastal regions of Bombay, Bassein, Surat and Goa are reported to have experienced earthquakes of moderate intensity during 1618, 1668, 1678, 1689, 1751 and 1752. The most devastating of the series has been the one which rocked almost the entire Peninsula on June 16th, 1819 and for which the epicenter was located in Kutch. Its magnitude was 8.3 and its impact had demonstrated that major earthquakes can and do occur also in continental interiors (intra-plate) and not necessarily only on the plate margins. This was followed by the Koyna earthquake of 10th December, 1967, with a maximum magnitude 6.7 and recently by the Latur earthquakes on the 30th September, 1993, with magnitudes 6.1 and 6.2.

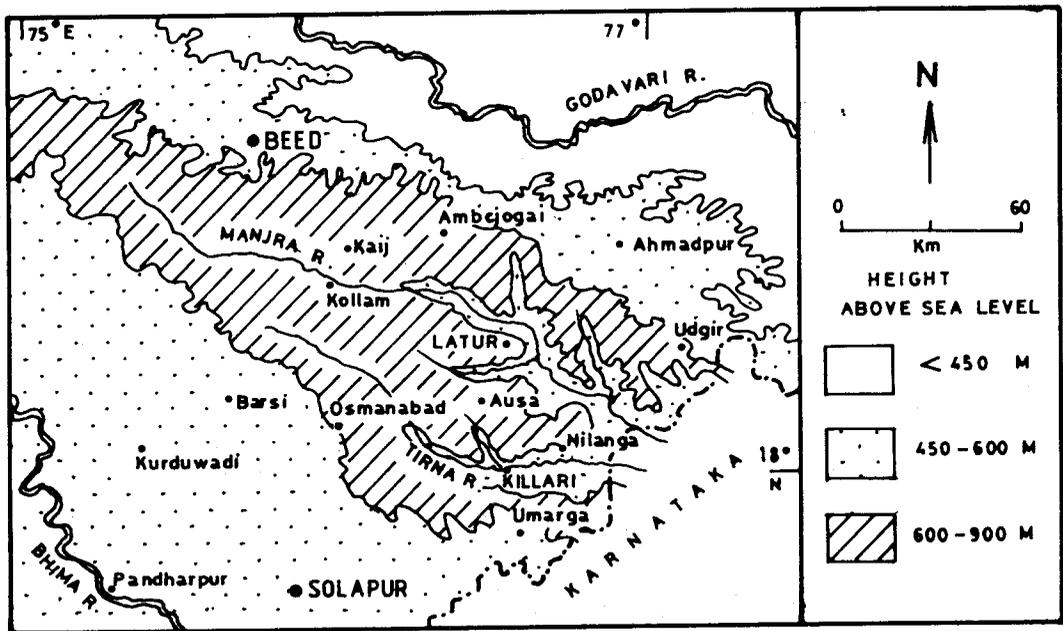


Fig.1 Location map showing earthquake affected region  
(GEOGRAPHICAL DETAILS AFTER DIXIT, 1986)

The major earthquake of 1819 in the Kutch region was not an isolated shock, many small and big tremors have continued to rock the region in the last 50 years. The latest spurt of seismicity began on the 24th August, 1993 when many shocks of magnitude 4, 5 and 6 have been recorded with the epicenters in Saurashtra but were felt severely also around Bombay and Goa and parts of western Maharashtra. Close on the heels were the quakes of 28th and 29th August and of 3rd September, 1993, which had their epicenters around Koyanagar and rocked a large part of Maharashtra, northern Karnataka and Madhya Pradesh. And then in the early hours (3.58 AM) of 30th September, 1993, the Latur earthquake struck which took a toll of above 9000 people and thousand others lost their houses and property in Maharashtra. The maximum damage was done around the villages of Killari and Umarga where an intensity

