Pradesh and adjoining Vidarbha, the Bharuch–Kachchh belt in Gujarat, the Doda–Kangra sector in NW Himalaya, the Kaunk–Uttarkashi belt in north-eastern Himachal and adjoining Garhwal and the Dharchula–Bajang region in the Indo–Nepal border, besides the eastern Arunachal Pradesh and Assam need to be included in this network of close seismological stations.

In my perception the Dharchula–Bajang region in the central sector of the Himalaya is under critically stressed condition and must be taken up for intensive investigation without delay Likewise, the Palghat–Salem region south of the Nilgiri massif needs to be comprehensively studied.

Coping with natural hazards

Natural hazards (such as earthquakes, floods, cyclones, avalanches, landslides) cannot be prevented from occurring, but their impacts can be reduced and risks minimized if effective measures are taken in time. This calls for advance planning for disaster preparedness. For this purpose, a national agency – to be called the Natural Hazards Management Commission[17] – can be formed. Functioning in the manner the Election Commission does during elections, this agency would (i) make appraisals of the magnitudes of risks of varied hazards (earthquakes, floods, coastal storms, landslides) on the basis of past occurrences and monitoring of geological, geophysical and physiographic changes in the identified vulnerable zones or areas; (ii) prepare and publish hazard-zoning maps, (iii) disseminate relevant information through media and popular publications. The hazard-zone mapping can be pursued through academic institutions, and if need be, on contractual basis; and (iv) the Commission would mobilize personnels (drawn from different organizations, including voluntary agencies) and resources for coordinated operations related to evacuation, relief, sanitation, medicare, food, shelter, resettlement, loans for economic recovery, etc.

1. Valdiya, K. S., *Platinum Jubilee Lecture*, Pune Session, Indian Sci. Congress, Calcutta, 1988.
2. Valdiya, K. S., *Indian J. Geol*, 1989, **61**, 1–13.
3. Chandra, Umesh, *Bull. Seismol. Soc. Am.*, 1977, **67**, 1387–1413.
4. Mohan, Indra, Sitaram, M. V. D. and Gupta, H. K., *J. Geol. Soc. India*, 1981, **22**, 292–298
5. Valdiya, K. S., *Aspects of Tectonics. Focus on South-Central Asia*, Tata-McGraw Hill, New Delhi, 1984, pp. 319.
6. Krishna Brahmam, N. and Kanungo, D. N, *J. Geol Soc India*, 1976, **17**, 45–53.
7. Gupta, H. K., Mohan, Indra and Narain, H, *Bull. Seismol. Soc. Am.*, 1970, **60**, 601–615.
8. Guha, S. K, *Tectonophysics*, 1979, **52**, 549–559.
9. Gupta, H K, Rao, C U., Rastogi, B. K. and Bhatia, S C., *Bull. Seismol. Soc Am*, 1980, **70**, 1833–1847.
10. Krishna Brahmam, N. and Negi, J. G., *Geophys. Res. Bull.*, 1973, **2**, 207–237.
11. Kaila, K. L., Reddy, P. R, Dixit, M. M. and Lazarenko, M. A., *J. Geol. Soc. India*, 1981, **22**, 1–16.
12. Powar, K. B, *Mem Geol. Soc. India*, 1980, **3**, 45–56.
13. Powar, K. B., *Curr. Sci.*, 1993, **64**, 793–796.
14. Radhakrishna, B P., *Curr. Sci*, 1993, **64**, 789–793
15. Rajaguru, S N., Kale, V. S. and Badam, G. L., *Curr. Sci*, 1993, **64**, 817–822.
16. Vaidyanandhan, R and Ghosh, R. N., *Curr. Sci.*, 1993, **64**, 804–816.
17. Valdiya, K. S., *Environmental Geology: Indian Context*, Tata-McGraw Hill, New Delhi, 1987, pp. 227–239.
18. Borodin, L. S., Gopal, V, Moralev, V. M, Subramanium, U. and Ponikarov, V., *J. Geol. Soc. India*, 1971, **12**, 101–112.
19. Grady, S. A., *J. Geol. Soc. India*, 1971, **12**, 56–62.

