

make-up programme for the shortcomings of the degree programmes

Further, polytechnic education needs a through shake-up. The World Bank loan will seal the fate of these institutions, unless the programme is stopped immediately and detailed discussions are held with the Confederation of Indian Industries, and employment opportunities for the diploma holders from these institutions are carefully evaluated. The number of polytechnics which are extremely ill-equipped,

poorly staffed and that are run in make-shift sheds are so large that unless some corrective measures are taken immediately the situation, which is already serious, will go out of hand. Since polytechnic education as it exists today has lost its relevance, the diploma holders from these institutions put pressure on the Government for admissions to degree level programmes, thus overburdening the already fragmented degree level institutions.

Lastly, professional societies should be allowed to continue enjoying themselves doing whatever they are doing now. They are good associations for relaxation and social evening hours.

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Geophysical and geodynamical aspects of the Maharashtra earthquake of September 30, 1993

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The Indian subcontinent is under severe compressive stress resulting from the collision of the northward moving Indian Plate with the Eurasian Plate about 50 million years ago, underthrusting the latter and producing the Himalaya mountain range and the Tibetan plateau. Whereas the Himalayan earthquakes are associated with plate collision, the earthquakes of peninsular India in the interior of the Indian Plate are primarily intra-plate earthquakes caused by crustal faults and epeirogenic vertical movements of crustal blocks.

The strong Koyna earthquake of 1967 with magnitude 6.7 on the Richter scale had unsettled the long-held view of the earth scientists in India that the Indian peninsular shield was a seismically stable region with a low order of seismicity. Both the Kallari-Latur and the Koyna earthquakes had a very shallow focal depth of 5–10 km.

The vast Deccan Trap region is covered by basaltic lavas over an area of roughly 600,000 sq km in Peninsular India. The present author and his colleagues in the Geological Survey of India conducted geophysical investigations over an area of roughly 400,000 sq km in the Deccan Plateau of Maharashtra, parts of Gujarat, Madhya Pradesh, Andhra Pradesh and Karnataka, from 1965 to 1978 first under the International Upper Mantle Project

(1964–1973) and continued under the International Geodynamics Project (1973–80).

The Koyna earthquake region was investigated by us immediately after the earthquake in 1967 employing gravity, seismic and magnetic techniques which brought out a deep crustal north-south fault zone passing through the western neighbourhood of Koyna which had apparently caused this earthquake. This fault zone comprising a system of parallel faults was subsequently traced all the way from the north Bombay coast to Ratnagiri on the coast in the south over a distance of 500 km traversing the Koyna region as reflected by the steep gravity gradient of 3–4 mgal/km (Figure 1). These first results were published earlier^{1–3}.

The results of the regional gravity surveys conducted in the Deccan Trap region to the south of the Narmada river with the Bouguer gravity map were first published in 1972 by Kailasam and colleagues³. The Koyna-Karad region is brought out as a deep tectonic sag bounded by the Koyna deep crustal fault zone to its west. A number of prominent gravity 'highs' and 'lows' appear in the Bouguer gravity map (Figure 1). The pronounced gravity 'high' in the Nasik area in the northwest and Sangola area in the southeast indicates zones of marked

uplift while the gravity 'lows' to the north of Nasik, and in the Kurudwad area, Kaladgi Basin and the Koyna region indicate zones of marked subsidence^{3,4}. The residual gravity anomalies in these zones of subsidence are negative, suggestive of lower density segments underlying the traps, corroborating and confirming the Bouguer anomalies. These zones of marked uplift and subsidence of crustal blocks (Figure 2) are deep seated and subcrustal in nature, related to processes within the mantle^{5–7}. The seismic depths to the base of the traps as computed by deep refraction seismic soundings at a large number of suitably located points all over the trap territory support this inference from the gravity data, inasmuch as relatively large thickness of traps is indicated in the zones of subsidence and smaller thickness of trap in the zones of uplift, suggesting that the strong gravity anomalies are due to deep crustal and sub-crustal effects, and not due to varying thickness of the high density trap (2.95 g/cc), the contribution of which is only small being of the order of 2–3 m gals generally in the area. The thickness of trap as computed from the seismic data is of the order of 100 m in the marginal portions in the south and eastern fringes, increasing to more than 1000 m in the eastern