of IX on the M M scale is estimated (Ramakrishna et al 1994) but the earthquake shocked practically the entire Maharashtra, border regions of Gujarat, Madhya Pradesh, Karnataka and Andhra Pradesh. it was felt severely in Pune, Bombay, Satara, Kolhapur, Solapur and Goa. According to the USGS the magnitudes recorded for at least two severe shocks were about 6.1 and 6.4 on the Richter scale which fortunately lasted only a few seconds but a large number of smaller shocks of magnitude > 4 inflicted further damage and, more than that, a chaos on the day and for the following few weeks. The natural calamity was most stunning and caught the population unawares. The epicenter location given by the USGS was at Lat 18.055 N and the Long 76.424 E and the depth of the hypocenter was about 6 km. Seismologists of the India Meteorology Department calculate even a deeper hypocenter at 15 km. to which many others

also agree. The area affected severely by the Latur earthquake experienced several shocks in the previous two years, most of them of magnitude  $< 4$ , before the calamity. In a couple of months to follow it was shaken again by at least two shocks of magnitude  $> 5$ . Since then frequent tremors of low magnitude are reported. Since there existed no historical record of seismicity, the shocks in the couple of years prior to the calamity were not taken seriously and no one ever expected that in this region of the peninsula a severe earthquake would take place.

### CONCURRENT EARTHQUAKES IN KOYNA REGION

On the 30th September a couple of second before the Latur earthquake struck, an earthquake of magnitude 6 also struck the Koyananagar region (reported in Kesari of October 1st) and more than 300 shocks of smaller magnitude caused damage to public utility systems and to many buildings on the very day. The cumulative effect of both did a lot of damage also in the region east of Koyna reservoir (Patwardhan, et al, 1995). The seismicity in the Koyna region has been a subject of academic controversy, since the devastating earthquakes of 1967, regarding its being reservoir induced or not. The region has been experiencing earthquakes ( $M < 4$ ) even before the impounding of water in the Shivajisagar reservoir (Guha et al, 1966). The seismicity which started in 1993 has continued through 1994 intermittently, the latest shocks of magnitude 3 and 4 originating from this region on the 5th and 6th of September, 1995 have shaken again a large part of Maharashtra. Incidentally, more than 50,000 tremors have already been recorded in the last 28 years of which about 150 have been of magnitude  $> 4$ . The continued seismicity and the depths of their hypocenters speak more towards their

tectonic origin by the reactivation of basement faults. On the 29th August, 30th September and in the first week of October 1993 a large number of shocks were recorded in the Koyna region also for which the epicenters lie in the region intervening the Koyna and the Varna dams.

### CRUSTAL STRUCTURE

Killari and the surrounding affected region is only at a 2 degrees arc distance from the Koyna epicenters. No significant difference in the crustal structure was therefore expected below these two regions. The thickness of the uppermost lithological unit, the Deccan Trap flows, decreases considerably from 1.0 km. around Koyananagar to about 0.5 km towards Killari. West of Koyna the thickness increases towards the Ghats to a maximum of about 2 km. In spite of the cover of Deccan basalts which is extensive but not very thick the entire region shows negative gravity anomalies, the general axes of which are in the NW-SE direction. It is the reflection of the presence of a thick crust, underneath the basalts, with lower density, granitic and granodioritic composition and of a comparatively deep-seated mantle. The thickness of the continental crust is estimated to be, on an average, about 35 km becoming thin near the west coast. In the Koyna - Karad region the - 100m gal Bouger anomaly is interpreted as indicating a thick crust and a deep mantle. The positive gravity anomaly at the west coast and a steep gradient of the anomaly westward indicates a tectonic heterogeneity in the lithosphere and a sudden shallowing of the mantle. The presence of high density material at shallow levels near Bombay coast was proposed 60 years ago (Glennie, 1934) on the basis of gravity measurements but the Deep Seismic Studies undertaken in recent years (Kaila et al, 1981) have revealed that the pre-Trap surface is undulatory, blocks of the un-

derlying crust have suffered vertical movement, the lithosphere is not uniformly thick, and the MOHO, which is the transitional boundary between the crust and the mantle, has also suffered displacements.