K. S. Valdiya is in the Department of Geology, Kumaun University, Nainital 263 002, India

COMMENTARY

A quick look at the Latur earthquake of 30 September 1993

Harsh K. Gupta, Indra Mohan, B. K. Rastogi, M. N. Rao and C. V. Ramakrishna Rao

A majority of people in the western and central parts of Peninsular India were awakened in the early hours of 30 September 1993 by the shaking caused by the Latur earthquake. We, at the National Geophysical Research Institute (NGRI), Hyderabad, rushed to the Seismological Observatory on our campus. We were all worried that the earthquake might have occurred in the Koyna region as there was an enhanced seismic activity in that region and a couple of earthquakes[1] exceeding magnitude 5 occurred on 28 August and 3 September 1993. A quick analysis of the seismograms at the NGRI Seismic Station revealed that the epicentre was some 220 km west–north–west of Hyderabad in Latur district. The NGRI seismograph system having a high magnification, the seismograms were saturated and the magnitude of the earthquake could not be estimated immediately. However, it was clear that the earthquake must have a 6+ magnitude. Finally, the following earthquake parameters were estimated for this earthquake:

Origin time	03 h 55 m 46 68 s IST
Epicentre.	18°N76°32'E
Depth:	5–15 km
Magnitude:	MS = 6 4, m_b = 6 3
Seismic moment.	Mo = 1 8 × 10^{25} dyne cm

This earthquake was followed by a number of aftershocks. Table 1 gives details of these aftershocks and their magnitudes as estimated at the NGRI Observatory.

Table 1. Earthquakes recorded at HYB from Latur region

Date	Origin time (IST)	Magnitude
30 09 93	03 55 47	6 4 (MS)
	04 13 37	
	04 18 28	
	04 24 11	
	04 40 57	4.4 (MS)
	04 53 39	
	05 16 30	
	05 36 08	
	06 23 12	4 3 (MS)
	06 33 13	2.7 (MD)
	07 46 55	4.3 (MS)
	09 01 40	3.1 (MD)
	09 41 30	
	10 45 42	
	11 46 47	
	14 22 42	2.3 (MD)
	14 44 39	
	15 49 35	2.7 (MD)
01.10.93	04 29 08	2.3 (MD)
	13 25 35	
	22 31 13	4.1 (MD)
02.10 93	01 01 15	2.1 (MD)
03.10.93	04 45 24	3.5 (MD)
05.10.93	02 49 34	3.3 (MD)
06.10.93	00 40 17	3.7 (MD)
07.10.93	00 49 56	2.0 (MD)
09.10 93	02 15 08	4.3 (MS)
10.10.93	12 45 29	2 5 (MD)
12.10 93	21 02 05	2.2 (MD)

MS – The surfacewave magnitude
MD – The magnitude estimated from total duration of the signal.