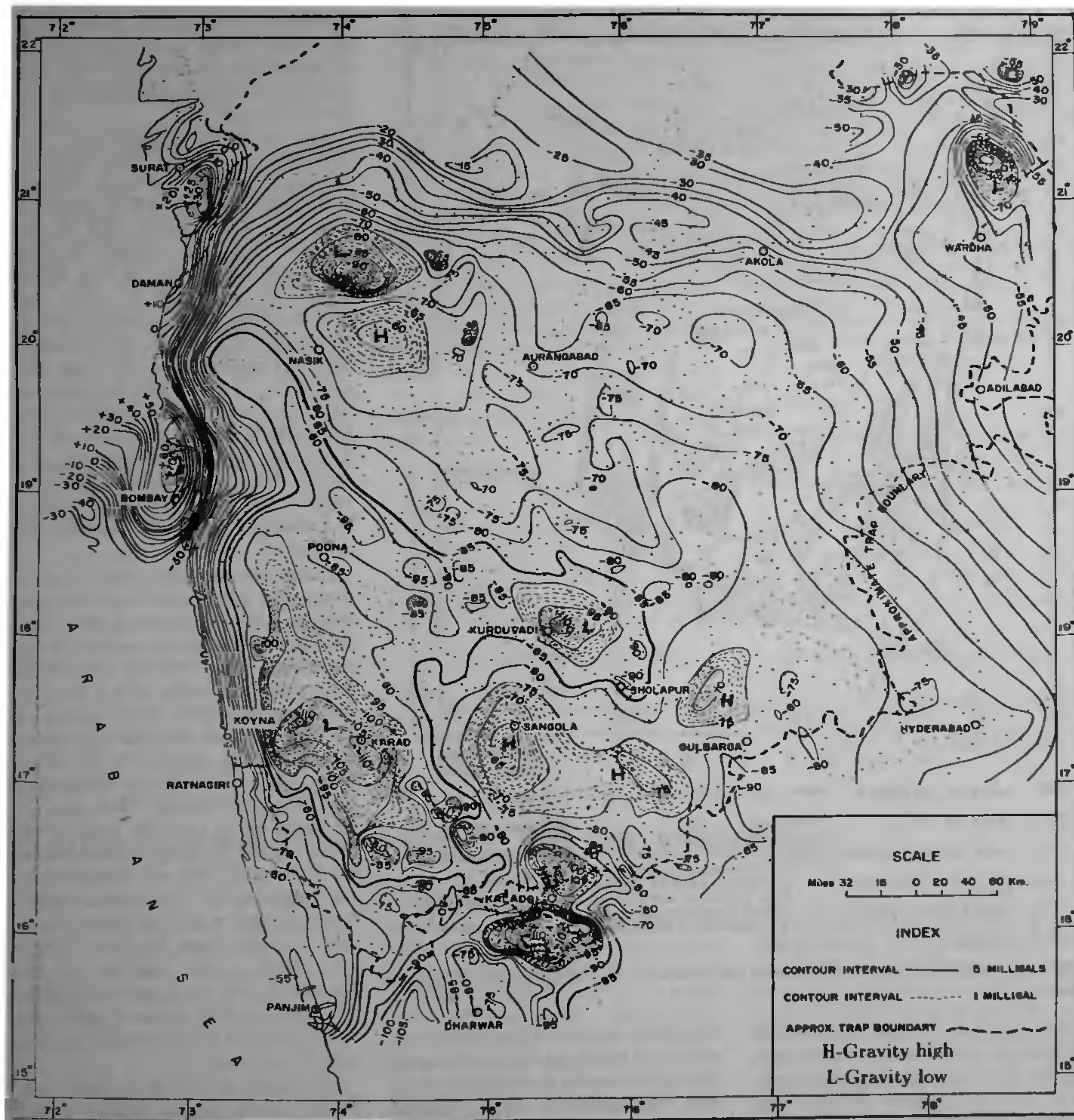


Figure 1. Bouguer gravity map of the Deccan Trap areas in Maharashtra, and parts of Mysore and Andhra. (From ref 3)

