data of different forms are available from Kachchh (instead of waiting for an approved plan of action), the earth scientists could carry out the above suggested and detailed micro-zonation studies immediately in earthquake-prone areas to provide valuable inputs for proper construction of earthquake-resistant structures.

In this respect we have to emulate the efforts made by USGS. As the nation's largest water, earth and biological sciences and civilian mapping agency, the USGS works in cooperation with more than 2000 organizations across USA to provide reliable, impartial, scientific information to resource managers, planners and other customers. This information is gathered in every state by USGS scientists to minimize the loss of life and property from natural disasters, contribute to sound economic and physical development of the nation's natural resources and enhance the quality of life by monitoring water, biological, energy and mineral resources. USGS provided all the relevant information on 28 February 2001 Seattle earthquake by the same evening itself, through the Internet (http://www.geophys.washington.edu/seis/PNSW).

Such prompt action and data dissemination is possible only when we have a scientific organization purely committed to the task, without hindrances from any quarter.

Since our country is continuously affected by different types of disasters, we should have a common centre/institute wherefrom we can provide valuable inputs to state and central governments and to the extent possible even to the common man. This institute should have both experienced and young individuals, who have single-minded service-oriented attitude. Even though it sounds like a 'dreamish ambition', I am sure we can establish such an institute if all like-minded individuals come forward to help in this venture. This institute should have experts from earth system, structural engineers, social workers, experts in planning and economics. For obvious reasons cited above this should be named 'National Disaster Mitigation and Reduction Institute', instead of the normally known 'Disaster Management Organization'.

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P. R. REDDY

National Geophysical Research Institute,
Uppal Road,
Hyderabad 500 007, India
e-mail: postmast@csngri.ren.nic.in

Seismic wave amplification – One more example as evidenced at Ahmedabad (Cambay Basin) on 26 January 2001

As discussed earlier[1–4] with reference to Burdwan, West Bengal, India and Seattle, USA seismic wave amplification phenomenon has been felt and has also created panic and destruction in Ahmedabad and other towns and cities in the Cambay Basin (graben) region in central and north Gujarat during the 26 January 2001 Bhuj (Kachchh) earthquake of 8.1 magnitude and aftershocks related to it. The epicentres of the earthquake and aftershocks are as far as 300 to 350 km from the towns and cities which have experienced destruction of various intensities. The aftershocks, which were recorded even after about more than six weeks were on the scale of 3 to 5.1 magnitude and are also being regularly felt by people of the Cambay Basin region. Development of cracks in majority of the 'C' type RCC column–beam structures indicates that the intensity on Michalias Menten scale could be more than 7 in Ahmedabad area and in Cambay Basin. These clearly indicate the phenomenon of seismic wave amplification in the Cambay Basin as discussed for West Bengal[1] and Seattle[2], as well as New Delhi[5].

The surface geology of the Cambay Basin consists of loose sediments ranging from > 60 m to > 500 m depth. The sediments are chiefly sand–silt–clay beds and lenses in alternations with few pebbles and calcrete pebble bands. Proportion of clay, silt and sand varies in different beds. Sediments are considered to be of alluvial origin, with few aeolian cycles towards the surface and estuarine to marine Tertiary sediments at depth. Palaeo-channels, palaeo-meanders and meander scars are common in the central and southern parts of the basin, which contains shallow vadose water pockets. The water level ranges from 50 to 150 m below the surface in multi-aquifer system in various parts of the basin.

The epicentre of Bhuj earthquake is on the east-west trending Kachchh mainland fault, while the extension of the Cambay Basin is almost north-south bounded by parallel faults. Ahmedabad is almost at a perpendicular distance from the epicentre, where destruction is the maximum. The propagation of the seismic waves might have been at a tangential angle more or less parallel to the surface from a distance of 300–350 km to the Ahmedabad region. As suggested earlier[1], here also the energy propagation could be attributed to trapping of the seismic energy by low velocity surface units (loose sediments) and propagation of waves at low tangential angle above the water table from the epicentre. The vadose water in the palaeo-meanders, meander scars and palaeo-channels must have created liquefaction of loose sediments at shallow depth and quick sand condition. The development of liquefied sediment-related structures (sand and mud-volcanoes, sand and mud-flows, along fissures and cracks, silty and muddy saline water fountains, sand domes, sand holes, sediment dykes, etc.) along the lower part of the Sabarmati river and adjacent areas from Fatehwadi near Sarkhej (~ 10 km from Ahmedabad) up to Gulf of Cambay and in Rann of Kachchh indicates such a condition. No such development is found in Sabarmati river upstream of Ahmedabad where shallow groundwater is absent. The same can be said about Greater Rann of Kachchh, where large amounts of mud and sand oozed out along with water, absorbing major part of energy and hence adjacent parts of Pakistan and Karachi experienced much less damage. In Ahmedabad also, the worst-affected areas like Maninagar, Vasna, Vejalpur, Vastrapur, Paldi, Ambawadi, Jodhpur, etc. are adjacent to Sabarmati river on meander scars, palaeo-meanders, palaeo-channels and palaeo-lakes/past filled lakes and ponds. Weaker constructions have also played their part, but in the above-mentioned areas few one- and two-storied buildings were also damaged and eventually collapsed.