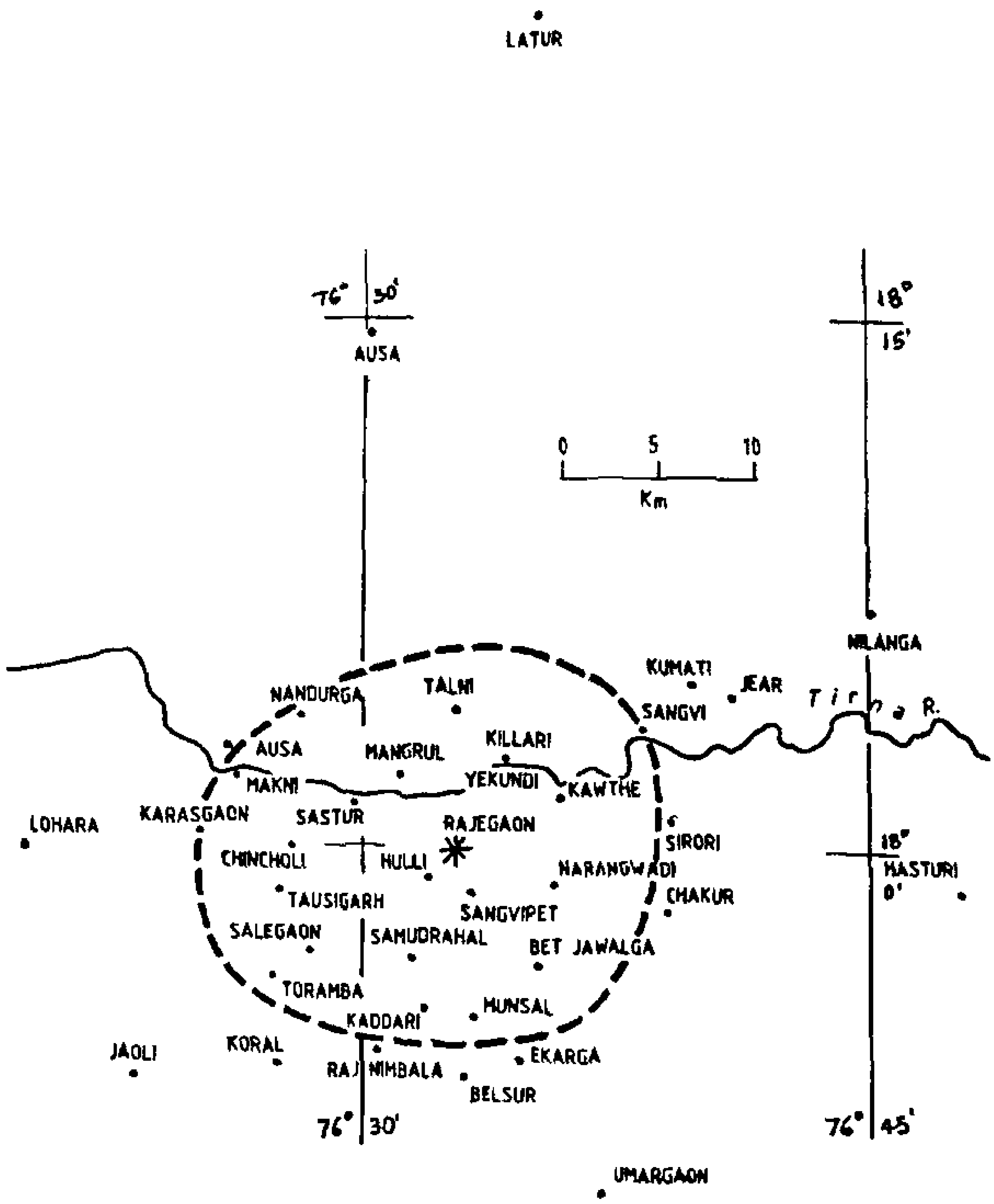

Figure 1. Epicentre location (star) and heavily damaged areas shown within the circle.

Earthquake intensity investigations

On 30 September 1993 itself a team of NGRI scientists proceeded to Latur to investigate strong motion effects of the earthquake. On the way from Hyderabad to Umarga it was observed that the intensity increased only marginally from IV at Hyderabad to +V at Umarga on the Modified Mercalli (MM) scale. At Umarga the earthquake was felt with jolts and objects had fallen off. The boulders kept on the tin roofs rattled badly but did not fall. No damage to the structures was observed or reported in Umarga, which is located some 20 km from the centre of the most affected region Figure 1 gives the location of the epicentre of this earthquake and the most affected areas. Villages like Killari, Sastur, Petsanghvi, Holli, Talni, Munsal, Kaddar, Toramba, Salegaon, Samudrahal, Bet Jawalga, Tausigarh and Karasgaon and several others were found to be very heavily affected. The style of damage was more or less the same in all the villages. The boulders in different sizes and shapes were stacked, making the two faces of the walls plane, and the in-between gaps are just filled with mud, pebbles and small boulders (Figure 2). Sometimes there was some bonding with locally available black cotton soil, which has the property to swell when moist. The soil had very low load-bearing capacity, and the walls had enormous thickness, up to 4'. This aggravated the problem further as during the earthquake these thick walls just crumbled, bringing down roofs and killing the people asleep. The roofs were also thickly covered with earth. After the earthquakes, the debris collected was almost up to waist high, in some cases even to the lintel level of the house The thick walls built on black cotton soil were basically responsible for the large damage. Moreover, heavy rains had lashed the area for a few days preceding this earthquake. Poor construction, bad foundations on black soil, an early-hour occurrence when every one was asleep and high population density were basically responsible for thousands of human lives lost in this earthquake. The official estimate of loss of human lives is about 11,000, whereas in newspapers up to 30,000 deaths have been reported.