### LATUR REGION

The epicentral region of Latur earthquakes with - 85m gals regional gravity anomaly is located on an elevated topography (Fig. 1) just like the epicentral region of the Koyna earthquakes. The gravity anomaly shows the presence of mantle at relatively shallow levels than under the Koyna region, applying the same analogy. It is possible that the elevation of these regions has not yet fully compensated the density difference between the crust and the deeper mantle. The residual mantle left below the lithosphere after it was depleted of the material constituting the Deccan basalts ought to be anomalous and denser. The volcanic eruption which rifted the lithosphere 65 million years ago should have also severely ruptured the continental crust, adding to its compositional (Reddy, 1995) and structural heterogeneity. Volcanic material including the accompanying fluids should have profusely entered the pre-existing faults and fractures of the Proterozoic, and created new weak planes and compositional boundaries. The seismic response and behaviour of such a continental block would be certainly different from those which have not been riddled with such sudden and profuse volcanic event.

### GEOMORPHOLOGY

The present relief of the Deccan basalts, after a prolonged period of erosion, seems to be undercompensated and is perhaps undergoing vertical adjustments. Slow and episodic vertical movements in the Peninsular region have long been envisaged (Wadia, 1944, p. 32), based on geomorphic and geological observations off

and along the west coast. It was also proposed then that the characteristic drainage pattern on the peninsula was an outcome of a southeasterly tilt it acquired after the underbuckling of its northern fringes in the Himalayan region. The progressive incision by the southeasterly flowing rivers Bhima, Godavari and its tributaries Tirna and Manjra and the tributaries of Koyna, Varna and Morna in the region of Satara district (Patwardhan et al, 1995) is a significant geomorphologic feature in this regard. It indicates compensation by repeated minor uplifts in some parts and corresponding subsidence in other parts along buried weak planes (Brown and Rellinger, 1986). As such movements seem to provide possible reasons for the earthquakes, there are many questions which still remain unanswered and require in-depth research and data generation. The region affected severely between the stretches of Godavari and Bhima rivers (Fig. 1) is a part of the narrow almost northwesterly stretched zone of high elevation (600 - 900M) depicted in the relief map of Maharashtra (Dikshit, 1986), covering parts of the Osmanabad, Latur, and Beed districts. A reverse fault solution with the fault plane striking NW-SE has been proposed for the Latur earthquake by the preliminary studies (Ramakrishnan et al, 1994).

### INTENSITY

It is necessary now to identify the two regions as seismicity prone regions in Peninsular India and to take steps in evaluating the ground motion caused even by the shocks of magnitude 3-4 which are more frequently felt. Strategic structures like dams and bridges should be built and reinforced, taking into consideration that they should be able to withstand the maximum amplitude of vibration during the few seconds of duration of earthquakes of magnitude 6-7. Complacency in this regard may prove costlier in future years. Earthquakes

of magnitude  $> 6$ , originating in Peninsular India, are felt over long distances of 6 to 9 hundred kilometers. This is a special characteristic which is related to the compositional heterogeneity of the crust. Much of the loss of property and life in the Latur earthquake, however, was caused because the houses were located on loose ground and the alluvial track of Tirna and, of course, more because of the poor quality of houses which collapsed readily. Strong ground motion is the single largest natural factor in causing earthquake damage, including landsliding, failure of structures, loss of life and property (Brown and Rellinger, 1986). The state of Maharashtra has many small and big irrigation projects located in the track of Nasik to Kolhapur and in the Beed, Osmanabad, Latur and Solapur districts. There are proposed and existing nuclear energy establishments nearer the west coast. It is time the impending hazards of this

seismicity were sensed and preventive measures were planned to minimise or, if possible, avert the same.

Short term earthquake prediction is still only a remote possibility. Geographers, geologists and geophysicists have an important role to play in identifying active faults, branch faults and subordinate faults, even if they are hidden and buried under the lava cover of Indian Peninsula. It is necessary to identify also the nature of these faults whether they are normal, reverse or strike faults, as on reactivating they achieve different orientations in response to the subjected stress. The Kutch, Koyna, and Latur earthquakes which occurred in that sequence in the months of August and September, 1993, were perhaps not isolated events that rocked the entire Maharashtra and surrounding states, they may be inter-related features of the intra-plate seismicity.

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