neighbourhood of the Western Ghats, while the total thickness of the traps over the northwestern Ghats is believed to be more than 2000 m

In the zones of subsidence in the Nasik area (Figure 2) as well in the northeastern zone, the traps are underlain presumably by Gondwana sediments (Permo-Carboniferous to

Jurassic of average density 2.5 g/cc) and away from these zones the traps appear to be underlain by Archaean granite and gneisses (density 2.65 g/cc) in the central area and possibly by Kaladgi and Bhima formations in the southern parts as indicated by the seismic data. This combined feature of uplift and subsidence indicated near

Nasik appears to be intervened by a fault with additional faults to its north-west and north and roughly E-W faults further to the east (Figure 2)

These zones of uplift and subsidence in the Deccan Trap region are associated with vertical (epeirogenic) movements. The extrusion of a huge pile of lava flows should have caused a general

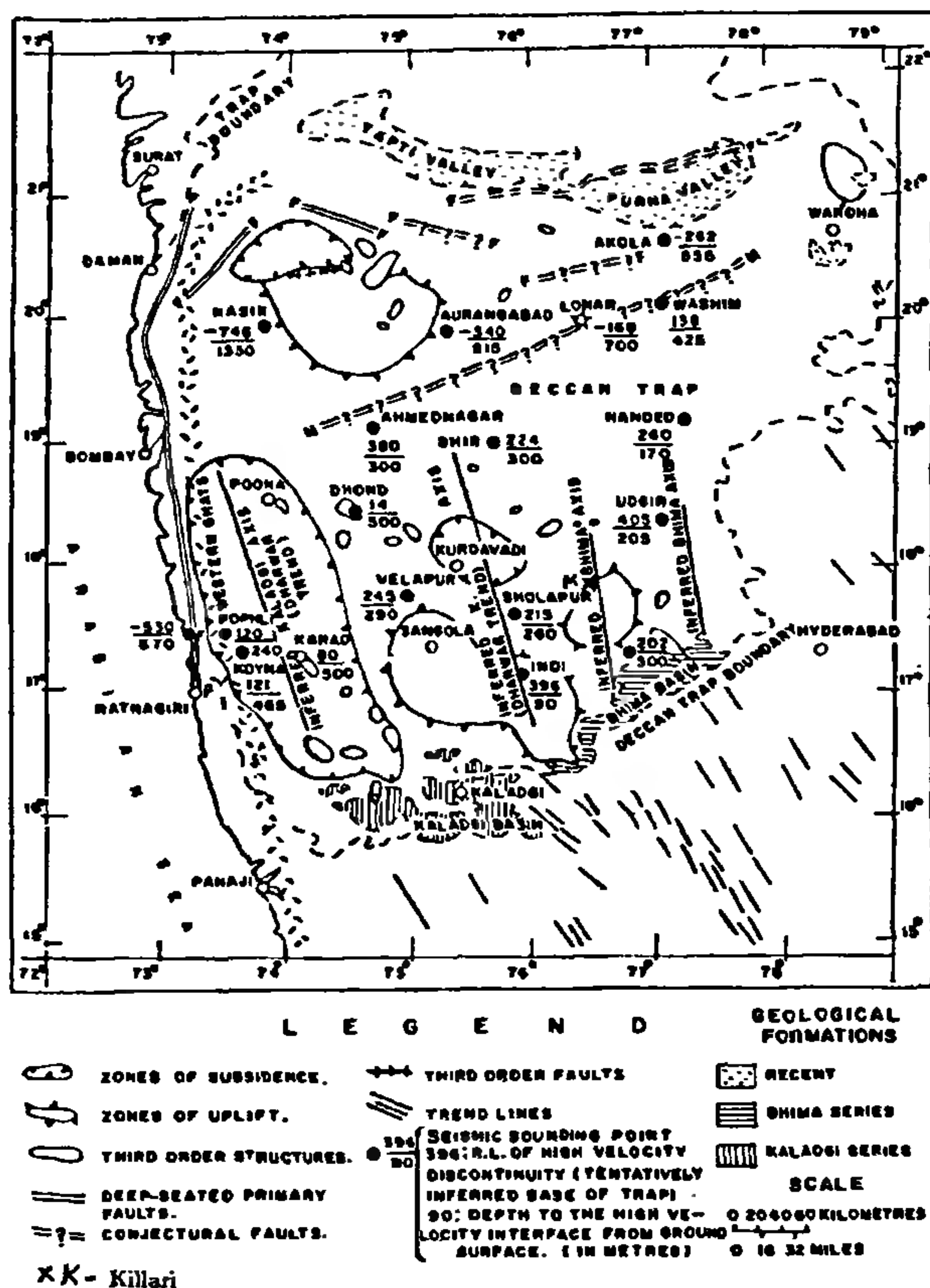


Figure 2. Tectonic features of the Deccan Trap area as deduced from gravity and seismic results.

depression of the Deccan syncline with differential subsidence over some parts of the Pre-Trappean floor, especially over the Precambrian Kaladgi and Bhima sedimentary basins in the southern margins of the Deccan Trap territory whose northward extension underneath the traps (Kaladgi and Bhima axes) (Figure 2) has been indicated by the geophysical data, and the Permo-Carboniferous Gondwana or Cretaceous sedimentary basins underlying the traps in the northwestern, northern and northeastern parts of the Deccan Trap region. The marked subsidence of these sedimentary basins should have been accompanied by complementary uplifts of crustal blocks

in response to isostatic forces which are manifested by the extensive epeirogenic vertical movements in the region which have been going on since Cenozoic times and have further aggravated the compressional stresses resulting from the plate collision⁵⁻⁷, and are causing the minor earthquakes and earth tremors in the Deccan shield.