Meizoseismal area is confined to an area of about 10 km radius, with the centre located near Holli village. It was also observed that the villages located on the banks of river Tirna, which flows from west to east, were worst affected. The river has segments of straight course, indicating the presence of faults/lineaments. The effect on the southern bank extends to a large distance compared

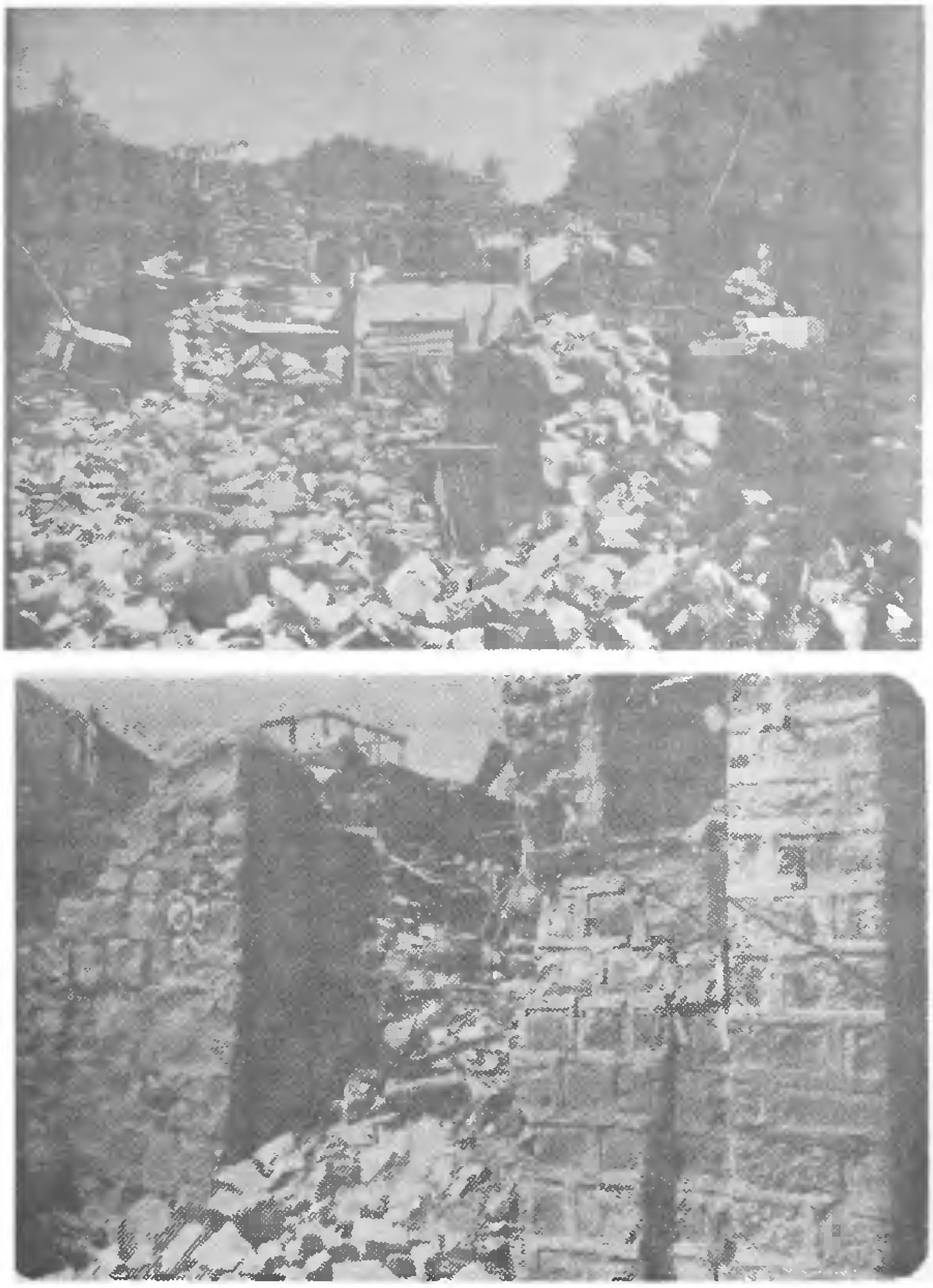

Figure 2. Typical damage to villages during Latur earthquake. Note the crumbling of walls with boulders and rocks.