Further, there is a strong correlation between the geometry of the basin filled with sediments and the amount of amplification of the seismic waves[1,2]. Previously studies had been based on artificial shots and seismic surveys[1,2], while in case of Ahmedabad in Cambay Basin seismic waves generated by natural earthquake have shown similar effect.

It has been stated[2] that the amplification results from either focusing associated with the entire basin or resonances and tapping of the seismic energy within the specific layers in the basin, probably the uppermost lower velocity Quaternary deposits, whose geometry may measure the geometry of the entire basin. This is probably true for Cambay Basin also.

As in case of West Bengal and Seattle Basins[1] and New Delhi[5], the seismic wave amplification phenomenon during the 26 January 2001 earthquake can be attributed to the impact of loose sedimentary formation in Rann of Kachchh and Cambay Basin. And as stated previously[1], nothing unusual has been noticed in the surrounding Olympic mountains regions could ascribed to a major extent to surrounding of Bengal Basin[1] near Beliator on crystalline part close to Burdwan. This could also be true even to the western and southern parts of Kachchh, Saurashtra, Nagarparkar ridge, Aravalli and south Gujarat, lying either directly on or with shallow hard rock regions.

Discussion on soil conditions in Delhi by Iyengar[5] also perfectly matches with the experience at Ahmedabad and in Cambay Basin. It is stated[5] that all other parameters such as magnitude and distance remaining the same, local soil conditions dramatically modify the amplitude and frequency content of ground motions. It is pointed out that wherever there are deep deposits of alluvium, tall buildings at such locations are likely to experience amplification of ground motion as the seismic wave passes through the intervening medium. It is further stated[5] that frequency response function – the ratio of the steady state surface amplitude to the amplitude of the bedrock motion – taken to be sinusoidal as a function of frequency, is important. At Delhi[5] maximum amplification was observed in the frequency band of 1–2 Hz, which would be in the range of the first natural frequency of the soil deposit itself. Multi-storied buildings are likely to have their first natural frequency in the same range and hence are prone to experience relatively higher levels of seismic force in comparison with shorter buildings, in case of thicker alluvial deposits. On the other hand, it was stated tentatively[5] that hard rock sites are expected to carry base motion as it is, with its energy more evenly distributed and with a shift towards the higher frequency range of 5–10 Hz, but non-resonance and mismatch of frequency saves constructed structures from larger damage. It is also noted[5] that soft soil sites filter the higher frequencies and exhibit surface motion with energy predominantly in the frequency range of 0–5 Hz.

As it was pointed[6] out for Bengal Basin[1] and North Delhi[5], crustal faults, sedimentary basin and loose deep soil created seismic hazard in Cambay Basin. This phenomenon should be an eye-opener and requires detailed study of the seismic behaviour of the basin for epi-/hypo-centre, outside the basin as well as within the basin. Based on the study, upward revision of the present-day status of earthquake zone-III of the Cambay Basin region needs attention.

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N. Y. BHATT

Geology Department,
M.G. Science Institute,
Navrangpura,
Ahmedabad 380 009, India

G. N. Ramachandran – Reminiscences

I met G. N. Ramachandran at the Indian Institute of Science, Bangalore around 1941 or so when he had just joined the institute. Within a year he had done enough work in optics which would have earned him a doctorate very easily, but was submitted for a mere master's degree. The late K. S. Krishnan was the examiner who was known to delay reports unmindful of the enormous anxiety it caused to the candidates and Raman had to write to him to speed up the report!

Because of my early association I could freely talk to him about various scientific subjects which he could grasp very quickly and go to the root of the matter. I had useful interaction with him after his return from Cambridge. The trio, Ramachandran, S. Ramaseshan and V. Chandrashekar, were working on an important paper on optics published in the *Journal of the Optical Society of America* and later as an article in the *Handbook der Physik*. During that time I had useful discussions with him on magneto-optic resonance. We had discussions at his home every week and I remember reporting the famous Lamb-Rutherford paper.

Of my work on nuclear magnetic resonance, particularly radiation damping and NMR of flowing liquids, he was the only one who could fully understand its