The major zone of subsidence in the Kurudwadi-Sholapur region appears in the gravity map as a closed basin of lighter sediments overlain by a thick section of the high-density Deccan lavas. There is a major zone of uplift to its south in the Sangola area and another to the east of Sholapur (Figure 2). The continuing vertical

movements of the crustal blocks cause the margins of the basins and uplifts to be fractured and faulted and these deep faults are covered and concealed by the flows of Deccan lava.

The disastrous earthquake of the Latur-Killari-Umargaon region has been apparently caused by such vertical movements of crustal blocks along the fault plane. The gravity data do not indicate any rift valley in the Kurudwadi region nor in the Koyna region as postulated by Negi and Krishna Brahman⁸. The gravity map of the Deccan region, as stated earlier, was first published by Kailasam and colleagues in 1972, on the basis of which Negi and Krishna Brahman have postulated in 1973 the existence of the Kurudwadi and Koyna rift valleys. The gravity data do not indicate these rift valleys, as proved by the seismic and electrical results of Kailasam and colleagues⁹.

The gravity anomalies (lows) in the Kurudwadi and Koyna regions are two separate entities indicating two separate basins. The gravity pattern of the Kurudwadi 'low' does not conform to an extended rift valley with a linear or rectilinear disposition in the manner of the Godavari and Narmada rift valleys or the Cambay graben. On the other hand, it is a closed feature conforming to a closed sedimentary basin beneath the traps as is also the case in the Nasik region. The gravity contours over the Kurudwadi 'low' are influenced by the Sangola uplift in its southern neighbourhood and a smaller uplift to its east. It is significant that these 'highs' and 'lows' occur together in the Kurudwadi and Nasik regions, signifying complementary zones of uplift and subsidence as a consequence of vertical crustal movements.