Figure 3. A hut in the Killari village which was made of straw and thin sheets Nothing happened to it

to the northern side.

Some of the well-engineered structures in cement were unaffected. Also, the huts of very poor people made up with straw and wooden frames fared much better during the earthquake (Figure 3). In the village Killari a water tank of 100,000 litres capacity as well as some engineered structures withstood the shaking. Most of the electrical poles withstood the shock although there was some tilting of poles in the vicinity of the Killari village. Houses in which wood was used for support have survived and most of the PWD buildings, roads, culverts, bridges were totally unaffected.

Historical seismicity

The seismicity of the Peninsular India has been reviewed from time to time[2,3]. The peninsular shield covering almost one-third of the Indian subcontinent has relatively low seismicity. Catalogues prepared by Chandra[2] covered the period from 1594 to 1974. Although small events have been reported from time to time, only three earthquakes of some consequence, with a maximum intensity of VIII on the MM scale, have been reported in this region before 1967. These earthquakes were at Mahabaleswar (1764), Bellari (1843) and Coimbatore (1900) However, in the 1960s damaging earthquakes occurred at Koyna[4] (1967), Bhadrachalam[5] (1969) and Bharuch[6] (1970) Installation of good seismic stations at several places, particularly at Gauribidanur and Hyderabad, has improved the detection and location capabilities of earthquakes for the shield region. Figure 4 depicts the epicentres located for the period 1901–1950 and Figure 5 for the period 1951–1990 It can be seen clearly that many more epicentres are reported during the last four decades than in the earlier half of the century.

Earthquake prediction

Whenever a major earthquake hits a region, and particularly when it causes loss of human lives, talks of 'earthquake prediction' become prevalent. The first scientifically accepted earthquake prediction was made in the Blue Mountain Lake[7] region of the New York, USA. An accurate prediction of the Heicheng[8] earthquake of 4 February 1975 of magnitude 7.3 by Sino-seismologists saved an estimated 100,000 human lives by timely evacuation to safer places. This raised the hopes that through multi-disciplinary approach it should be possible to make reliable earthquake forecasts. The Sino-seismologists developed a methodology of narrowing down earthquake prediction from a long-term prediction lasting several years to medium-term and then to the short-term prediction (immediately prior to the earthquake, giving location and magnitude of the earthquake) However, it was revealed that several earlier forecasts before the occurrence of the Heicheng earthquake did not come true Also Sino-seismologists could not predict the much

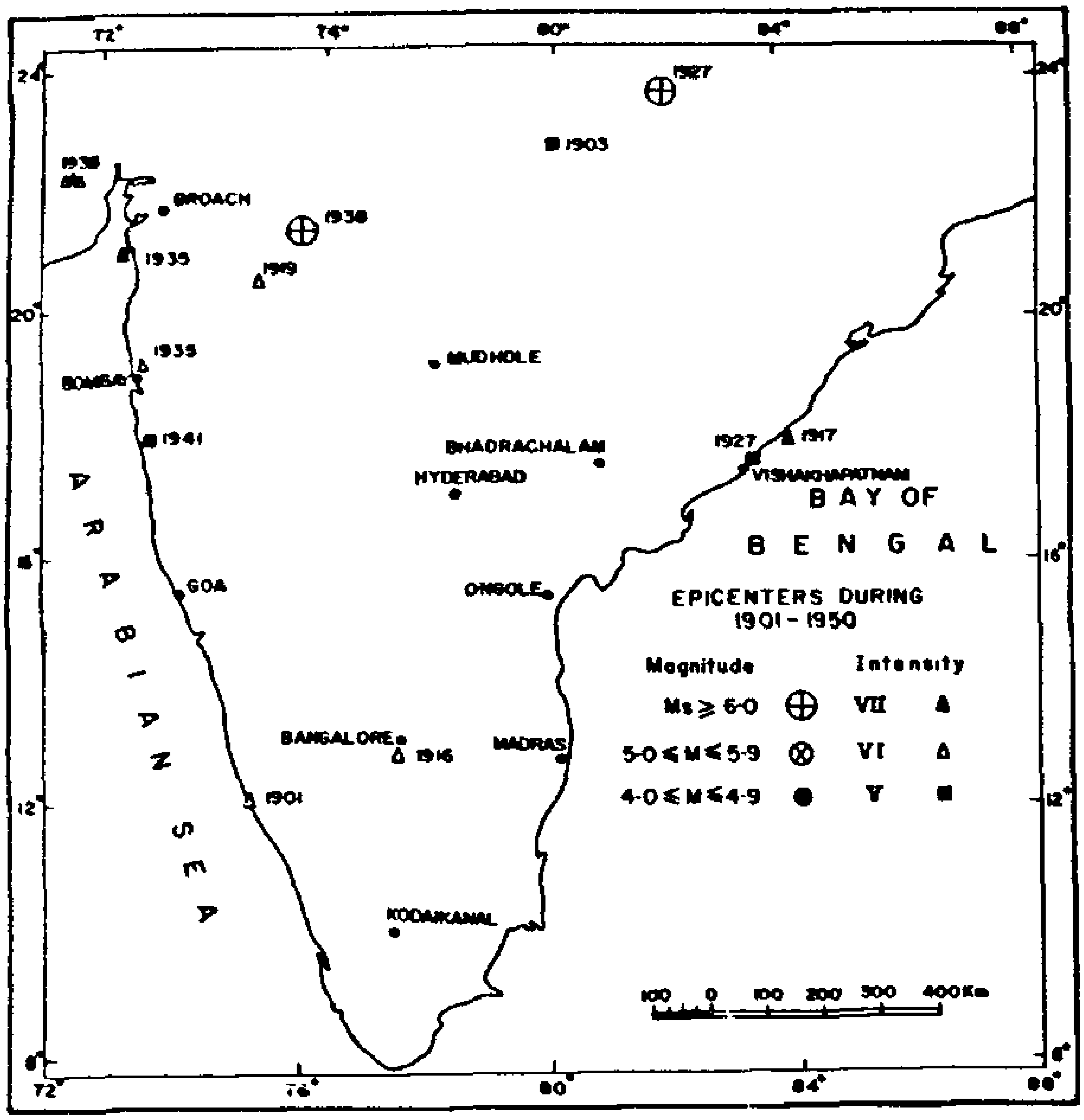

Figure 4. Seismicity of the Peninsular shield for the period 1901–1950.