The Koyna depression is flanked to its west by the Bombay-Ratnagiri deep crustal fault zone and by the uplifts to its east also includes the northward extension of the Kaladgi basin. The Bhima basin of Precambrian sediments appears to extend northward beneath the traps between the Sangola uplift and the other uplift to its east in the direction of the Bhima axis^{4,5}. The shallow devastating earthquake which occurred in the Killari-Latur-Umarga area on 30 September 1993, appears to have been caused by the strong upward movement of the uplifted crustal blocks in its neighbourhood, especially the smaller

one to the east of Sholapur (Figure 2). Killari appears as located on the western margin of this eastern block. The violent upward movement of this block appears to have caused the faulted margin of the traps and Bhima sediments bounding this uplifted block to split and rupture vertically. This could account for the devastation at Killari to be restricted within a narrow zone without spreading laterally. This aspect needs to be attended to further, as it has serious portents for future earthquakes in the other areas of uplift and subsidence indicated in the gravity map. The depth to the base of the traps as indicated seismically is of the order of 260 metres. The trap rock has high elastic coefficients and longitudinal seismic velocity (~ 5300 m/s) and transmits highly the earthquake energy.

The Killari-Latur-Umarga region is reported to have experienced earth tremors for more than a year prior to the earthquake. While it is difficult to predict earthquakes, especially the magnitude and the time of occurrence, adequate monitoring of these tremors

and ground movements might perhaps have provided some advance warning of the disaster. The other zones of subsidence and uplift indicated in the gravity map are also apparently earthquake-prone, especially the Nasik region in the northwestern part and the neighbouring fault zones (Figure 2), with potentialities for future earthquakes. It is advisable that these zones as well as the Bombay coastal area and the Koyna region and other earthquake-prone areas in India are monitored for ground movements on a long-term basis with modern seismological equipment and techniques and the latest satellite-based Global Positioning System, which may afford a better understanding of such disastrous intra-plate earthquakes.

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OPINION

Science and technology for development

Articles on Science and Technology in India in recent issues of *Current Science* and some newspapers should be of great interest and value to the intelligentsia in general and scientists in particular. Open discussions are essential to evaluate our achievements and focus attention on the future needs. I congratulate C. N. R. Rao for taking a lead in such a discussion and compliment *Current Science* for publishing differing viewpoints on such a vital subject at a critical time when there are changes of far reaching consequences in our economic and industrial policies.

India under the enlightened Prime Ministership of Pandit Jawaharlal Nehru recognized the importance of science and technology and established appropriate agencies and infrastructure in areas of vital interest to the nation. Today the country is in a position to

boast of the third largest scientific manpower in the world and a large number of institutions of higher learning and research in every field of activity. There are some notable achievements particularly in the fields of agriculture, space and defence technologies, computer sciences, etc. to our credit. The science budget has increased from about 0.3% of the GNP in 1970 to about 1.1% in 1990. There has been some reduction recently in the eighth five-year plan allocations, bringing down the figure to about 0.9% of the GNP.

We have been supporting science and technology all these years. However it appears that sufficient thought has not been given to the obvious question - 'Science and technology for whom and for what purpose?'. Science for science sake - for revealing mysteries of the

Universe and for understanding principles governing the physical, chemical and biological processes is most fascinating. Some of such studies may result in technological innovations for the benefit of mankind. Whereas basic science is universal, development of technologies have to be area-specific to fulfil the needs of the people.

Basic science has been going on in the country for long, but it has hardly resulted in any significant technological innovations. The industry and the government both have been freely importing foreign know-how and technologies for practically all the industries which have been set up in the country. And in the present situation of liberalization, we may find foreign companies coming in large numbers with their technology, equipment and machinery to flood markets in India