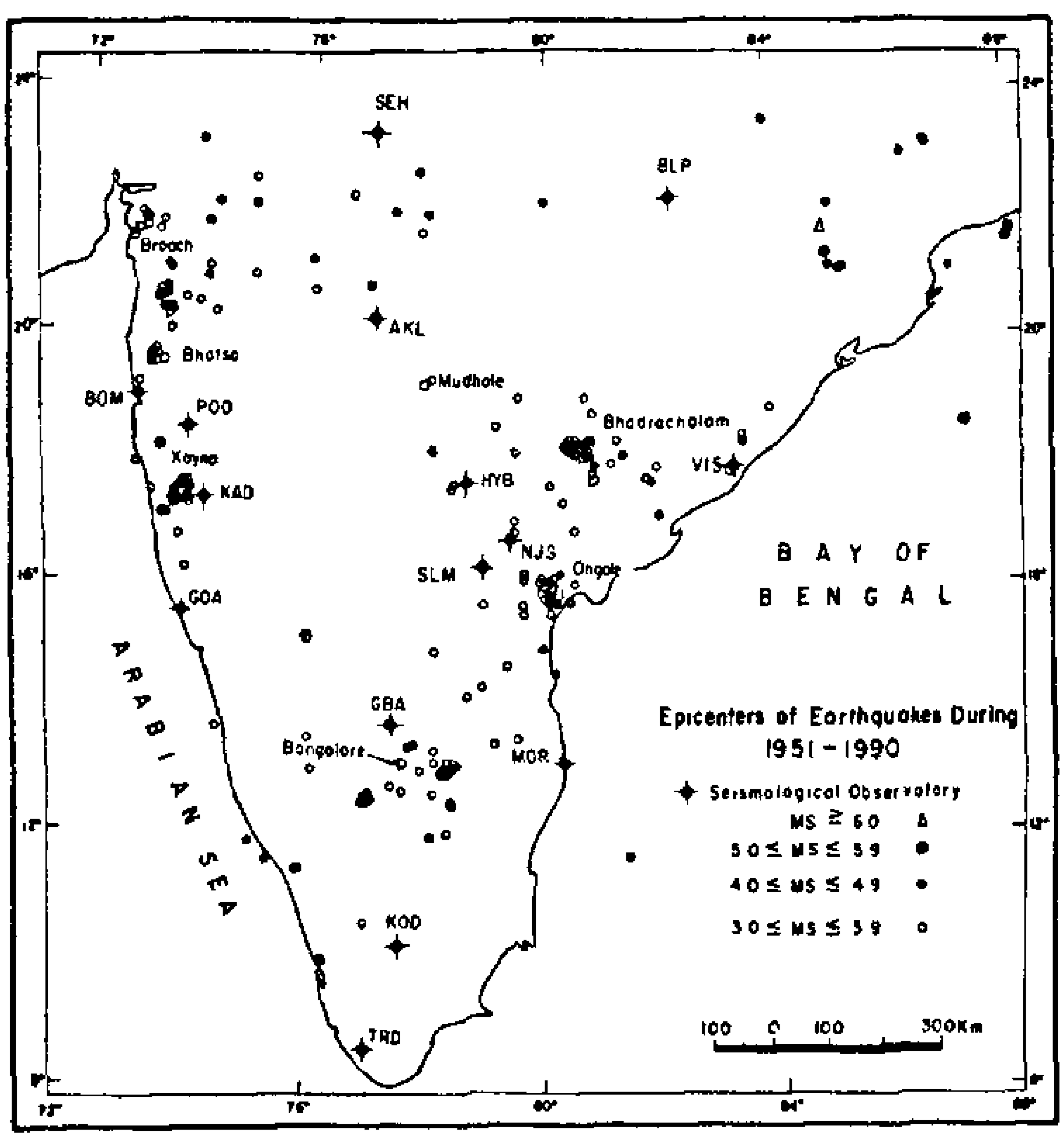

Figure 5. Seismicity of the Peninsular shield for the period 1951–1990.

more devastating Tangshan earthquake[9] of 27 July 1976, which claimed an estimated 500,000 lives. Observations and experiments are being conducted in several countries to make short-term predictions feasible. The earthquake prediction-related studies in India have recently been reviewed by Gupta[10]. It may be observed that, as of today, there is no scientifically accepted and globally applicable method of forecasting earthquakes and recognizing a shock or a swarm as a foreshock or foreswarm, as they occur, in real time

IDNDR and the need of the hour

The United Nations have declared 1990s as the International Decade of the Natural Disaster Reduction[11] (IDNDR). The objectives of the IDNDR are to reduce through concerted international action, particularly in the developing countries, the loss of life, property damage and social and economic disruption caused by natural disasters such as earthquakes, windstorm, tsunamis, floods, landslides, volcanic eruptions, wild fires, grass-hoppers and locust infestations, drought and desertification and other calamities of natural origin. Earthquakes are one of the worst natural disasters and are of much relevance to India. The Latur earthquake occurred in Zone I of the seismic-zoning map prepared by the Indian Standards Institute[12]. The maximum expected intensity of an earthquake is V or less on the MM scale in Zone I. The maximum intensity of the Latur earthquake reached VIII on the MM scale. So, it could be said that the intensity was much more than anticipated for the region according to the ISI seismic-zoning map. What is necessary is to update seismic zoning of the country taking into account the recent occurrences as well as the necessary geological/geophysical inputs. It may also be pointed out that the vast damage in Latur was because of non-engineered structures. Had the houses been built on firmer ground and with some engineering considerations, the tragedy would not have been so severe. The lessons learnt from this earthquake should be utilized properly so that the future earthquakes do not cause such devastation.

1. Gupta, H. K., *J. Geol. Soc. India*, 1993, **42**, 413–415.
2. Chandra, U., *Bull. Seismol. Soc. Am.*, 1977, **67**, 1387–1413

3. Indra Mohan, Sitaram, M. V. D. and Gupta, H. K., *J. Geol. Soc. India*, 1981, **22**, 292–298.
4. Gupta, H. K., Narain, H., Rastogi, B. K. and Indra Mohan, *Bull. Seismol. Soc. Am.*, 1969, **59**, 1149–1162.
5. Gupta, H. K., Indra Mohan and Narain, H., *Bull. Seismol. Soc. Am.*, 1970, **60**, 601–615.
6. Gupta, H. K., Indra Mohan and Narain, H., *Bull Seismol. Soc. Am.*, 1972, **62**, 47–61.
7. Aggarwal, Y. P., Sykes, L. R., Ambruster, J. and Shar, M. L., *Nature*, 1973, **241**, 101–104.
8. Cha, C., Proceedings: Lectures by Seismological Delegation, NASA, 1976, vol 5.
9. Wang, C., *Chinese Geophys.*, 1978, **1**, 157.
10. Gupta, H. K., *Curr. Sci.*, 1992, **62**, 257–263.
11. International Decade for Natural Disaster Reduction Report 1990/1991, IDNDR.
12. Indian Standards Institution, Criteria for Earthquake-resistant Design of Structures, Fourth Revision, UDC 699 841; 624.042.7, 1986.

The authors are in the National Geophysical Research Institute, Hyderabad 500 007, India.

MEETINGS/SYMPOSIA/SEMINARS

XXV National Seminar on Crystallography

Place Madras
Date. 15–17 December 1993

Subject categories. Methods in crystal structure analysis including computational methods, Crystallography in biology, biochemistry and pharmacology; Inorganic and mineralogical crystallography; Structures of organic organo-metallic coordination compounds and polymers; Crystal growth and characterization; Materials science; Atomic scale mechanisms, physical properties and structure; Real and ideal crystals; Apparatus and techniques; Structure methods other than diffraction, Education, data retrieval and other topics in crystallography.

Contact. Dr E. Subramanian
Convener, XXV-NSC
Department of Crystallography and Biophysics
University of Madras, Guindy Campus
Madras 600 025
Phone· 44-2351367, 2351137 extn 211
Tlx· 41-6376 UIOM IN

Solid-State Physics Symposium

Place Bombay
Date 27–31 December 1993

Topics include· Phonon physics; electron states and electronic properties; magnetism and magnetic properties; semiconductor physics; physics of defects and disordered materials; Transport properties; Superconductivity and superfluidity; liquids, liquid crystals and plastic crystals; Phase transitions and critical phenomena, Surface and interface physics; Non-equilibrium phenomena in solids; Resonance studies and relaxation phenomena; Solid-state devices, techniques and instrumentation

Contact Dr S K Deb
Secretary, SSP Symposium
Solid State Physics Division
Bhabha Atomic Research Centre
Trombay, Bombay 400 085
Phone. 11-5563060 extn 2010
Tlx 11-71017 BARC IN, 11-72322 BARC IN
Fax 22-5560750

Polymers 94

Place. Vadodara
Date. 8–10 February 1994

Topics include: Polymerization chemistry new synthetic methods, kinetics and mechanism, modification of polymers, polymer degradation and stabilization, polymer–metal complexes and polymer catalysis; Structure and properties of polymers: spectroscopy, chromatography, new analytical methods; High-performance and functional polymers; Chemistry and technology of fibres; Polymer blends, alloys and composites; Polymerization process technologies; Polymer processing and applications

Contact. Dr M Ravindranathan
Convener, POLYMERS '94
Research Centre, IPCL
Vadodara 391 346
Phone· 265-72011, 72031, 72711 extn 3492
Fax: 265-72098, Gram. PETCOMPLEX
Tlx· 175-6364 & 175-6365

3rd International Conference on Advances in Pattern Recognition and Digital Techniques, ICAPRDT-1993

Place: Calcutta, India
Date. 28–31 December 1993

Topics include: Pattern recognition; Image processing and computer vision; Speech and music; Artificial intelligence; Natural language processing; Remote sensing and environmental studies.

Contact: Convener, Organizing Committee
ICAPRDT-'93
Indian Statistical Institute
203, B. T. Road
Calcutta 700 035
Phone: 33-520004, 527004
Tlx: 91-21-2210 STAT IN
Fax· 91-33-282070/284040